Mega-Dams, Mega Trouble

The claim that hydropower is clean and green does not hold water.

BY MARIANNE HILL

U.S. STATES AND COUNTRIES AROUND THE WORLD ARE TURNING TO hydropower as a supposedly green, renewable energy source. Hydropower, they hope, will enable them to reduce their use of fossil fuels and bring them closer to the goal of net zero greenhouse gas emissions by 2050, in line with the 2015 United Nations Paris Accord. But, sadly, the monster dams on major rivers around the world built to deliver hydropower disrupt and damage regional ecosystems, with devastating effects on both planet and people. Hydropower, as it turns out, is far from clean and green.

Asia is the leading location of planned new mega-dams, followed by Africa and South America. North America and Europe are also expanding capacity. Of the 10 peak years for the construction of dams more than 100 meters high, seven were after the year 2000. An earlier surge in the construction of massive hydropower dams occurred in the mid-20th century, with dams built on every continent except Antarctica. Several of the world's largest dams by surface area in Canada, Africa, and Russia were also built during this period.

A dam might be termed a "mega-dam" based on the surface area of its reservoirs, its generating capacity, its height, or the volume of water it impounds. The International Commission on Large Dams keeps track of dams that are 100 meters high or higher, and these dams are termed "mega-dams" by several organizations. The term "mega-dam," however, is often used loosely for any very large dam. Some relevant numbers: In the United States, there are 30 dams whose reservoirs cover 100 or more square miles. Globally there are 15 dams whose reservoirs cover more than 1,000 square miles. ››

The Wudongde hydropower station dam on the Jinsha River in China, March 28, 2021.

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By capacity, the largest dam in the United States is the Grand Coulee Dam in Washington state, completed in 1942. It has a capacity of 6,809 megawatts; the surface area of its reservoir is 125 square miles. A hydropower plant with a 1,000-megawatt capacity, if operating continuously over the course of a year, could generate more than half the electricity used by Washington, D.C., or Boston. Huge dams, regardless of which definition of mega-dam might apply, should be scrutinized for their ecological and social impacts.

Sizable amounts of methane are emitted from the hydropower reservoirs behind dams. The damaged ecosystems surrounding dams are less able to store greenhouse gases, protect supplies of water and oxygen, and in other ways safeguard wildlife habitat and the environment. Disrupted ecosystems are major contributors to drought, wildfires, and other disasters, and to global warming itself. In addition, about 100 million people have been displaced by these dams, with indigenous peoples disproportionately affected. Wildlife, especially aquatic life, loses vital habitat; some species have gone extinct.

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Unsurprisingly, the International Hydropower Association, a lobbying group for the hydropower sector, nonetheless applauds current moves to expand the production of hydropower, claiming that hydropower is "accelerating the global clean energy transition," and pointing to the many gigawatts of hydropower capacity currently on the way, capacity that will be installed at dams on all of the five largest continents. This growth will increase current world hydropower capacity by an estimated 75% while pouring billions of dollars into economies due to investments in construction, the revenue generated by sales of electricity and, if electricity rates are lowered locally, powering new industries in the region. Unfortunately, the claim that hydropower is "clean and green" does not hold water. Maintaining and increasing the Earth's capacity to store greenhouse gases is just as critical to the future as ending our dependence on fossil fuels. The widespread, ongoing disruption of ecosystems inflicted by mega-dams and other abusive uses of Earth's waters accelerate and amplify global warming. The focus on hydropower also diverts efforts from increasing production and distribution of electricity from solar panels, wind turbines, and battery storage. Let's examine these dams more closely.

A Case Study of the Harms of Mega-Dams: Quebec's James Bay Project

The James Bay Project, a hydroelectric project on La Grande River in northwestern Quebec, illustrates many of the adverse impacts of mega-dams. It is one of the larger projects of Hydro-Québec (H-Q), a power company owned by Quebec's provincial government. This project includes seven reservoirs, with surface areas ranging from 206 to over 1,600 square miles. This project began in 1971 with the relocation of inhabitants and the clear-cutting and burning of boreal forests, followed by the diversion of two rivers, the subsequent flooding of over 4,000 square miles, and the installation of hundreds of miles of transmission lines. Over 16,000 Cree and Inuit peoples were displaced, without any consultation beforehand and little compensation afterward. Among the wildlife and aquatic species impacted were caribou and salmon; over 10,000 caribou died and the number of salmon in the Bay dwindled as their migratory routes were cut off. "[Hydro-Québec] has cost my people everything; our heritage, our culture, our way of life," Lucien Wabanonik, a former grand chief of the Anishnabeg Nation Tribal Council whose lands were impacted by this project, declared in a 2021 op-ed in the Lewiston (Maine) *Sun Journal*.

