2023

World Hydropower Outlook

Opportunities to advance net zero

iha
international hydropower association















Jatiluhur assessment, Indonesia
Credit: Amina Kadyrzhanova

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Contents

Foreword 3
Executive summary 4
Tracking Hydropower Against Net Zero 8
Hydropower's contribution to net zero 8
Hydropower potential: where are the opportunities? 12
Developing new hydropower 12
Pumped Storage Hydropower (PSH) potential 12
Modernising existing infrastructure 13
Retrofitting non-powered dams 15
What is currently in the new development pipeline? 16
Evolution of the global hydropower projects pipeline 18
Are there enough projects in the pipeline to meet net zero targets? 19
Priority policy themes 22
Climate resilience and drought 22
Floating solar/hybrids 24
Equality in the Hydropower sector 27
Global trends 28
Regional Analysis in depth 32
Europe 32
North and Central America 39
South America 44
Africa 49
South and Central Asia 57
East Asia and Pacific 62
Practical solutions for the future development of sustainable hydropower 67
Installed capacity and generation 2022 69
Acknowledgements 71

Foreword

Welcome to the first edition of the World Hydropower Outlook. While climate change remains the biggest threat facing the planet and progress is falling short of what is needed to achieve net zero by 2050, this report identifies where we are seeing the green shoots of a sustainable hydropower renaissance. Nonetheless, further significant expansion of sustainable hydropower capacity is essential to underpin the global transition to renewables.

The Hydropower Sustainability Standard, the first sustainability standard of its kind in the renewables sector, celebrated the first certification in Tajikistan this year. Many more are in the pipeline helping to ensure that hydropower in the 21st century can be built and operated sustainably.

We have seen positive announcements in China, India and the United States supporting pumped storage hydropower (PSH). These water batteries will form a vital part of the future of hydropower development. In 2021 China announced a target of 120 GW of pumped storage capacity by 2030. The US Inflation Reduction Act, announced in 2022, includes a US$369 bn package of tax credits for the nation's energy sector which will encourage pumped hydro projects. In early 2023 the Indian Government also published their 'Guidelines to Promote Development of Pump Storage Projects' which set out the financial mechanisms and policies required to achieve 18.8 GW of pumped storage by 2032.

In a sign of how these policy decisions affect investments, New South Wales in Australia announced in September 2022 an A$45 million funding package to unlock the development of five new PSH projects. Just a month later, the Queensland Premier announced a plan to investigate the world's largest PSH project, which could provide 5 GW of installed capacity and 24-hour storage to the state grid.

In 2022 more than 34 GW of new hydropower capacity was commissioned around the world. This is the first time since 2016 that more than 30 GW of new capacity has been delivered. IHA is proud of the growing momentum of hydropower development globally, and its ability to provide wider opportunities for water management in mitigating the impacts of floods and drought. This Outlook covers these areas and more, including highlighting the opportunities modernisation brings and the levels of investment needed to achieve this.

With the support of our members, we will continue to build a steady drumbeat of events and activities to support this momentum. This will include high-level policy missions, the continuation of the #WithHydropower campaign, a second Global Hydropower Day and co-hosting the World Hydropower Congress with the Government of Indonesia. All setting the stage for sustainable hydropower's 21st century role in the lead up to COP28.

We understand this is a marathon and not a sprint, but momentum must be increased if we are to reach net zero by 2050 and keep the global temperature rise below 1.5°C. The key message from this World Hydropower Outlook, is the urgent need to fill the gap between planned and required hydropower capacity for 2050. This will not happen without clear political action, supported by industry, regulators and the wider stakeholder community.



Roger Gill
IHA President





Eddie Rich
IHA CEO



Executive summary



Baihetan hydropower station, China
Credit: CTG

This first edition of the World Hydropower Outlook looks ahead to the opportunities and challenges facing the sector during the energy transition. It also provides a status of the present situation and a review of recent developments.

We know that sustainable hydropower plays a vital role in the energy transition; its unique characteristics – flexible, renewable electricity generation that is deployable at scale – mean it can deliver reliable power, back up wind and solar photovoltaic (PV) generation and ensure that we do not have to fall back on fossil fuels or yet-to-be-deployed technologies to keep the lights on.

The scale of deployment needed is big, yet attainable. The International Energy Agency (IEA) and International Renewable Energy Agency (IRENA) both estimate that the most cost effective, achievable global net zero energy system will require around twice as much hydropower by 2050 as there is today - that is between 2,500 GW and 3,000 GW, including pumped storage hydropower (PSH).

To get there we need to deploy over 45 GW a year. The hydropower sector and its partners have achieved this before - in 2012, 47 GW was commissioned. However, our forecast of the pipeline suggests that without urgent action we will fall a long way short with 590 GW of projects at various stages of development, including 214 GW of pumped storage. Even if all this capacity is built (only 131 GW of the pipeline is actually under construction) it will still leave a gap of over 700 GW.

We know the potential is out there. Off-river pumped storage can be widely deployed and the Australian National University has identified over half a million potential PSH sites globally and 23 million GWh of storage capacity. For conventional hydropower, there remains a vast amount of economically viable potential across all continents, more than enough to deliver hydropower's essential role in the energy transition.

Potential does not just sit within greenfield sites; the hydropower fleet is ageing. Almost half of the global

4,408 TWh
Electricity generated from hydropower in 2022

+3.7%
increase from 2021

1,397 GW
Hydropower installed capacity reached in 2022

+2.7%
on 2021

34 GW
Capacity added in 2022, including pumped storage

up on
26GW
added in 2021

175 GW
Pumped storage installed capacity reached in 2022

+6%
on 2021

10.5 GW
Pumped storage capacity added in 2022

up on
4.7GW
added in 2021



Credit: Erhard by Talis

To unlock this potential IHA urges governments and policy makers to take these important steps:

1 **Incentivise sustainable hydropower development through financial and market mechanisms that reward flexibility.**

2 **Accelerate the development of renewables through streamlined permitting and licensing.**

3 **Embed hydropower sustainability practices in government regulation.**

capacity (630 GW) is over 30 years of age, and almost 40 per cent (490 GW) is over 40 years old, according to IHA data. This presents a huge investment opportunity, not only to secure existing capacity, but also to increase both generating capacity and capability, allowing more flexible operation in response to changing electricity grids and climate change.

We also know that most dams are not used for hydropower – out of nearly 59,000 large dams (higher than 15 metres) and reservoirs (more than 3 million cubic metres), only 21 per cent of single purpose and 16 per cent of multipurpose reservoirs are used for electricity generation. While not all these non-powered dams would be appropriate for hydropower, where in-depth assessments have been carried out, considerable retrofitting potential has been identified. In the US for example, the Department of Energy Wind and Water Program found as much as 12 GW of potential, which could increase the US's fleet by 15 per cent – enough to power nearly 5 million US homes annually.

Of course, not all economically viable potential will be suitable for development, due to social and environmental constraints which must be carefully assessed and considered. IHA strongly encourages developers to use the Hydropower Sustainability Standard, the first global certification system of its kind in the renewables sector. Governed by the Hydropower Sustainability Alliance, a multi-stakeholder body, the Standard defines globally accepted environmental, social and governance good practice requirements for hydropower. It covers 12 topics and is aligned with the World Bank and IFC Sustainability Framework, green bonds, carbon credits, and private investor safeguards.

In March 2023, the Sebzor hydropower project, an 11 MW hydropower project owned by Pamir Energy in Tajikistan, was the world's first hydropower project to be certified against the Hydropower Sustainability Standard. Many more are in the pipeline, demonstrating that, in the words of the 2021 San José Declaration: "going forward, the only acceptable hydropower is sustainable hydropower".

2022 in brief

In 2022 more than 34 GW of new capacity was commissioned around the world, including over 10 GW of pumped storage. This is the first time since 2016 that more than 30 GW of new capacity has been delivered. While direct year on year comparisons can be misleading due to the large size of individual projects, it is nonetheless a positive sign that governments, industry and wider stakeholders appreciate the essential role that hydropower will play on the electricity grids of the future.

Hydropower provides around 4,400 TWh, which is over 15 per cent of the world's electricity.

In **east Asia** and indeed globally, China continues to lead the way, with nearly 24 GW of new capacity brought into service in 2022, including the final units at the huge 16 GW Baihetan project. China's new capacity included over 8 GW of PSH, reflecting its high ambitions for pumped storage which could see as much as 270 GW of capacity by the 2030s. Elsewhere in the region Laos, with over 1 GW of new capacity, was the only country to add significant new capacity. However, developments in pumped storage continue apace, with an announcement in Australia of what will be the world's largest pumped hydro facility in the state of Queensland, and more developments underway in the Philippines and Thailand.

In **central and southern Asia** nearly 2 GW of new capacity was installed, including large projects in Pakistan (Karot, 720 MW) and India (Bajoli Holi, 180 MW), with many large-scale projects nearing completion and set to be commissioned in 2024/25. In a further welcome development, the Government of India published its Guidelines on Pumped Storage Projects, recognising the importance of PSH in providing grid services as India's grid sees increasing levels of variable renewables like wind and solar PV.

Both **North and South America** gained more than 1 GW in new capacity in 2022, with notable increases in Canada (over 1 GW), Colombia (618 MW) and Chile (477 MW) from several large plants in those countries. There were continued positive policy developments including in the USA with the Inflation Reduction Act and in Canada, the 2023 budget will incentivise hydropower development through innovative tax credit schemes.

In **Africa** steady progress continues with just under 2 GW added in 2022, with a mixture of big projects over 50 MW (Ethiopia, Guinea and Zambia) and smaller projects (including in Madagascar, Uganda and Rwanda) commissioning with support from private and public sources of investment. While much more needs to be done to increase hydropower in Africa, big projects are expected to be commissioned next year in Angola (Caculo Cabaça, 2 GW) and Cameroon (Nachtigal, 420 MW), which will help the continent in its clean energy transition.

