Global Energy Monitor

BRIEFING: MAY 2023

Led by China, Eastern Asia can meet key target for pumped storage

Summary

A massive planned buildout of pumped storage hydropower (PSH) in Eastern Asia, driven by China, would allow this region to single-handedly meet the International Renewable Energy Agency's (IRENA) 1.5°C Scenario target of 420 gigawatts of pumped storage worldwide by 2050, according to new data from Global Energy Monitor.

PSH is a crucial component of the global energy transition, and GEM's new Global Hydropower Tracker, which catalogs PSH projects as well as conventional and run-of-river projects 75 megawatts (MW) or larger, shows that the Eastern Asia region represents 73% of current and future PSH capacity. Operating capacity within this region is currently dominated by China and Japan, and China is far and away the leader for prospective capacity. China's ambitious PSH targets, which include plans for at least one facility in each province, are within reach given these prospective additions and a larger average capacity per plant than nearly all other countries worldwide.

Background

The worldwide growth in variable renewable energy sources like wind and solar is increasing the need for energy storage solutions, especially pumped storage hydropower. Modeling by the International Renewable Energy Agency (IRENA) suggests that 420 GW of PSH will be needed in order to allow the world to meet the climate goals outlined in the Paris Agreement by 2050.

PSH functions as a utility-scale method of energy storage, like a battery, by moving water between two reservoirs at different elevations. Water is pumped into the higher reservoir using energy from the grid during conditions of abundant energy supply, when prices are low. During conditions of abundant energy demand, when prices are high, water flows from the higher to the lower reservoir, generating electricity that the PSH facility supplies to the grid.

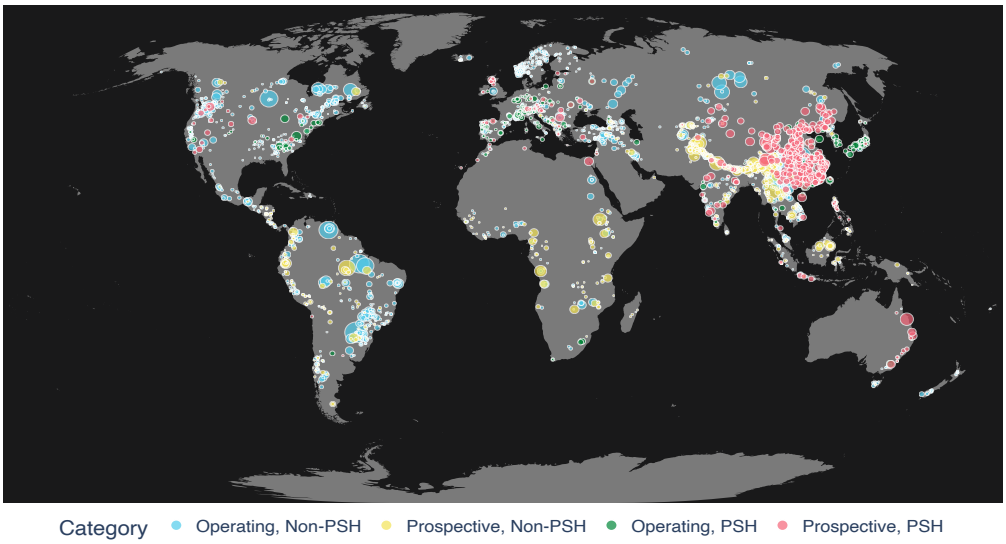
While its utility in conjunction with intermittent power sources is widely recognized, PSH does have drawbacks. These facilities can only be built where specific geographic conditions exist, allowing for two large bodies of water at different elevations to be created, connected, and maintained. Projects, especially greenfield developments, can face opposition, as with conventional hydropower. Additionally, PSH requires regulatory ecosystems and market structures that accommodate and incentivize energy storage systems.

PSH in the Context of Global Hydropower Trends

PSH is set to take on an increased role in global energy systems in the coming years, based on summary data from the Global Hydropower Tracker. Of all operating hydropower projects with at least 75 MW of nameplate capacity, only 14% (161 GW) is PSH. The other 86% of operating capacity (967 GW) is conventional storage or run-of-river. But PSH makes up 49% (439 GW) of prospective capacity, indicating the rising importance of this technology relative to other types of hydropower in the coming years.