Mercury contamination, a common problem in reservoirs, has impacted the James Bay Project. Mercury, a naturally occurring element, is released as matter decays, and binds strongly to proteins in fish tissue as methylmercury. This mercury makes fish inedible, affecting both wildlife and humans near or downstream from the reservoir.

The decomposition of flora, fauna, fungi, and bacteria in a reservoir also results in the emission of methane and carbon. The decay of bacteria that breed in the anaerobic depths of dams' reservoirs adds to the emissions of methane as well. A 2016 study of 1,500 dams globally found that six of H-Q's reservoirs, including some in the James Bay Project, emitted as much, or more, greenhouse gases per kilowatt hour as do natural gas power plants.

Hydro-Québec supplies electricity not only to Canada but also to several U.S. states through a series of dams. Fourteen of these dams have reservoirs with surface areas of over 150 square miles and the combined surface area of all the reservoirs is over 10,800 square miles—an area larger than that of the state of Massachusetts. This has had a profound impact on ecosystems in the province.

Dams providing pumped storage hydropower (PSH) are on also the rise within the United States. PSH reservoirs supply water to plants that generate hydropower for the grid during times of peak demand, or as needed. Four of the 10 largest hydropower plants by installed capacity in the country are PSH plants. (*Installed capacity* is the maximum amount of electricity that the plant's generators can produce under specific conditions.) As of 2022, the United States had 43 PSH plants. The height of these structures from the water surface of the top reservoir to the surface of the water at the base can be over 1,000 feet. The Department of Energy supports the spread of PSH, noting that there is the "potential to add enough new PSH plants to more than double current PSH capacity." The environmental threat that these new dams pose deserves greater scrutiny than it has received so far.

Guri Dam on the Caroní River in Puerto Ordaz, Venezuela, September 30, 2012.

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Mega Damage

The impact of mega-dams on water flows is especially consequential and too often underestimated. Dams affect the temperature, nutrients, and oxygen levels of water. Waters flowing downstream from a dam's reservoir are warmer in the winter and cooler in the summer than before the dam was built. Flows no longer follow normal seasonal patterns, and nutrients in the water are greatly reduced as well—changes which in turn alter the composition of the local flora and fauna. Water vapor from reservoirs increases humidity, significantly warming nearby areas. Water vapor is a powerful greenhouse gas, accounting for at least half of all greenhouse gas emissions. Until recently, water vapor was not a major concern because it cycles regularly from earth to clouds and back. But its share in atmospheric greenhouse gases has been increasing, by about 1–2% per decade, exacerbating global warming.

The methane emissions of reservoirs are of particular concern because methane traps much more heat than carbon dioxide (CO2). Scientists measure the ability of a greenhouse gas to trap heat by its global warming potential. A gas's global warming potential measures how much heat it traps in the atmosphere compared with CO2, which is assigned a global warming potential of 1. The global warming potential of methane is over 100 times that of CO2 in its first year in the atmosphere. Over a 100-year period, its global warming potential is 28 times that of CO2. Methane accounts for an estimated 25% of global warming since the Industrial Revolution, and its share in atmospheric greenhouse gas has been increasing, making the attainment of net zero greenhouse gas emissions by 2050 a more difficult task.

The measurement of methane emissions from reservoirs and surrounding vicinities has improved with satellite data, which is available through internet sources like ClimateTrace.org. It is now recognized that reservoirs are significant emitters of methane. A 2024 study cited by the International Hydropower Association estimates that 5.2% of human-source methane emissions come from reservoirs.