Alongside the urgent need for new sources of low-carbon power in Africa, the current hydropower fleet requires modernisation to maintain existing generating capacity and enable more flexible operation to integrate increasing amounts of wind and solar. IHA has been supporting the African Development Bank's (AfDB) hydropower modernisation project, with a mapping study looking at the modernisation needs across the continent. IHA identified that modernising the existing fleet could help secure the availability of over 14.7 GW of installed capacity, increase project flexibility, reduce maintenance costs, enhance water management, and enable safer operations, all while being less cost-intensive than developing greenfield projects. For those projects in the highest-need category, approximately US$2.1bn will need to be invested. For medium-need projects, a further US$4.7bn investment will be required.

Perhaps one of the more unexpected developments in 2022 was the significant increase in hydropower capacity in **Europe**. Outside of China, Europe (including Türkiye) saw the largest increase in capacity (nearly 3 GW) of any of our regions, driven by pumped storage facilities each just under 1 GW in capacity being commissioned in Switzerland and Portugal.

In the sections that follow, this report provides further details on these developments and some of the key areas of hydropower potential that are available across the globe. These areas are the key to driving the clean energy transition and meeting our net zero goals for 2050.

Methodology

The data presented in this report has been continuously tracked and updated to account for new information in our global hydropower database, which tracks more than 13,000 stations in over 150 countries.

Data were compiled by a team of analysts using information sourced from (1) official statistics from governments, regulation agencies, transmission network operators and asset owners; (2) scientific articles and reports; (3) daily news reports involving hydropower plant development, official declarations of contracts, and equipment deals; and (4) direct consultation with operators and industry sources.

It is important to note that different sources report on capacity and generation using their own methodologies. For example, some countries may not include 'off-grid' facilities (hydropower plants not connected to the main electricity grid) in their official statistics, while others do. Where possible we have tried to account for these differences, but it is likely that inconsistencies remain.

When generation data from primary sources is not available, estimates are prepared based on the previous year's figure, averaged capacity factors and regional meteorological events and data.

For a small number of countries, capacity data from previous years has been updated with new information. This means that those countries will see a year-on-year change compared to previous years' reports, but these increased capacity numbers are not treated as capacity added or lost in 2022.



Dhaulagiri Rural Municipality , Myagdi District, Nepal
Credit: IES Team, Bizbell

world hydropower congress

Book your place now for the 2023 World Hydropower Congress

The 2023 World Hydropower Congress, co-hosted by the Government of the Republic of Indonesia, Indonesian electricity utility PLN, and the International Hydropower Association, will take place in Bali from the 31 October to 2 November.

Under the theme 'Powering Sustainable Growth,' the Congress will focus on renewable energy as a driver of industrial development for a clean and sustainable future.

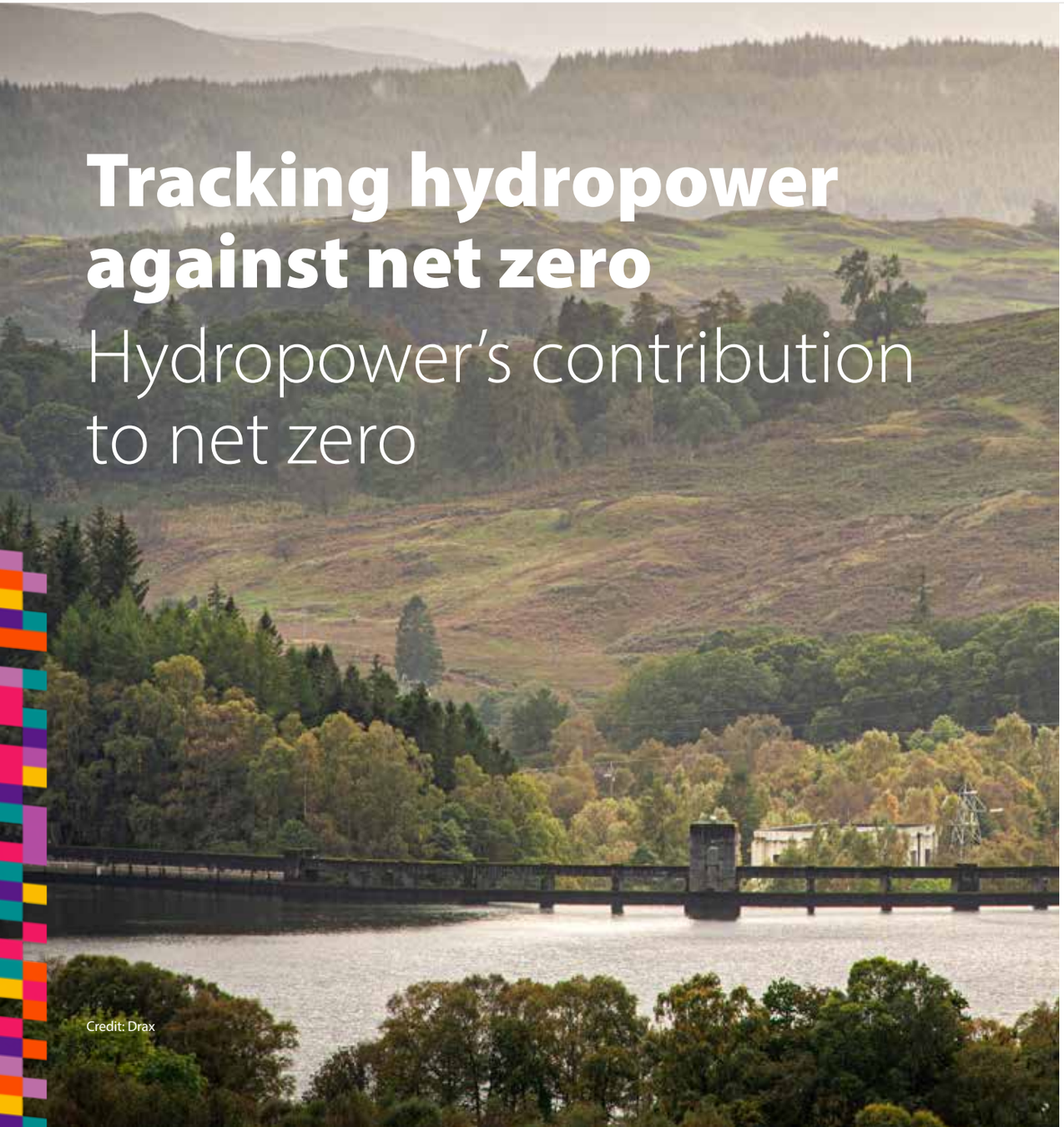
Book now to join global leaders from the hydropower sector and beyond for a programme of over 30 sessions across a full suite of topics, discussing the importance of sustainable hydropower in global clean energy transitions.

Attendees will hear from high profile speakers at plenary and parallel sessions, attend workshops on topics such as climate resilience and sustainability, and network with colleagues from around the world to keep up-to-date with the latest innovations in sustainable hydropower.

Go above and beyond in showing your support for the World Hydropower Congress by getting involved in more than just attending. We are offering a variety of partnership packages including the ability to display your innovations in our exhibition zone.

Book now at worldhydropowercongress.org





Credit: Drax

Tracking hydropower against net zero

Hydropower's contribution to net zero

The power sector is responsible for 40 per cent of global carbon emissions, making it the single largest contributor to global warming. To limit global temperature rises to 1.5°C, it will need to rapidly decarbonise. In parallel, the overall level of electricity generation is expected to more than double as economies grow, and electricity replaces other fuels in a wide range of sectors, including the transport sector. The International Energy Agency (IEA) and the International Renewable Energy Agency (IRENA) estimate that to achieve a net zero economy, global annual electricity demand will grow to around 75,000 TWh by 2050, almost three times today's demand (28,000 TWh in 2021).

The gap between planned and required hydropower capacity for 2050

IEA models suggest that by 2030, the global hydropower fleet will need to grow by over 420 GW. With the current pipeline, it is unlikely that this will exceed 230 GW, causing a gap in capacity of 190 GW.

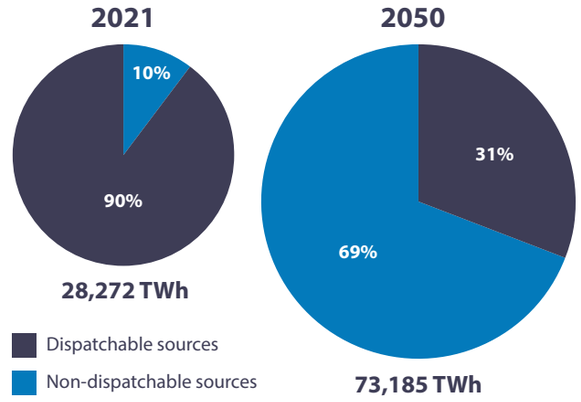
Even under the most optimistic assumptions the gap between IEA net zero targets and the existing pipeline will grow in the long term. Assuming that all the current pipeline of projects monitored by IHA will be completed by 2050, this analysis suggests that at least an additional 737 GW of hydropower (new capacity) will need to be identified and developed to achieve the capacity required to support the energy transition towards a net zero economy.

The changing face of global energy supply

Over the last century, electric power systems have relied on the stability provided by a fleet that is highly dispatchable (i.e., power plants that can control and adjust their power production to demand) such as coal, gas, nuclear and hydropower. As of today, these resources combined are responsible for almost 90 per cent of global electricity generation. But now this landscape is rapidly changing, and all the net zero projections for change rely heavily on a dramatic shift in the composition of the world's electricity-generating fleet. variable renewable energy sources (wind and solar) will become dominant, and their total contribution is forecast to evolve from 10 per cent today to a level close to 70 per cent by 2050.