Eastern Asia[1] is a massive outlier both for hydropower in general and for PSH specifically. This subregion has a total capacity — operating and prospective, PSH and non-PSH — of 922 GW. This sets it well apart from the world's other 16 subregions, none of which have a corresponding total of more than 300 GW. Just over half of all capacity in Eastern Asia is PSH. The only UN subregion where PSH is a higher percentage of the total is in Australia and New Zealand. There, however, total capacity is only 27 GW, or 3% of the total capacity in Eastern Asia.

Figure 1: Global facilities by capacity, type, and status



Source: Global Energy Monitor, Global Hydropower Tracker

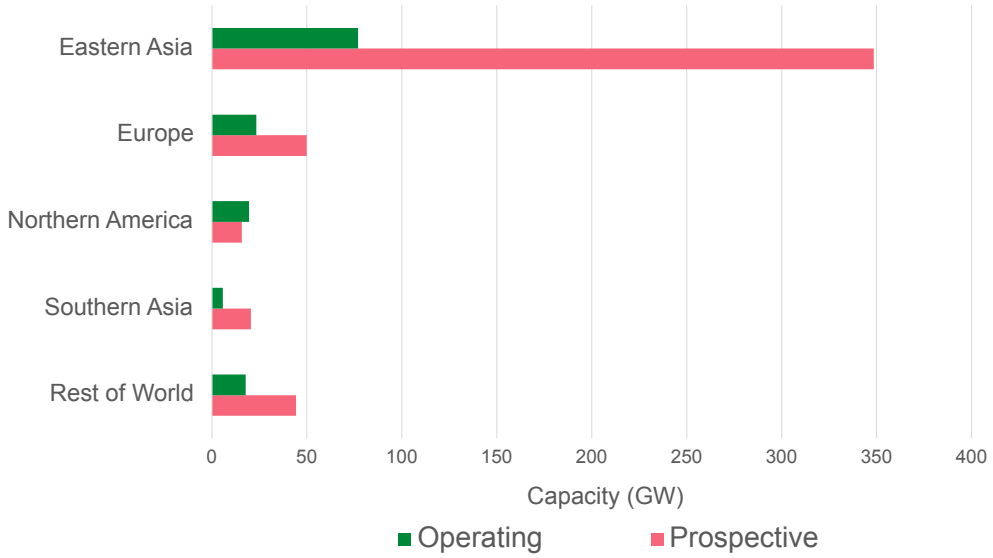
When considering PSH specifically, Eastern Asia leads the way, with a total of 425 GW: 77 GW operating and 348 GW prospective. Based on these numbers, Eastern Asia alone could meet IRENA's 420 GW goal, assuming that all of the current prospective capacity is built and all of the currently operational capacity remains operating.

Additional caveats apply: IRENA's targets are intended to be worldwide, and solely having 420 GW of PSH capacity in Eastern Asia will not single-handedly meet the worldwide needs of the global energy transition. Furthermore, not every prospective project will move through the development pipeline to become operational, and not every project currently in operation will remain so for over 30 years. IRENA's modeling also calls for an additional 2580 GW of conventional hydropower beyond the 420 GW of PSH.

The two countries with the largest operational PSH capacity are China (50.7 GW) and Japan (23.7 GW). Other than the United States with 21.6 GW, no other country has more than 10 GW. Japan's projected growth is relatively minor, while China's prospective PSH is on another order of magnitude.

1. Eastern Asia is a subregion as defined by the United Nations Statistics Division. Global Energy Monitor uses these definitions of regions and subregions in the Global Hydropower Tracker.

