EEE-102 Homework 3: Hydro Power Plants
Spring 2024-2025, EE, IIT Roorkee

Fast Facts About Hydropower

This document is taken from the Understand Energy Learning Hub of the School of Sustainability, Stanford University.

Principal Energy Uses: Electricity
Forms of Energy: Kinetic, Potential

Hydropower, also known as hydroelectricity, is a semi-renewable resource that uses the flow of water to generate electricity. We categorize this resource as semi-renewable, because it has to be carefully managed to ensure we are not using it faster than it can be replenished. There are two major approaches to *generating* electricity from hydropower:

1. **Storage hydroelectric systems** store water for later use, which makes them a versatile resource for the grid. For example, large hydroelectric dams can be sited on rivers with valleys, creating an artificial lake or reservoir. Turbines and generators in the powerhouse generate electricity when water flows from higher-to-lower elevation. The six largest electricity generation facilities in the world are all conventional storage hydropower facilities.
2. **Run-of-river systems** are generally smaller and use the river's natural flow to generate electricity, so there is no water being stored and less disruption to the natural river system.

Hydro can also be used to *store* electricity in systems called **pumped storage hydropower**. These systems pump water to higher elevation when electricity demand is low so they can use the water to generate electricity during periods of high demand. Pumped storage hydropower represents the largest share (> 90%) of global energy storage capacity today.

Note: The small amount of marine/ocean-based hydropower is not included in this data and is covered on our Ocean Energy page.

Significance

Energy Mix
6% of world 🌎
2% of US 🇺🇸

??% India

Electricity Generation
15% of world 🌎
6% of US 🇺🇸

??% India

Largest (By MW Capacity) hydro power plant India?

Make List of Three Indian hydro power plant names and capacity of each type

Hydroelectric Capacity by Type
Conventional Storage and Run-of-River Systems
(Electricity Generation)
90%

Pumped Storage Systems
(Energy Storage)
10%

Global Electricity Generation from Hydropower
Increase:
⇧ 6%
(2017-2022)

World

Most Installed Capacity
China 30% 🇨🇳
of global hydroelectric generation installed capacity (excluding pumped storage)

Most Generation
China 32% 🇨🇳
of global hydroelectric generation

Highest Penetration
Paraguay >99% 🇵🇾
of country's electricity generation comes from hydroelectricity

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US

Most Installed Capacity
Washington 27%
of US hydroelectric generation installed capacity

Most Generation
Washington 27%
of US hydroelectricity generation

Highest Penetration
Washington 55%
of state's electricity generation comes from hydroelectricity

Note: These figures do not account for non-utility scale or off-grid hydropower generation.

Pumped Storage Hydropower

Most Installed Capacity
China 22% 🇨🇳
of global pumped storage installed capacity

Share of Global Energy Storage Capacity
Pumped Storage Hydropower: 92%
Lithium-Ion Batteries: 5%
Other: 3%

Pumped Storage "Roundtrip" Efficiency
70-85%
of the energy used to pump water uphill can be converted back into electricity

Global Pumped Storage Capacity
Increase:
⇧ 10%
(2016-2021)

Drivers

- Abundant
- Co-benefits: flood control, water storage for agricultural, residential, commercial, recreational purposes
- Can be used to "black start" the electricity grid after major outages*
- The lowest-cost source of electricity globally based on LCOE**
- Qualifies under some nations' renewable energy targets (although large hydro may not count in some jurisdictions due to environmental impacts)
- Financial incentives such as production tax

Barriers

- Site-specific resource, only available in some geographies
- Droughts and climate change can impact water cycle, changing long-term resource availability
- Competing downstream uses for water can limit its use for electricity generation
- Destruction of cultural heritage sites and human settlements, forcing mass relocation and compensation
- Flooding of terrestrial habitat, disrupting ecosystems that rely on lakes and rivers
- Impacts on aquatic species (e.g., fish mortality and barriers to migration); may also be culturally

credits (PTC) and feed-in tariffs
- Pumped Storage alleviates intermittency when integrating other renewables

and economically important to Indigenous communities
- Seasonal changes in reservoir levels can affect soil quality and crop yields
- Seismic impacts from large reservoirs
- Expensive initial capital costs to build dams
- Lengthy planning, permitting, and construction process
- Local opposition to dam construction (NIMBY/ BANANA***)
- Inconsistent policy support
- Movement to remove dams due to environmental harms

**Black start - recovering from a blackout by individually restarting power systems and gradually reconnecting them to form an interconnected grid*
***LCOE (levelized cost of energy) - allows for the comparison of different electricity generating technologies*
****NIMBY - not in my backyard; BANANA - build absolutely nothing anywhere near anything*

Q. What is the classification of Hydro Projects based on Installed Capacity?
Micro: upto 100 KW
Mini: 101KW to 2 MW
Small: 2 MW to 25 MW
Mega: Hydro projects with installed capacity >= 500 MW

Q. How does cost of generation from Hydropower Plant compare with other sources of electricity?
The hydropower generation is highly capital-intensive mode of electricity generation but being renewable source of energy with no consumables involved; there is very little recurring cost and hence no high long term expenditure. It is cheaper as compared to electricity generated from coal and gas fired plants. It also reduces the financial losses due to frequency fluctuations and it is more reliable as it is inflation free due to not usage of fossil fuel.

Q. What is the estimated total Hydropower potential of India?
The hydropower potential of India is around 1,45,000 MW and at 60% load factor, it can meet the demand of around 85, 000 MW.