The expansion of non-dispatchable power sources in the world electricity mix (2021 vs 2050 IEA (International Energy Agency) Net-zero economy scenario)

Source: IEA



Hydropower's future

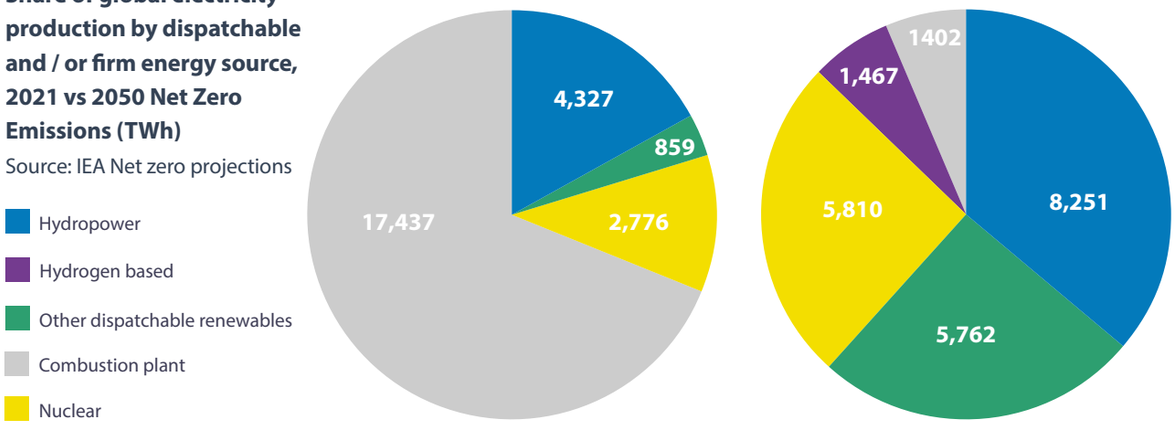
Wind and solar contributions will grow to 70 per cent while coal, oil and gas capacity will need to reduce at a rate of 100 GW per year. Low-carbon dispatchable technologies will have to step in to take over the role of 'guardians of the grid.' Like coal, oil and gas, these technologies will need to guarantee reliable, long-lasting, and affordable electricity generation for consumers.

Hydropower is not only today's main source of low-carbon electricity but is also equipped to become the lead provider of grid flexibility – it will be the backbone of reliable, safe, and decarbonised power systems. Net zero projections published by IEA, show how, in a decarbonised economy, hydropower is expected to become the predominant source of dispatchable electricity, contributing more than 40 per cent of the annual electricity production (approximately 22,700 TWh) of this group by 2050.

Both IRENA and IEA show that substantial amounts of green and brownfield hydropower capacity are urgently required to provide reliable low carbon electricity to back up variable wind and solar power. To achieve a net zero economy by 2050, IEA indicates that more than 1,300 GW of additional hydropower capacity is needed, reaching a total installed capacity of almost 2,700 GW. Similar conclusions are presented in the 1.5°C pathway scenario produced by IRENA, where the hydropower fleet will need to double over the next 30 years, reaching an overall installed capacity of more than 2,900 GW, of which almost 420 GW is pumped hydro.

Share of global electricity production by dispatchable and / or firm energy source, 2021 vs 2050 Net Zero Emissions (TWh)

Source: IEA Net zero projections



International Hydropower Association

Doubling of hydropower capacity will not happen by market forces alone. Governments will need to develop mechanisms that reward flexibility to balance the system.



Mai Beni Assessment, Nepal
Credit: Amina Kadyrzhanova

Hydropower's current growth levels

Despite the significant global efforts that both public and private sectors have undertaken in recent years to shift towards a more sustainable energy mix, our analysis shows that hydropower is not developing fast enough to meet global targets. To reach a net zero economy, according to the IEA net zero projections, hydropower should be growing at an average pace of circa 46 GW per year, the equivalent of the combined capacity of Norway and Mexico, but the current rate of development is well below these levels. Between 2016 and 2021, hydropower grew at an average rate of 22 GW, half the required rate. Furthermore, this pace was below that recorded during the previous five years (2011-2016), which saw an average annual capacity addition of circa 34 GW.

Despite this trend, the hydropower sector has demonstrated that it can deliver at the pace required. For instance, in 2012, about 47 GW of installed capacity was commissioned, as well as 38 GW the following year.

The risk is great, and the consequences are irreversible. If this trend does not improve, it will cause a shortage of dispatchable low-carbon power over the next decades in the order of 700 GW, with an implied reliance on coal and gas. The associated carbon emissions would range from 1,100 Mt to 1,800 Mt per year – comparable to the sum of the current annual emissions of three major economies such as Germany, France and Italy.

IRENA provides a set of regional breakdowns of its 1.5°C pathway. They indicate that most of these developments are expected to take place in Asia, with over 570 GW of additional capacity required. The Middle East and Latin America will also play a crucial role, bringing over 200 GW of new hydropower projects online respectively.

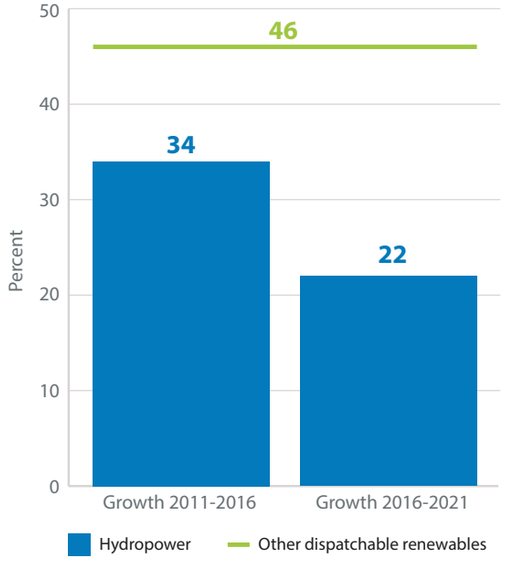
China and the Asian continent have led the way in recent years, but growth slowed down when major projects, like Three Gorges and Xiluodu, reached completion. Over the last five years, hydropower has failed to grow fast enough in any of the macro-regions analysed, and this gap seems to have widened over time.

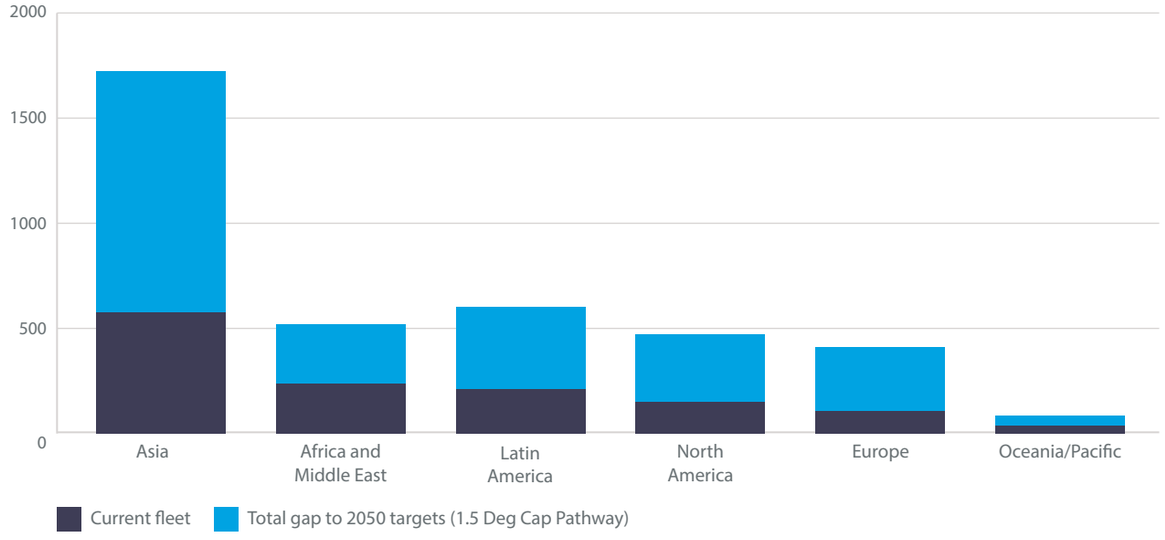
The challenge is even more evident in Europe and North America, where, due to the ambitious targets for the deployment of variable renewable energies, the regional electric power systems will require substantial amounts of flexibility to stabilise the grid and secure production at any given time. Currently, the level of deployment of new hydropower plants in these regions is well below the requirements for the 1.5°C pathway.

The largest gap in terms of growth rate is recorded in the African continent, where huge hydropower potential will need to be unlocked to support electrification without generating new CO2 emissions which typically result from economic development.