Figure 2: PSH capacity for selected regions and subregions



Source: Global Energy Monitor, Global Hydropower Tracker

Pumped Storage Hydropower in China

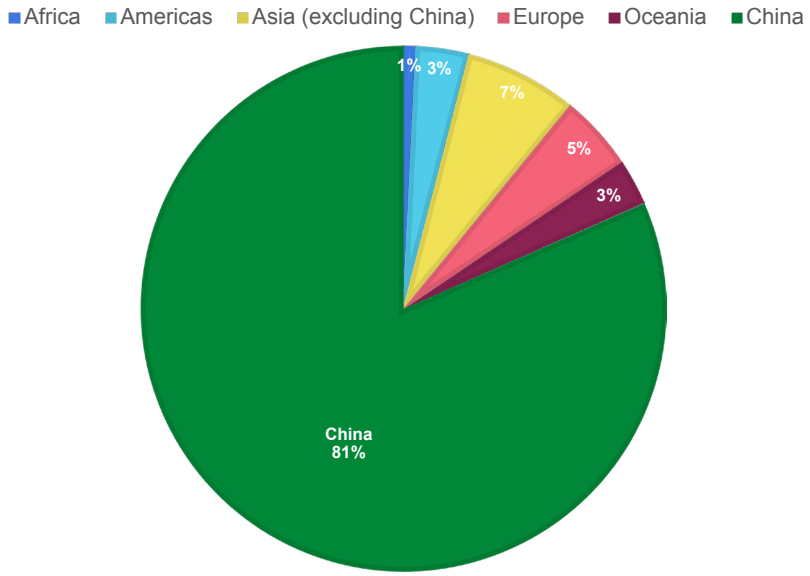
China Leads PSH by Capacity

China is the top-ranked country in terms of operating PSH capacity with 50.7 GW, holding 30% of the world's total. This is roughly equivalent to the combined PSH capacity of all European countries. China's current share of global prospective capacity exceeds 80%, making it the primary country for the development of the pumped storage industry.

Among the top ten PSH projects with the highest operating and prospective capacity, China holds seven of the spots for operating capacity and eight for prospective capacity. Furthermore, most of the Chinese projects have a capacity exceeding 2 GW.

The Fengning hydroelectric plant, when completed, will have a nameplate capacity of 3.6 GW through its twelve turbines, making it the world's largest pumped storage plant. As of April 2023, nine turbines were in operation, with the other three under construction.

Figure 3: Prospective PSH: Global vs China



Source: Global Energy Monitor, Global Hydropower Tracker

Table 1: 10 Largest operating PSH projects by capacity

Capacity Rank	Project Name	Operating Capacity (MW)	Country
1	Bath County hydroelectric plant	2,862	United States
2	Fengning hydroelectric plant	2,700	China
3	Meizhou hydroelectric plant	2,400	China
4	Yangjiang hydroelectric plant	2,400	China
5	Guangzhou hydroelectric plant	2,400	China
6	Huizhou hydroelectric plant	2,400	China
7	Changlongshan hydroelectric plant	2,100	China
8	Ludington hydroelectric plant	1,979	United States
9	Okutataragi hydroelectric plant	1,932	Japan
10	Tianhuangping hydroelectric plant	1,800	China

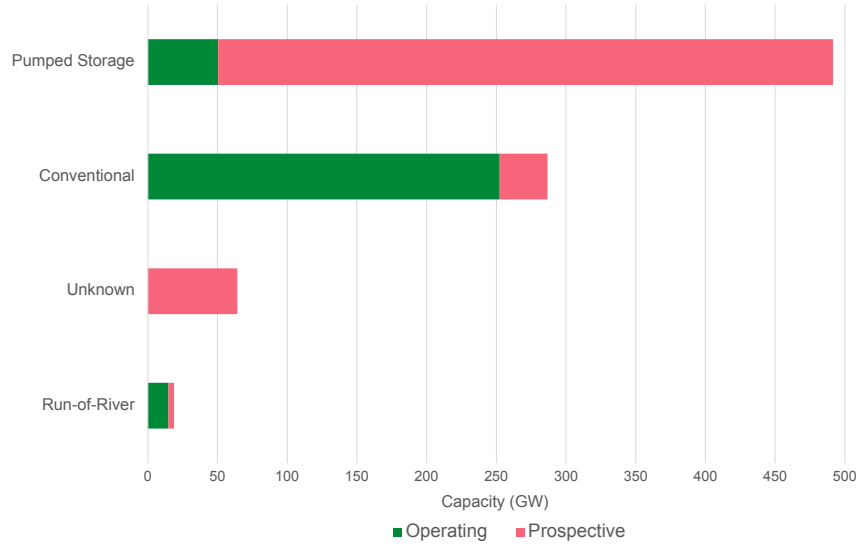
Table 2: 10 Largest prospective PSH projects by capacity