Due to their disruption of ecosystems, dams are contributing to the effects of climate change including recent droughts, wildfires, flooding, species loss, human migrations, and the spread of disease. Carbon sinks—any natural system that absorbs more carbon from the atmosphere than it releases—are being lost. Already the Arctic has become a net carbon emitter, not a carbon sink,

Tarbela Dam on the Indus River, Khyber Pakhtunkhwa, Pakistan, September 13, 2014. Credit: Omeas Mumtaz Siddiqui, via Wikimedia Commons, CC BY-SA 3.0 license.

Dams Near the Arctic

The risks associated with mega-dams located near the Arctic are especially high. The Arctic has warmed four times faster than the rest of the globe since 1979. Temperature increases there have already led to the melting of permafrost, ice, and glaciers, changes that are contributing to rising sea levels, declining fisheries, global warming, and changing ocean currents, with potentially devastating effects during this century. The Arctic Institute notes that the world's permafrost may contain as much as 1.7 trillion tons of carbon, which is almost double the amount of carbon in the Earth's atmosphere, and four times more than what has already been emitted by humans since the Industrial Revolution. If all permafrost were degraded to the point of decomposition, the disastrous effects would be felt all over the world.

There are strong reasons, then, to exercise extreme caution when carrying out activities in the Arctic. Countries with land in the Arctic—which include Canada, Denmark (Greenland), Finland, Iceland, Norway, Russia, Sweden, and the United States (Alaska)—are scrambling to stake out their interests in new trade routes, access to the extensive mineral deposits, and more. Most have huge dams generating hydropower near or within the Arctic Circle, with discharged water often flowing north towards the Arctic. Even Greenland, despite its low population, may soon have a mega-dam: investors are excited by the prospect of a massive hydropower plant that could utilize the water from melting glaciers to produce products such as green hydrogen (which is produced by applying a direct electric current from renewable sources to water, splitting it into hydrogen and oxygen) for export as demand for green products grows. These countries have shown little commitment to halting or slowing the warming trend in the region.

and the same is true of the east Amazon region and other places.

Restoration and protection of the environment hold great potential in the fight against climate change. "About one-third of the greenhouse gas emissions reductions needed in the next decade could be achieved by improving nature's ability to absorb emissions," according to the U.N. Convention on Biological Diversity. The goal set by this U.N. Convention is to preserve 30% of the earth's land and water by 2030 (often referred to as "30 by 30"). The spread of dams is hampering progress toward this goal.

The loss of nutrients and habitat for flora and fauna caused by dams also leads to human interventions to make up for those losses. Farming, fishing, and hunting, especially downstream, must adjust. Expenditures may rise on manufactured fertilizer and pesticides, on irrigation and drainage systems, and more.

Billions in Revenues—and Costs

There are powerful economic incentives behind the continued construction of mega-dams. The huge demand for electricity means there is the potential for huge profits. H-Q is among the entities planning to build more dams to expand their generation of electricity. Although H-Q has recently claimed to have excess capacity, in fact it routinely imports electricity from Ontario in the winter; the only identifiable "excess capacity" is that of reservoirs they use to meet fluctuations in demand. The expansion of exports to the United States depends on more dam construction. H-Q's latest mega-dam, with 2,500-megawatt capacity, will be built at Gull Island near Quebec in the province of Newfoundland and Labrador.

H-Q's net income, which was Canadian $4.6 billion in 2023, contributes to Quebec's annual budget of about Canadian $150 billion. A severe drought in Quebec in 2024, however, forced the company to reduce its exports of electricity, which reduced its income.

Drought has become a recurring problem, not only in Canada, but for dams around the world. Severe drops in water levels bring sharp declines in efficiency, so much so that experts suggest that the case for large-scale hydro projects is not strong. Still, dam construction around the world continues apace. The World Bank, which had put a pause on lending for large dams, resumed funding such projects as of December 2024.

Resistance to mega-dams has been strong. A 2019 study of the 220 conflicts listed in the Environmental Justice Atlas found that, in the categories covering economic-industrial activities, water management conflicts (including around dams) are among the most intense, along with mining, nuclear energy, and fossil fuel projects. Many people have been killed during these conflicts, although the vast majority of protests are peaceful. Indigenous peoples are often in the forefront of these struggles. (See Déborah Nunes, "Movement of People Affected by Dams in Brazil," *D&S*, March/April 2020.) Global Dam Watch, Environmental Justice, and other organizations collect information about peoples and places impacted by major dams.