Historic growth rates compared required additions (GW per annum)

Source: IHA and IRENA data





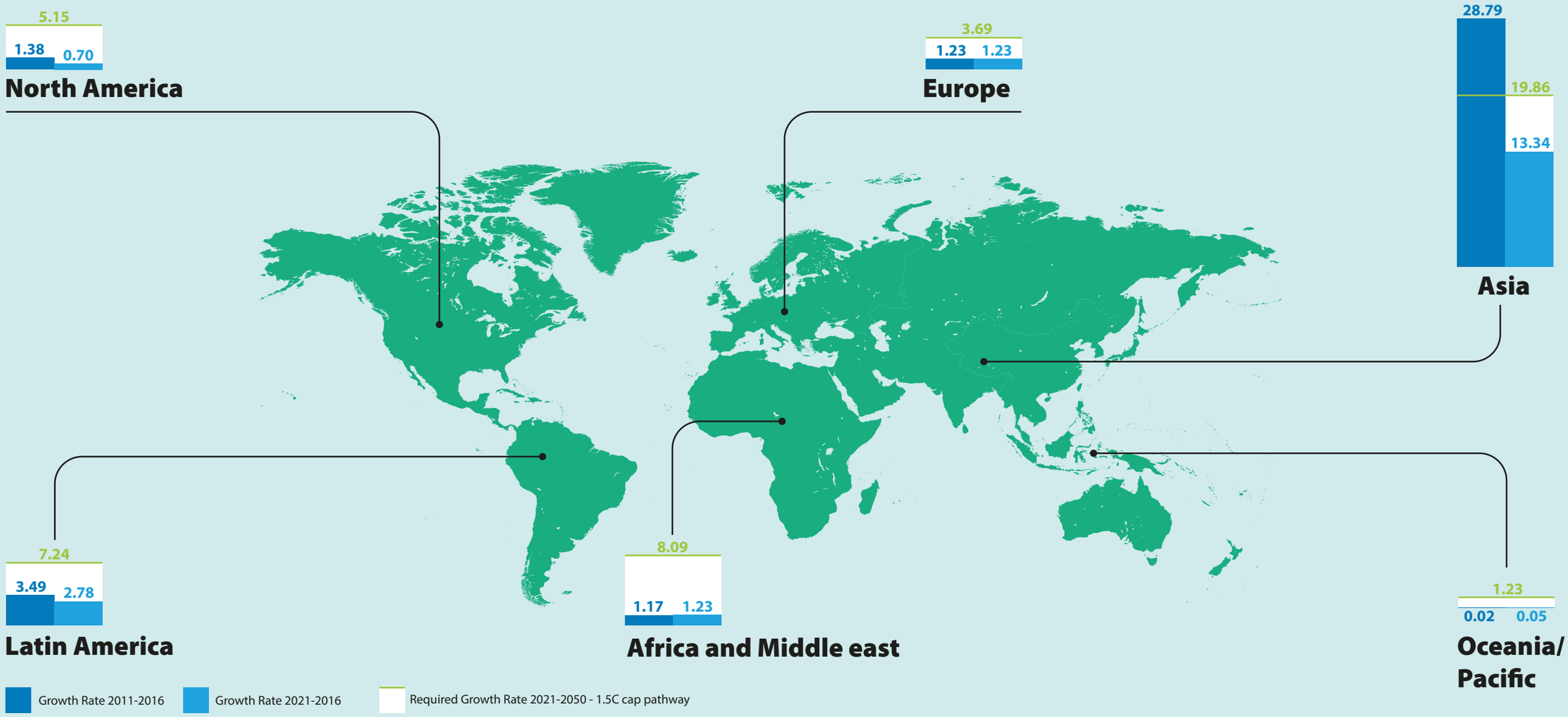
Regional existing installed capacity* and gap towards the 2050 IRENA 1.5°C pathway targets (GW)

Source: IRENA 1.5°C pathway and IHA database. *The figures presented exclude pumped storage

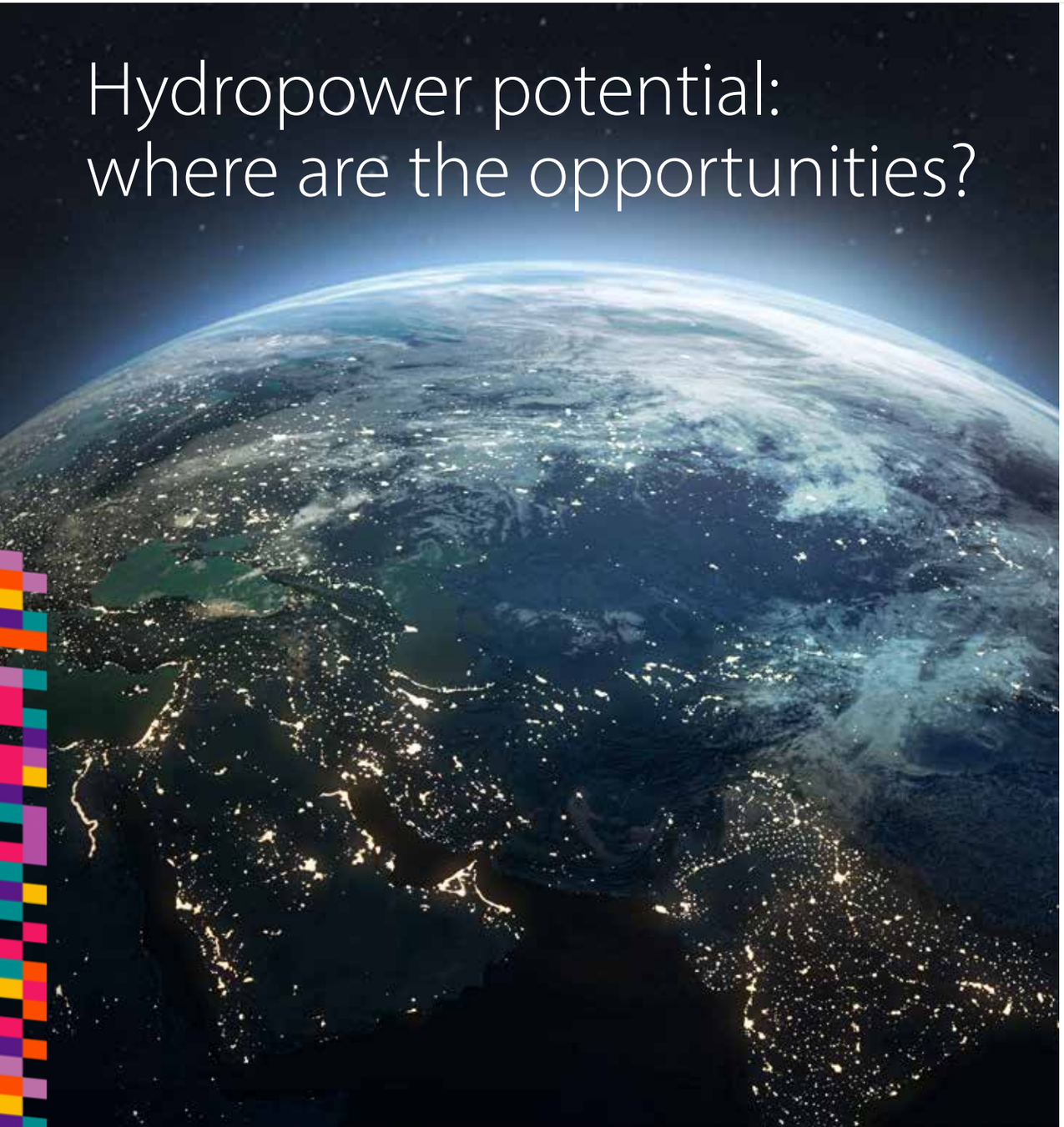
Average annual capacity additions* actual (2011-2016 and 2016-2021, GW) vs IRENA 1.5°C pathway regional targets

Source: IHA and IRENA data *Excluding pump-storage

The map shows for IRENA's hydropower capacity additions needed for net zero (green line) and the historic average capacity additions during 2011-2016 (dark blue) and during 2016-2021 (light blue) for each region. All figures are in GW.



Hydropower potential: where are the opportunities?



IHA's analysis shows that there is more than enough hydropower potential to achieve the net zero targets set by IEA and IRENA for 2050. More importantly, around half of the economically feasible hydropower potential remains untapped. This potential can be achieved through four broad actions: developing new hydropower, developing PSH, modernising existing infrastructure, and retrofitting non-powered dams.

Developing new hydropower

Substantial potential for new hydropower development is present globally, but the question that arises is – where are the most significant opportunities located? The Hydropower 2050 report published by IHA in 2021 identified remaining hydropower potential at the global and regional levels. The results are shown in the table below.

As we march towards a net zero future, we must recognise the critical role of economic, environmental and social factors in the assessment of hydropower potential. As stated by the 2021 San José Declaration: 'going forward, the only acceptable hydropower is sustainable hydropower.' We need a deeper understanding of hydropower potential through a comprehensive, objective, and uniform quantification of environmental and social factors on a global and continental scale.

Pumped Storage Hydropower (PSH) potential

PSH is a proven and mature technology with tremendous potential for energy storage. Compared to other forms of energy storage, PSH can be more cost-effective, especially for very large capacity storage. This technology has competitive round-trip efficiency and long life spans, making it ideal for providing short and long duration storage.

PSH has the potential to increase globally, and it can also be developed in areas with very low conventional

Region	Indicative Potential Hydropower Capacity (GW)*	Installed Capacity 2022 (GW)**
East Asia and Pacific**	1100	464
South and Central Asia**	600	157
Africa	630	37
North & Central America	620	184
South America	500	179
Europe	350	202

* All estimates of hydropower potential in the table include existing capacity. These figures should not be taken literally but instead provide an indication of regions of the world where hydropower is relatively underdeveloped.
** Note that the Installed Capacity here does not include pumped storage.

hydropower potential. The Australian National University published the world's first atlas of greenfield off-river PSH potential in 2021, which identified over half a million potential PSH sites and 23 million GWh of storage capacity (roughly equivalent to the world's entire annual electricity consumption today). Another recent study focused on the PSH potential for seasonal storage, including cost curves, highly valuable information for energy planners. Their estimated world energy storage capacity below a cost of US$50/MWh is 17.3 million GWh, approximately 68 per cent of the world's electricity consumption in 2021.