Capacity Rank	Project Name	Prospective Capacity (MW)	Country
1	Pioneer Burdekin hydroelectric plant	5,000	Australia
2	Yebatan Pumped Storage hydroelectric plan	4,500	China
3	Gonghe hydroelectric plant	3,900	China
4	Reba Pumped Storage hydroelectric plant	3,600	China
5	Cuolonggongma hydroelectric plant	3,000	China
6	Shihu Dam hydroelectric plant	3,000	China
7	Tielishi hydroelectric plant	3,000	China
8	Warang hydroelectric plant	2,800	China
9	Longhua hydroelectric plant	2,800	China
10	Halverson Canyon hydroelectric plant	2,650	United States

PSH Attributes in China

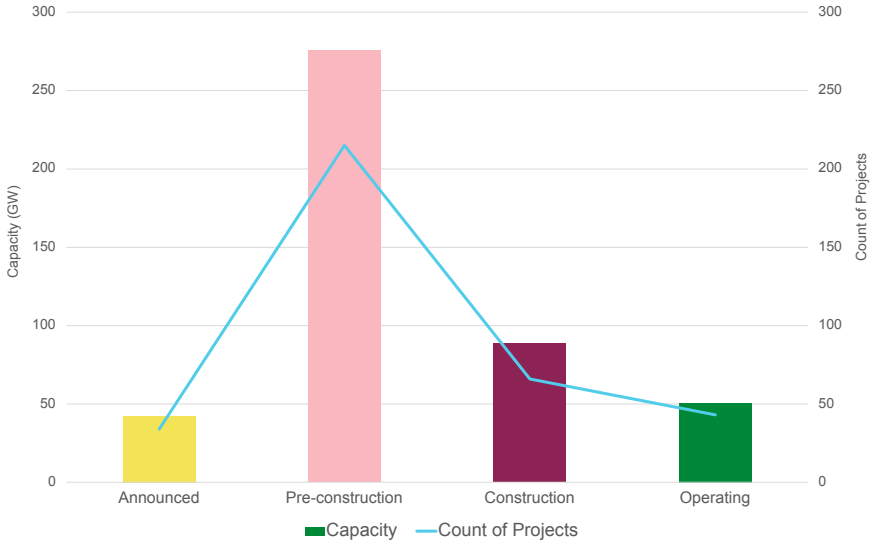
Among the three different hydropower technologies that are currently operational in China, PSH accounts for only 16%. But PSH comprises over 86% of the prospective capacity in China as of April 2023. Most of the prospective PSH projects are in the pre-construction stage: those for which construction has not yet begun, but that are moving forward in seeking governmental approvals, land rights, and financing.

Figure 4: Hydropower status by technology type in China



Source: Global Energy Monitor, Global Hydropower Tracker

Figure 5: China PSH by status



Source: Global Energy Monitor, Global Hydropower Tracker

Worldwide, the average PSH facility in the Global Hydropower Tracker has an operating capacity of 620 MW. The top three countries with the highest average capacity for operating PSH plants are Taiwan (1301 MW), Luxembourg (1294 MW), and China (1179 MW).

Notably, though, these countries have a much lower count of operational PSH facilities than China: there are two in Taiwan and one in Luxembourg, compared to 43 in China. Japan is the country with the next highest count, with 34. So among operating facilities, China has both a larger number and a higher average capacity per facility.

In terms of prospective facilities, China ranks third by average capacity, again behind only countries with a much smaller number of prospective plants. Egypt has a single prospective facility at 2400 MW, and Vietnam's two facilities average 1350 MW. The average capacity among China's prospective PSH facilities is 1291 MW, which is above the worldwide average of 1122 MW. For China, this average is from 315 projects, far and away the highest number of pumped storage facilities recorded in the world.