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Wind, solar, and geothermal power are the most cost-competitive energy sources, with their cost per kilowatt hour lower than that of electricity generated using fossil fuels or hydropower. Growth of these clean, renewable energies is inhibited by a variety of factors. In developed countries, finding locations for wind and solar has proven a challenge. Another factor in both developed and developing countries is the fact that it is more difficult to concentrate the production and distribution of clean energy, which reduces the potential for huge corporate profits.

Storage has been an issue as well for renewable energy sources, but this can be addressed in large part by large-scale batteries and subsidized home backup batteries, especially when powered in part by solar panels. Vermont is among the states where consumers have access to low-cost home backup batteries. These batteries can be used during periods of high demand or power outages, reducing pressure on the grid. They can also feed power into the grid. California's home battery programs have reduced the need for power plants. The transition to total reliance on clean energy sources, nonetheless, also requires changes to electrical transmission grids and distribution networks.

The Way Ahead

A climate tipping point is looming for the planet. Besides ending our dependence on fossil fuels, we must also protect the Earth's ability to store and absorb greenhouse gases if we are to avoid the catastrophes expected if net zero greenhouse gas emissions are not achieved by 2050. U.S. states, if they aim for sustainability, should avoid the purchase of hydropower from destructive mega-dams. In particular, rather than buying more electricity from H-Q, which continues to build mega-dams in Canada, states should increase their energy efficiency, clean energy production (from solar, wind, and geothermal), battery storage capacity, and investments in eco-friendly products and services throughout their economies. Strong pushback against hydropower as clean and green is an urgent necessity globally in the struggle to protect the planet. D&S

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SOURCES: Arctic Institute. "Permafrost thaw warming world". Fall 2020 (thearcticinstitute.org); Maciej Bartosiewicz et al., "Hot tops, cold bottoms," *Limnology and Oceanography Letters*, August 2019 (aslopubs.onlinelibrary.wiley.com); "Top ten largest hydro plants in US," Certrec, December 19, 2022 (certrec.dom); Daniela Del Bene, "Dam violence against environmental defenders", *The Ecologist,* May 14, 2019 (theecologist.org); "James Bay Project," *Canadian Encyclopedia,* January 17, 2023 (thecanadianencyclopedia.ca); Edgar Hertwich. "Addressing Biogenic Greenhouse Gas Emissions from Hydropower in LCA," *Environmental Science and Technology*, August 2, 2013; Annual Report 2024, International Hydropower Association (hydropower.org) ; "Hydropower Industry," International Rivers (internationalrivers.org); Stephen Kasprzak, *Arctic Blue Deserts: Flatlining the Arctic's Pulse,* Tall Pine Publishing, 2021; Christopher Ketcham, "The Dam Truth," Truthdig, April 25, 2024 (truthdig.com); "Levelized Cost of Energy Report 2025," Lazard (lazard.com); Jacques Leslie, "As warming and drought increase, a new case for ending big dams," Yale Environment360, Nov. 4, 2021; "Steamy Relationships," NASA Science Editorial Team, February 8, 2022; updated October 2024 (science.nasa.gov); Déborah Nunes, "Movement of People Affected by Dams in Brazil," *Dollars & Sense*, March/April 2020 (dollarsandsense.org); Stephan Pfister and Laura Scherer, "Hydropower's Biogenic Carbon Footprint," PLoS One, Environmental Science, September 14, 2016 (journals.plos.org/plosone); Mika Rantanen et al., "The Arctic has warmed ...", Communications Earth & Environment August 11, 2022; U.N. Convention of Biological Diversity, March 25, 2021 (unep.org); "HydroWIRES Initiative Research Roadmap," U.S. Department of Energy, January 2022 (energy.gov); "Understanding Global Warming Potentials," U.S. Environmental Protection Agency (epa.gov);; Lucien Wabanonik. "Lucien Wabanonik: My People were robbed, ignored by Hydro-Québec, Quebec government," (Lewiston, Maine) *Sun Journal,* op-ed February 21, 2021 (sunjournal.com), "Could soil help limit global warming?" World Economic Forum, December 4, 2015 (weforum.org).