Similarly, the National Renewable Energy Laboratory (NREL) estimates that the U.S. alone has the potential for as much as 2,300 GW of 10-hour energy storage capacity from PSH. In China, the government has set long-term targets for PSH development, with plans to launch over 62 GW of pumped hydro storage by 2025 and 120 GW by 2030. Even more ambitious goals have been identified by PowerChina, with construction to be started on more than 200 PSH projects with a capacity of 270 GW by the 2030s. In India, the Government recently underscored that the potential for pumped storage has been relatively untapped, with a revised potential of 103 GW and only 4.7 GW PSH currently operating.

To fully leverage the potential of PSH in a renewable-dominated energy landscape, the following policy recommendations should be considered in line with the International Forum on Pumped Storage Hydropower recommendations:

- Comprehensive Planning: policymakers must anticipate long-term clean electricity requirements, considering the need for storage to support the integration of a high share of variable renewables into the energy mix.
- Site Identification: a systematic mapping and assessment of existing and potential hydropower sites suitable for PSH is necessary to guide sustainable infrastructure development and inform energy policy decisions.
- Financial Frameworks: policymakers must construct robust financial policy mechanisms that incentivise PSH and enable long-term revenue visibility. Electricity markets should reward grid stability contributions provided by PSH. PSH could also be included in green finance initiatives.
- Sustainability Assessment: rigorous sustainability evaluations using internationally recognised assessment tools should be integrated into development processes.

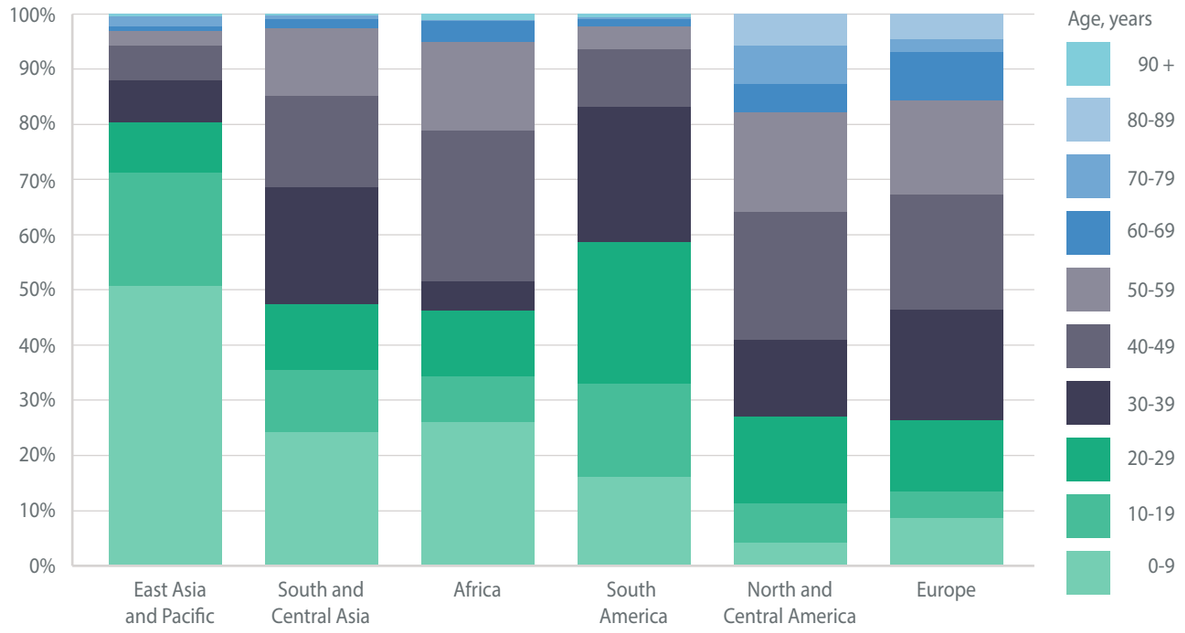
Modernising existing infrastructure

Modernisation of ageing hydropower infrastructure represents a business opportunity for the sector, while at the same time being a necessity to maintain output and increase efficiency and flexibility.

Innovative technologies can be implemented to increase the power flexibility and efficiency of hydropower stations, and they can give access to new revenue streams, thus helping to harness hydropower's full potential. Governments must encourage investment in modernisation programmes, both public and private finance, to secure the future of hydropower and net zero.

Hydropower is known as a 'forever' technology. A typical hydropower facility can have an operating life of more than a hundred years when maintained regularly.

Age profile of installed hydropower capacity, 2022



The capital requirements for modernisation projects are much less significant than those for greenfield projects and have modest or negligible environmental and social impacts.



Generator circuit breaker overhaul
Bakun Hydroelectric Plant, Malaysia
Credit: Sarawak Energy

As the oldest renewable technology, hydropower faces the challenge of an ageing fleet, with almost half of its global capacity (630 GW) over 30 years of age, and almost 40 per cent of the capacity (490 GW) over 40 years old, according to IHA data. By upgrading older plants, a considerable increase in capacity, efficiency and power generation can be achieved. IHA has collaborated closely with development banks in Asia, Latin America, and Africa to identify modernisation potential and prioritise investment needs.

Hydropower is known as a 'forever' technology. A typical hydropower facility can have an operating life of more than a hundred years when maintained regularly. The performance and reliability of components decrease as the stations age, impacting output, revenue, and safety. Therefore, modernisation programs, from repairing and replacing components to implementing innovative technologies, represent a significant opportunity for existing hydropower infrastructure to provide benefits such as optimised power production through improved efficiency or capacity additions, optimised operations and maintenance (O&M), enhanced flexibility, and water services at multipurpose hydropower sites.

The capital requirements for modernisation projects are much less significant than those for greenfield projects and have modest or negligible environmental and social impacts. The low marginal cost of hydropower means that failing to adequately modernise hydropower assets can result in higher electricity prices for consumers. In instances where the station operates significantly below its rated capacity for prolonged periods, the shortfall in electricity supply could be substituted by more expensive thermal alternatives such as coal and gas, leading to increased greenhouse gas emissions and higher costs for utilities and customers. For example, the modernisation of the Mount Coffee Hydropower station in Liberia provided 1 million people with a stable electricity supply, replacing diesel generators, and helping bring down electricity prices in Liberia. It is essential to consider the long-term benefits of modernisation projects, not only for the environment but also for communities and the economy.

In addition to securing the existing resources, two additional benefits from modernisation stand out: the potential increase in generation and the enhancement of flexibility. The U.S. Department of Energy estimates that the modernisation of equipment through retrofitting at hydropower projects has the potential to enhance the electricity generation capability by 8-10 per cent or more. According to IEA Hydropower, renewing electromechanical components can boost output by up to 20 per cent, while civil works refurbishments, such as dam heightening or improving intake facilities, can raise power by up to 50 per cent. Digitalisation of hydropower technologies and operation and maintenance practices is well established in many of the more mature energy markets and has become a key feature of modernisation programmes. Specifically, the installation of advanced digital controls, intelligent condition monitoring systems, remotely operated systems, and supervisory control and data acquisition systems are being included in projects to enable the digitalisation of existing stations' operations and control. According to a 2017 study conducted by General Electric and IHA, if the world's then 1,225 GW of installed capacity was digitised, it could result in an increase of 42 TWh of incremental generation, and a reduction of US$5 billion in operation costs per year.

XFLEX HYDRO programme

Flexibility is another key benefit of hydropower modernisation achieved through increasing the unit regulating margin, improving electro-mechanical performance, increasing storage capacity, battery hybridisation, and interconnecting hydropower plants with other energy sources such as wind and solar. The EU's XFLEX HYDRO programme provides an illustrative example of how modernisation programmes can deliver much more than the maintenance of existing capacity, but also increased flexibility and better participation in ancillary and short-term spot markets. The project studies a range of advanced software solutions and technological upgrades, including hydraulic short circuit, battery hybridisation and variable speed turbines, which are applicable to any existing asset. An example is the Grand'Maison pumped storage plant in France, where during the XFLEX HYDRO project, hydraulic short circuits were studied and successfully implemented using automation techniques for advanced control and efficiency. Thanks to the hydraulic short circuit, the plant is now capable of simultaneously pumping water into the reservoir, storing the surplus electricity injected in the grid by variable renewable energies, and providing grid regulating services.

Governments can encourage modernisation by:

- ensuring regulatory and licensing regimes are fit for purpose and do not disincentivise investment by station owners or operators;
- ensuring that electricity markets remunerate the flexibility and the dispatchability that modernised hydropower facilities can excel in providing, to safeguard grid stability;
- providing long term visibility of revenues including through long term contracts, that will further incentivise investment.
- Allocate part of the revenues from hydropower projects to community development fostering a more inclusive and sustainable development path.

XFLEX HYDRO

1 Alqueva (Portugal)
2 Alto Lindoso (Portugal)
3 Caniçada (Spain)
4 Frades 2 (Portugal)
5 Grand'Maison (France)
6 Z'Mutt (Switzerland)
7 Vogelgrun (France)



Retrofitting non-powered dams

Despite the large number of dams and reservoirs worldwide, only a small percentage of them are currently used for hydropower. According to the International Commission on Large Dams (ICOLD) database, out of nearly 59,000 large dams (higher than 15 metres) and reservoirs (more than 3 million cubic metres), only 21 per cent of single purpose and 16 per cent of multipurpose reservoirs are used for hydropower. The primary use for these structures is irrigation, leaving vast potential for non-powered dams (NPDs) to be transformed into powered dams for hydropower generation.

Upgrading existing non-powered dams presents a promising opportunity to augment global hydropower capacity, with estimates indicating a potential increase of 60 GW. In the United States alone, there are approximately 80,000 dams, with only 3 per cent currently generating electricity. A report by the United States Department of Energy Wind and Water Program revealed that 54,391 NPDs across the country have the potential to be transformed into powered dams. This has the potential to add up to 12 GW of new renewable capacity, which is equivalent to increasing the size of the existing conventional hydropower fleet by 15 per cent. Importantly, this 12 GW of hydropower has the capacity to power nearly 4.8 million U.S. homes on an annual basis.