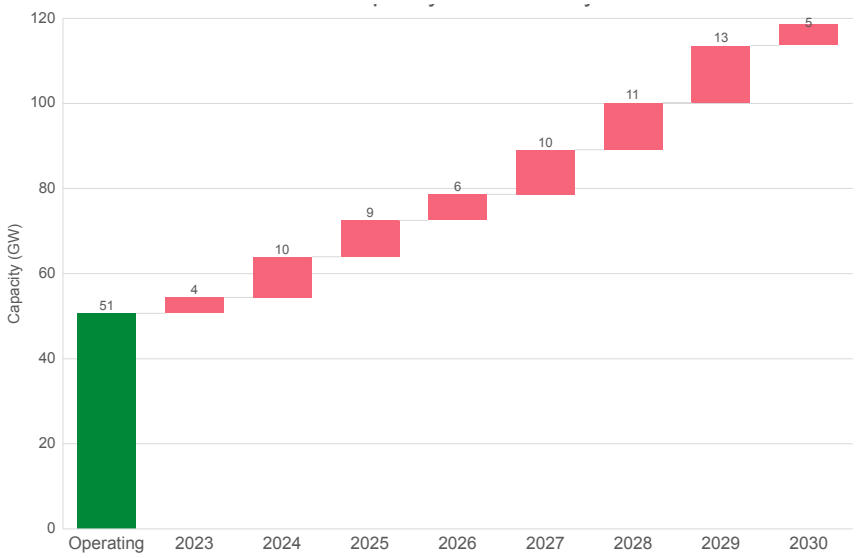
China's Growth and National Energy Administration Goals

In September 2021, China's National Energy Administration (NEA) released its "Mid-term and Long-term Development Plan for Pumped Storage Hydropower 2021-2035." The official goal is to reach 62 GW of operating capacity by 2025, 120 GW by 2030, and 305 GW by 2035.

From the data collected in the Global Hydropower Tracker, the prospective capacity expected to be online by 2025 (assuming no retirements) is 75 GW, exceeding the 62 GW target. The expected mark by 2030 based on Global Hydropower Tracker data is also close to its corresponding NEA goal. GEM data show that the average annual growth of PSH capacity in China through 2030 is 8.5 GW annually.

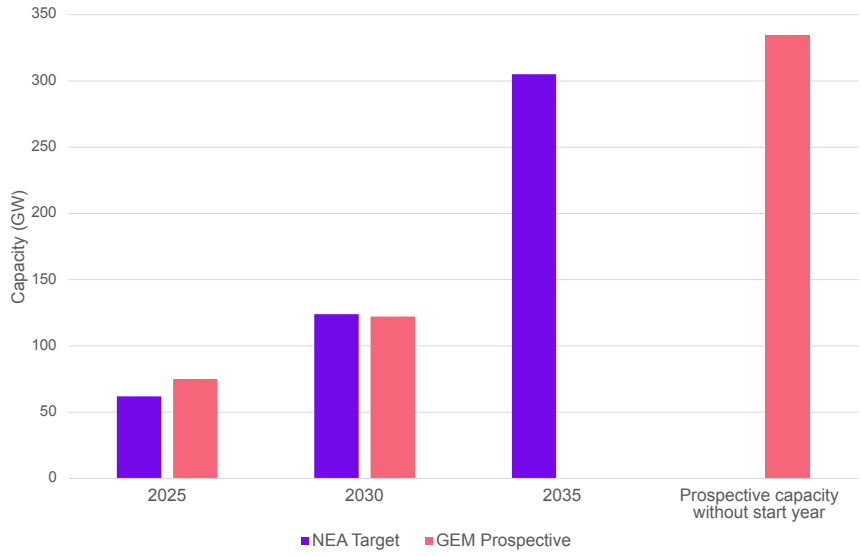
Although there are no Chinese PSH projects officially announced to come online in years beyond 2031, the official 2035 goal of 305 GW still appears to be within reach: Another 259 projects with a total of ~335 GW for which a start date is not yet available have been identified. These projects could be expected to gradually come online in time to meet the 2035 target.

Figure 6: China PSH capacity increases by year



Source: Global Energy Monitor, Global Hydropower Tracker

Figure 7: PSH capacity: NEA target vs GEM Prospective

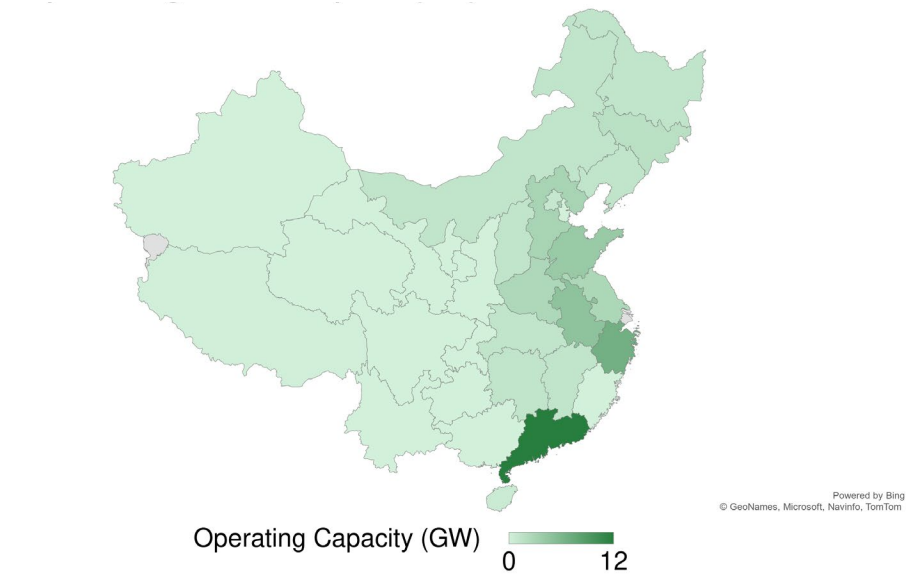


Sources: China's National Energy Administration (NEA), Global Energy Monitor, Global Hydropower Tracker

PSH Development Across China

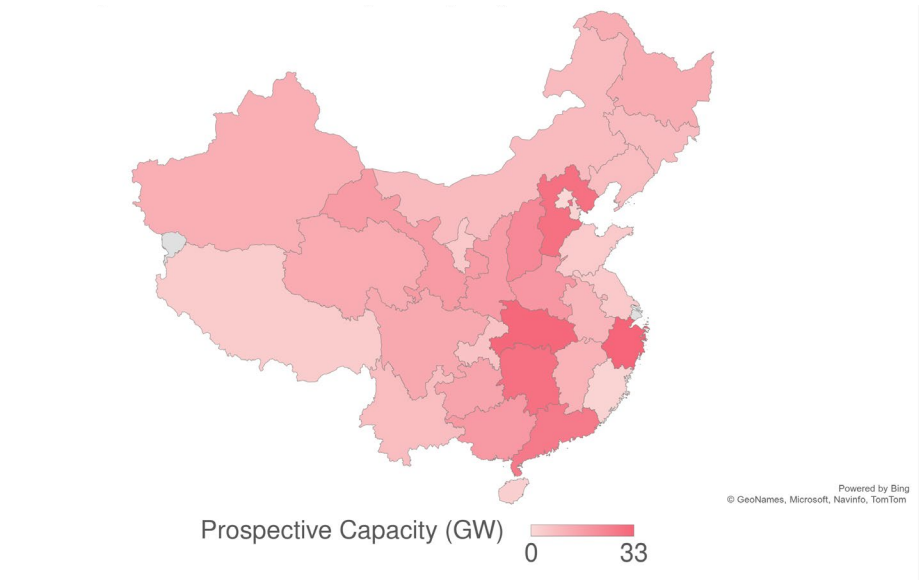
At present, the top three provinces with the highest operating PSH capacity are Guangdong, Zhejiang, and Anhui. The majority of operating PSH facilities are concentrated in Guangdong, with a collective capacity that surpasses that of Zhejiang and Anhui combined.