Overall, the untapped potential of non-powered dams for the generation of hydropower presents a significant opportunity for renewable energy development, and further exploration and investment in this area could lead to a substantial increase in clean energy production. The realisation of hydropower potential from non-powered dams calls for a concerted effort to foster coordination among diverse stakeholders. A focus on the development of creative technical or market-based solutions that align with principles of circularity and sustainability is paramount.

The realisation of hydropower potential from non-powered dams calls for a series of strategic policy recommendations:

- Support research and development of innovative technologies which could help to lower the costs of retrofitting non-powered dams.
- Improve the existing processes to streamline hydropower licensing, relicensing, and license surrender, making them more efficient and responsive to the needs of retrofitting non-powered dams.
- Increase financial support for dam rehabilitation and retrofitting projects. This could be facilitated through greater budget allocations, tax incentives, or low-interest loans specifically designed for these initiatives.

What is currently in the new development pipeline?



The hydropower pipeline is growing and over the last two years the total capacity of the projects included had an increase of 50 GW. 77 GW of new projects were added to the announced (+20 per cent) and pending approval categories (+40 per cent), showing a positive trend that hopefully will continue over the next few years. Conversely, the capacity currently under construction has seen a contraction, with a decrease of 25 GW compared to two years ago.

Data collected by IHA shows that the current global pipeline represents over 590 GW of new hydropower projects. These are classified in four categories representing the general project status:

- **Under Construction** and **Regulator Approved** are projects that have reached construction phase or that have received approvals from the local authorities and are waiting to start construction.
- **Pending Regulator Approval** includes stations that have conducted feasibility studies and have submitted documentation to be approved by energy regulators.
- **Announced** includes proposed stations at the earliest stage of development. This is also the category with the highest level of uncertainty.

131 GW or 22 per cent of the projects included in the pipeline are currently under construction and 27 per cent of the total, representing a capacity of 163 GW, have received approvals from the local authorities. Hypothetically, if these were all completed over the next 10 years, it would imply an average growth rate in the sector of ~30 GW per annum, which is not enough to be on-track with the net zero pathways.

Challenge to the pipeline

Hydropower projects, like other large infrastructure projects, can face many challenges across their lifecycle. We see issues around long lead times for projects across the world. Some of the main issues include expensive feasibility studies and upfront costs, a general concern for bankability, and issues around local opposition. These challenges can lead to delays or even cancellation, with direct impacts on national and local decarbonisation efforts.

In recent years, there has been a clear improvement in cost and schedule accuracy. Research published in 2019 found that for projects developed after 2000, the average cost overrun was 33 per cent and schedule overrun was 18 per cent, compared with 46 per cent and 37 per cent respectively for pre-2000 projects.

Nonetheless, delays can still have a large impact. Governments can miss out on the economic gains from projects and may need to defer to using other electricity sources to meet their needs. In Uganda, project delays led to an estimated impact of 1 per cent loss of potential GDP for each year that one large hydropower project was delayed. Similarly, Laos, was deprived of 3-7 per cent of gross GDP growth that was expected to be generated by a hydropower project. Individuals in communities may be left waiting for employment, which can lead to availability issues if they were to find work elsewhere when the project is ready to begin. The wider community will miss out on access to clean and affordable electricity and lose the potential benefit of flood control and mitigation, while experiencing prolonged pollution from construction. Investors may lose confidence in projects and look to other opportunities.

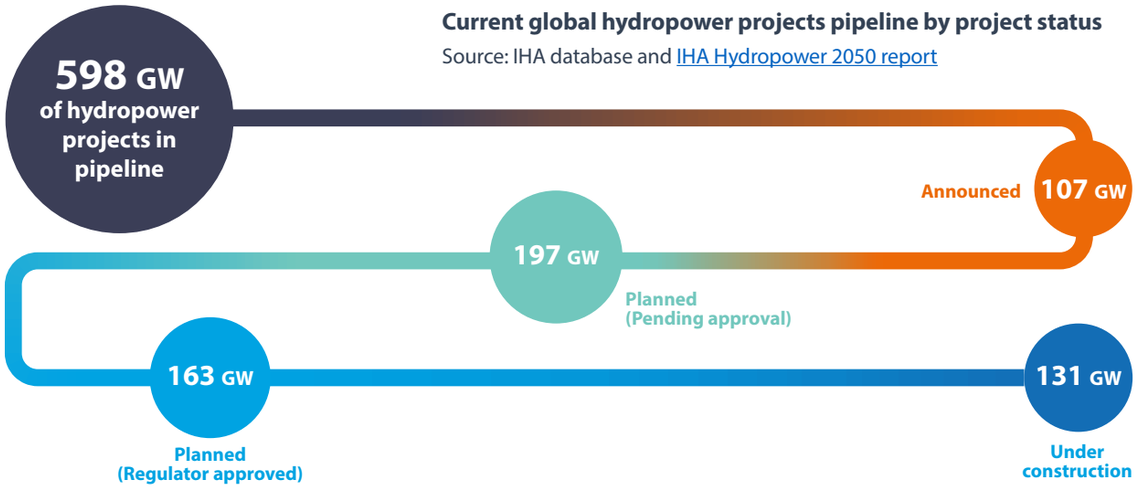
Governments have sought to identify the key reasons for these project overruns. For example, the Indian Government published guidelines in 2020 which noted some of the main reasons for time overrun in hydropower included "delay in award of works, land acquisition, natural calamities, rehabilitation and resettlement". IHA analysis shows that many projects have received their initial relevant regulatory approvals (such as environmental permitting) but are yet to proceed to construction. If construction does not begin within the timeframe established by the regulatory body, the project managers may need to restart the permitting process and, in some cases, the entire opportunity for development could be lost.

This helps to illustrate how challenging and complex the navigation of the permitting phase can be for hydropower projects and despite commitments to develop, the ongoing risk they will not reach completion.

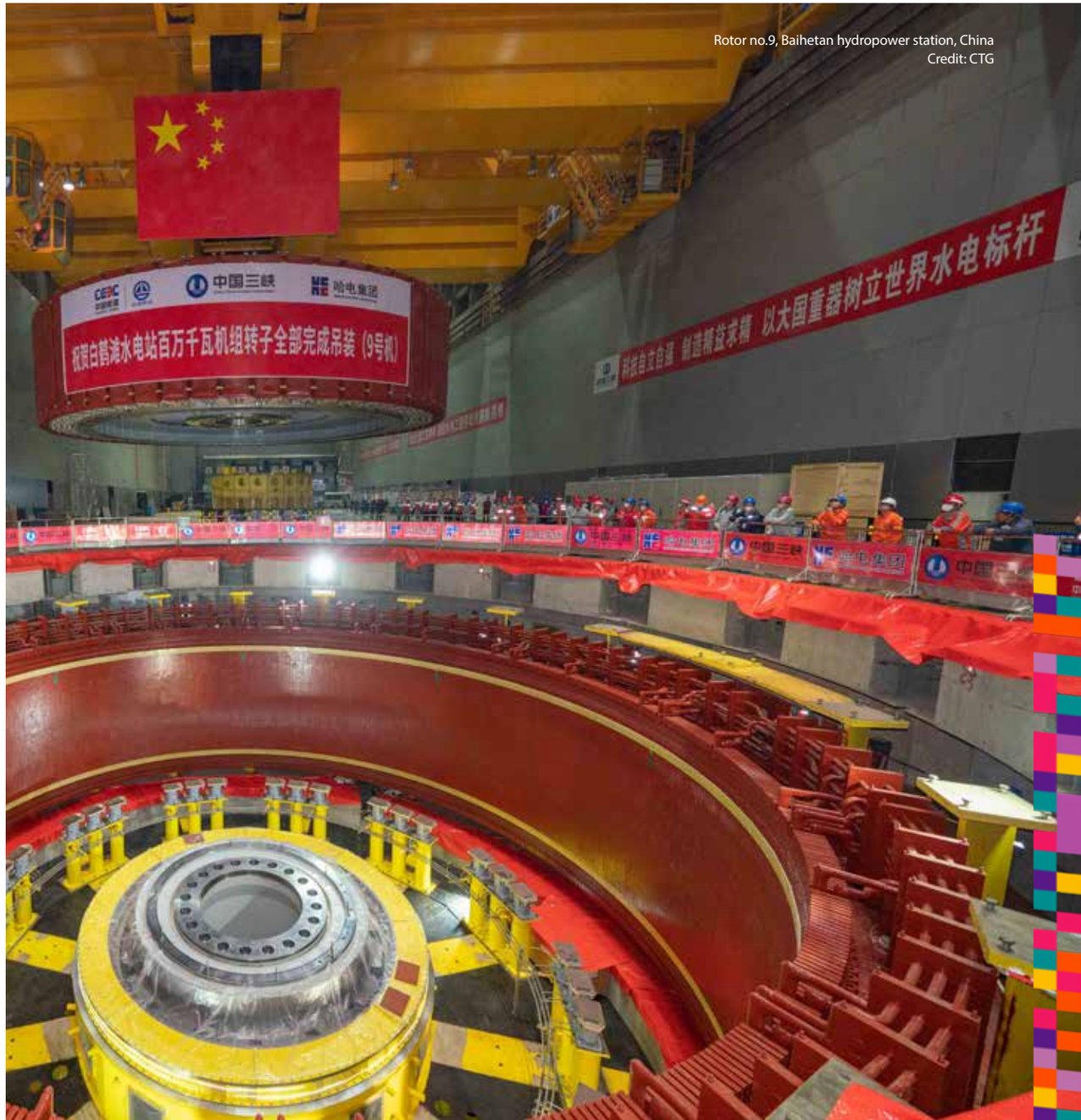
The good news for PSH is that its contribution to the pipeline is rapidly increasing. Open and closed loop pump storage projects amount to 214 GW, an increase of almost 90 GW compared with two years ago. The global pumped storage capacity over the next two decades is expected to double in capacity, a pleasing recognition of the crucial role that is played by these types of facilities, providing flexibility as well as long and short duration storage capacity.