Figure 8: Operating PSH capacity by province in China



Source: Global Energy Monitor, Global Hydropower Tracker

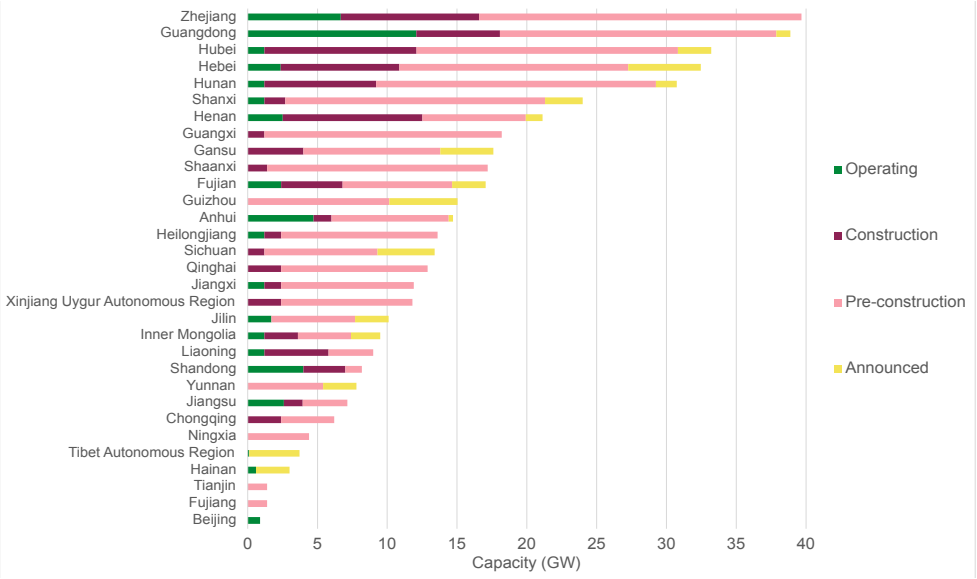
Figure 9: Prospective PSH capacity by province in China



Source: Global Energy Monitor, Global Hydropower Tracker

PSH development is expected to expand nationwide in the future. In the central China region, the provinces of Zhejiang, Hubei, and Hunan possess the largest prospective capacities in the pipeline, with 95 GW across 79 projects. Moreover, 13 provinces that do not presently have any operating pumped storage facilities boast over 127 GW of prospective capacity. Each province, except for Beijing, plans to establish at least one pumped storage hydroelectric plant with an average operating capacity of approximately 1300 MW.

Figure 10: PSH capacity by status, all China provinces



Source: Global Energy Monitor, Global Hydropower Tracker

PSH in Other Regions Worldwide

Southern Asia and Northern America are the two regions outside of Eastern Asia that have the most prospective PSH capacity. Northern America's projected increases are driven by the United States, while Southern Asia's prospective capacity is found in India (15.9 GW) and Nepal (4.6 GW). Nepal, like Indonesia (3.4 GW prospective) and Vietnam (2.7 GW prospective), does not currently have any operational PSH facilities. Similarly, the Philippines only has 0.7 GW of operating PSH capacity, but has 4.3 GW of prospective capacity.

In contrast to the massive PSH buildout in Eastern Asia, the Global Hydropower Tracker data also shows that there is comparatively little PSH capacity, current or future, in Africa or Latin America and the Caribbean (LAC). Conventional reservoir storage is much more common in these regions, both for operating and prospective projects. In the LAC region, non-PSH capacity totals 178 GW for operating and 56 GW for prospective, while both operating and prospective PSH capacities are below 1 GW. In Africa, operating non-PSH capacity totals 33 GW, with 38 GW more non-PSH marked as prospective. Corresponding PSH capacity in Africa is roughly one-tenth of its non-PSH counterparts, with only 3.4 GW operating and 3.7 GW prospective.

Data Gaps and Future Research

Further research will allow continued monitoring of the role of pumped storage in the global energy transition and China's role in driving much of this growth. In recent years, new projects have been announced almost every week in China, and continuing to monitor these developments will be important. Future updates to the Global Hydropower Tracker will expand GEM's data coverage to include projects below 75 MW and track changes in the status of prospective projects as they move through the pipeline towards operation.

Acknowledgments

This briefing was written by Joe Bernardi, Project Manager for the Global Hydropower Tracker and Cheng Cheng Wu, Project Manager for the Global Energy Transition Tracker. Maps and figures were developed by Joe Bernardi and Cheng Cheng Wu; layout was designed by Carolina Chau; copy editing was done by Amanda DeBord and editing contributions were provided by Ingrid Behrsin and David Hoffman.

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About the Global Hydropower Tracker

The Global Hydropower Tracker is a worldwide dataset of hydropower facilities. The tracker provides project-level details on capacity, status, technology type, ownership, geolocation, and over 25 other categories.

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