Current global hydropower projects pipeline by project status

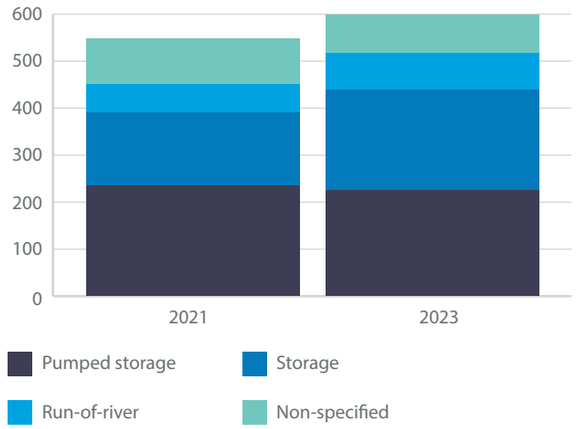
Source: IHA database and IHA Hydropower 2050 report



International Hydropower Association



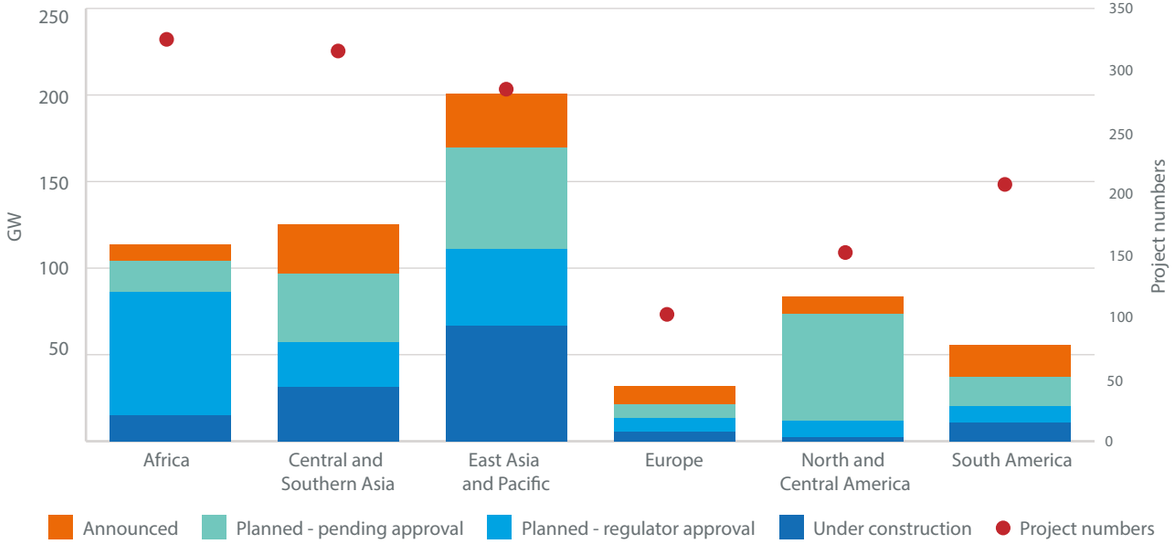
Rotor no.9, Baihetan hydropower station, China
Credit: CTG



Evolution of the global hydropower projects pipeline by type of plant

Source: IHA database. Pumped storage includes both closed and open loop pump storage hydropower plants

Projects that have been announced, have sought and achieved regulatory approval, and are under construction by region



Evolution of the global hydropower projects pipeline by region and type of plant

East Asia and the Pacific has the largest number of projects in the pipeline as well as the largest proportion of projects currently noted as **Under Construction**, with the vast majority in China. Interestingly, almost 32 per cent of these are pumped storage stations. This number is strongly boosted by China, which has 68 GW of pumped storage projects alone. This follows the immense target that China has set itself to rapidly expand its hydropower fleet to support its equally rapid solar and wind deployment to phase down coal-fired generation. Hydropower and PSH is considered a core part of the country's ongoing five-year plan. Australia, Indonesia, Laos, Papua New Guinea could also see substantial increases in capacity with significant projects recently announced and under construction.

Africa's pipeline has 120 GW in development in the region, with the largest proportion of projects having received regulatory approval, but considerably less capacity under construction. Due to the urgent need to electrify the continent, most projects in the pipeline are conventional hydropower. Around 84 GW (excluding closed loop pumped storage) are reported to be at an advanced development stage (approved from the regulator or under construction), suggesting that Africa could substantially accelerate its development process over the next decade, reaching a level close to 8 GW per year, in line with IRENA's 1.5°C Pathway projections. Even excluding the Grand Inga project currently in the pipeline, which alone accounts for 39 GW, African hydropower is expected to experience accelerated growth. Initial analysis suggests that the long period from project announcement to construction is usually due to lack of financial partnership and/or funding availability. In some cases, projects have received international **financial support** but have not met the requirements to use the funds due to lack of local community buy-in or because of the slow procurement of consultancy services. Considering Africa's high potential for hydropower development and a need to rapidly increase electricity to meet demand, accelerating access to financing and sustainable construction is crucial for the region.

Europe has fewer hydropower projects in the pipeline than other regions, reflecting the fact its fleet is one of the oldest and most developed. Of the future projects in the pipeline, over 90 per cent are pumped storage projects. The most common challenge shared by stakeholders is the lack of policy to incentivise upfront investment. As governments in Europe rapidly increase

Considering Africa's high potential for hydropower development and a need to rapidly increase electricity to meet demand, accelerating access to financing and sustainable construction is crucial for the region

wind and solar deployments over the next decade, this will see urgent requirements for additional storage capacity to avoid curtailment and balance the electric power systems. Revisions to the EU Electricity Market to support flexibility may see a shift towards dispatchable hydropower projects.

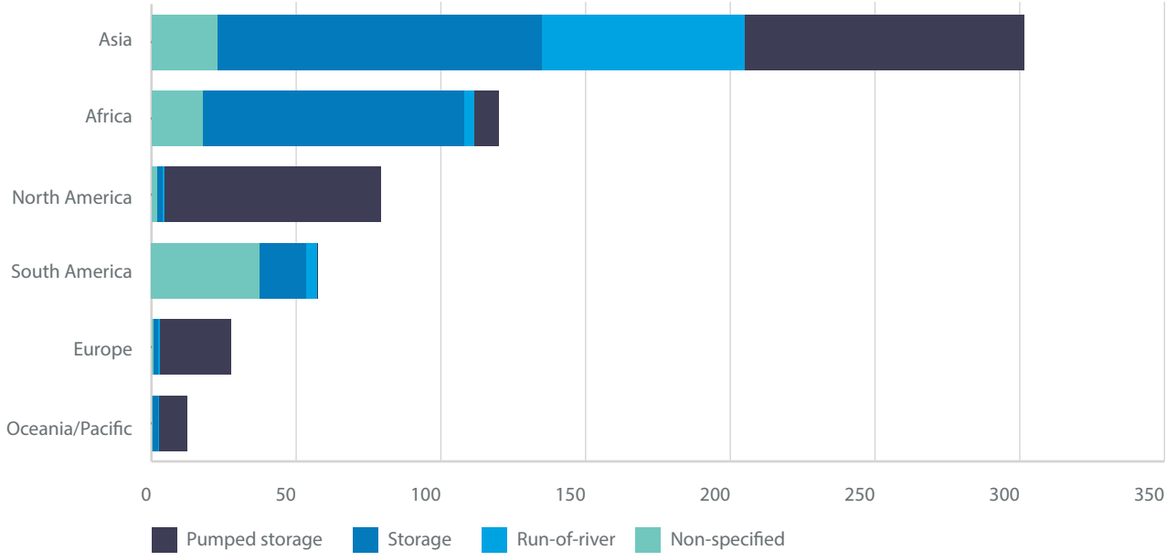
North and Central America has the largest proportion of projects that have been announced and are awaiting regulatory approval. It is theorised that this is because regulatory processes take considerably more time in this region compared to others. Like Europe, pumped storage projects represent over 90 per cent of future projects. With governments prioritising the immense roll-out of variable renewable energy, storage will become an increasingly important element of the grid.

South America has a large volume of smaller hydropower projects that have been announced which are typically run-of-river or small-scale reservoir storage. Many of these projects are ready but awaiting financial support.

South and Central Asia has many projects in the pipeline especially in India, Pakistan, Nepal, and Bhutan, whose governments have all recently made announcements to prioritise hydropower. The pipeline data indicates a large volume of small hydropower projects have been planned and are awaiting appropriate permissions.

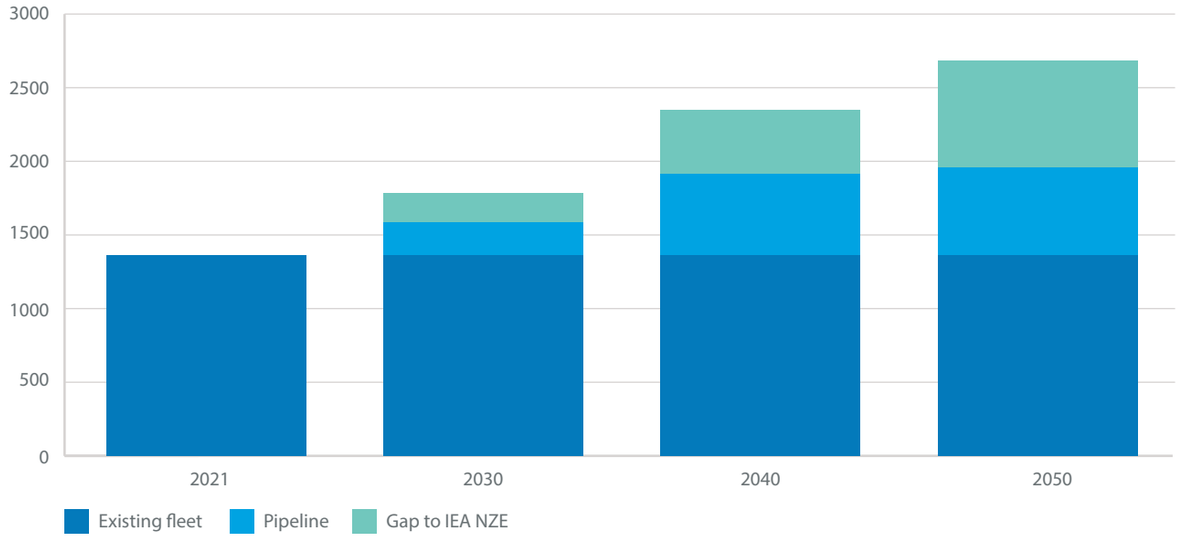
Current regional hydropower projects pipeline by project type* (GW)

Source: IHA database. *Pump storage includes both close and open loop pump hydropower plants



Hydropower development based on the current global hydropower projects pipeline and gap to the IEA Net Zero Emissions scenario projections (GW)

Source: IHA database and IEA NZE scenario projections



It is by no means certain that all the projects in the pipeline will reach final completion, as there are several barriers to overcome. Local contexts may change, and some of the proposed stations may not be approved by regulators. Nonetheless, this pipeline is useful to understand the scale of the challenge awaiting the hydropower sector, and society as a whole, to reach a net zero economy.

Are there enough projects in the pipeline to meet net zero targets?

It is key to understand that the existing pipeline alone is not sufficient to meet the challenging targets identified by IEA. According to IEA projections by 2030, the global hydropower fleet is expected to grow by over 420 GW. While looking at the current pipeline, it is unlikely that the actual increase will exceed 230 GW, causing a gap of 190 GW. Even under the most optimistic assumptions, the gap between the IEA net zero models and the existing pipeline seems to grow bigger in the long term, reaching over 430 GW by 2040. Finally, even if all the current pipeline of projects monitored by IHA are completed by 2050, this analysis suggests that at least additional 727 GW of hydropower new capacity will need to be identified and developed to achieve the capacity required to support the energy transition towards a net zero economy.

Recommendations

Doubling the pace of hydropower development is essential for the energy transition, yet IHA analysis shows we are not on track. It is urgent for today's energy policies to focus on three key aspects associated with hydropower development.

1 Incentivise sustainable hydropower development through market mechanisms that reward flexibility. To meet the objectives of the Paris Agreement and the UN Sustainable Development Goals, IEA estimates that investment in hydropower needs to double to US$100bn a year. This cannot happen without appropriate market frameworks to incentivise new investment.

2 Accelerate the development of renewables through streamlined permitting and licensing. Hydropower planning and approval processes typically take more than five years before a project can even begin construction. Meanwhile, the default option is often to fall back on fossil fuels. The massive deployment of renewables needed to meet global climate goals through sustainable development should be accelerated by streamlining these processes wherever possible.

3 Embed hydropower sustainability practices in government regulation. Accelerating development does not mean cutting corners. Application of the Hydropower Sustainability Standard, built and governed through multi-stakeholder consensus, should be integrated into regulatory frameworks to maximise the benefits of projects and mitigate any negative impacts.

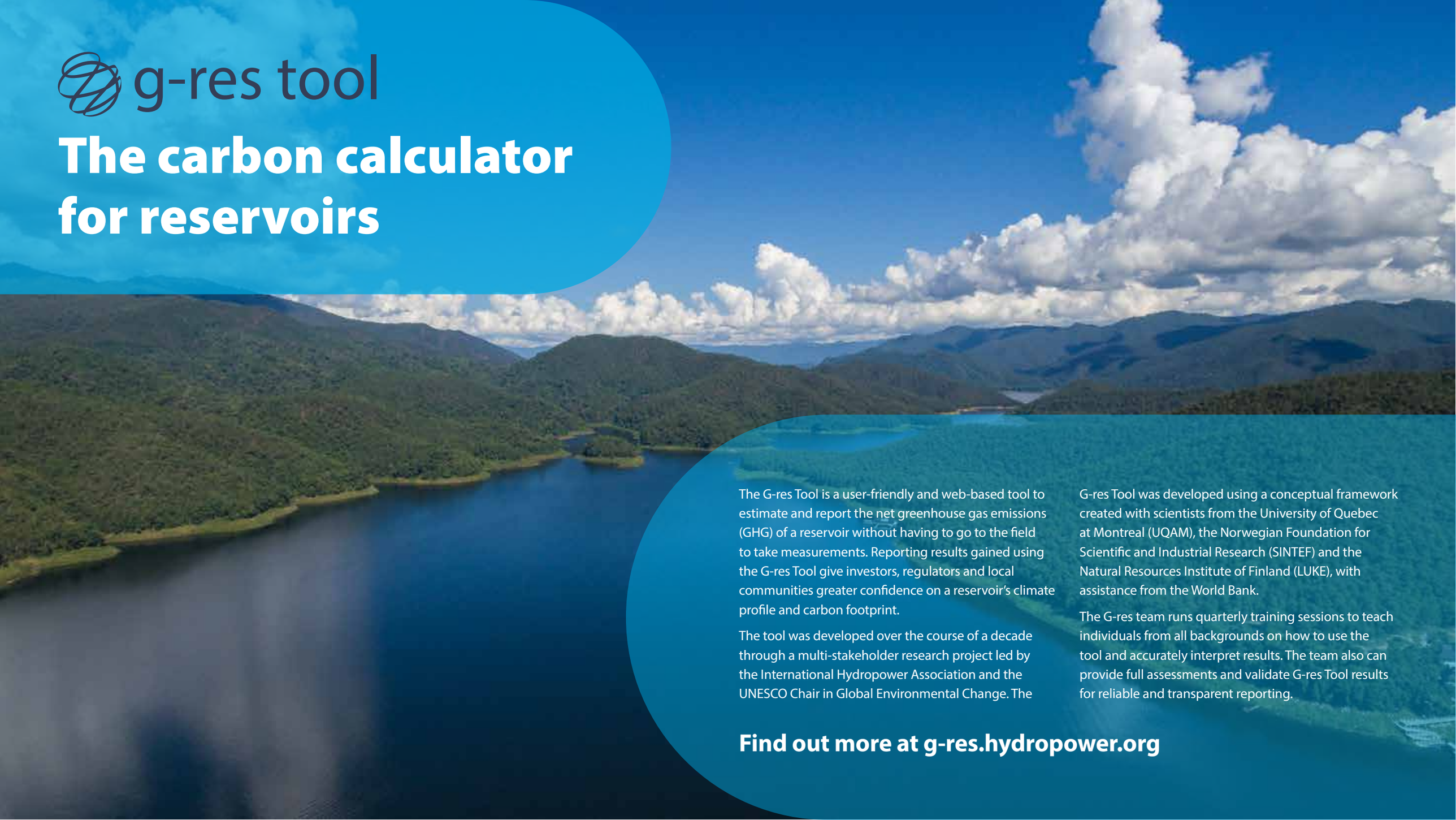
In addition, project risk mitigation strategies can be utilised to reduce the time delay and possibility of cancellation. Some measures include applying the FutureDams Risk Framework or using Hydropower How-to-Guides to follow industry best practices to reduce risk and increase stakeholder input.

How can we unlock quicker deployment?

IHA will be conducting an extensive survey of the sector over summer 2023 to identify the key barriers and actions that can unlock quicker, more cost-effective deployment. The survey will be launched in June 2023.



Cruachan turbine hall, Scotland
Credit: Drax Hydro



g-res tool

The carbon calculator for reservoirs

The G-res Tool is a user-friendly and web-based tool to estimate and report the net greenhouse gas emissions (GHG) of a reservoir without having to go to the field to take measurements. Reporting results gained using the G-res Tool give investors, regulators and local communities greater confidence on a reservoir's climate profile and carbon footprint.

The tool was developed over the course of a decade through a multi-stakeholder research project led by the International Hydropower Association and the UNESCO Chair in Global Environmental Change. The G-res Tool was developed using a conceptual framework created with scientists from the University of Quebec at Montreal (UQAM), the Norwegian Foundation for Scientific and Industrial Research (SINTEF) and the Natural Resources Institute of Finland (LUKE), with assistance from the World Bank.

The G-res team runs quarterly training sessions to teach individuals from all backgrounds on how to use the tool and accurately interpret results. The team also can provide full assessments and validate G-res Tool results for reliable and transparent reporting.

Find out more at g-res.hydropower.org

Priority policy themes

Climate resilience and drought



Baihetan hydropower station, China
Credit: CTG

The past year has been marked with headlines accompanied by stark images of extreme drought conditions in many parts of the world. With the spotlight on the rare absence or reduction of electricity generated by hydropower, these regions noticed the value it had silently been providing for years.

It is worthwhile to look past the headlines and remember that hydropower facilities can provide other services through its water control infrastructure and water storage capabilities, which play a crucial mitigating role in an era of increasing climate extremes. As noted by the World Bank in its urgent appeal for integrated water storage solutions, water storage provides three major services: improving the availability of water; reducing the impacts of floods; and regulating water flows to support energy, transportation, and other sectors. In times of drought, water can be withheld to ensure a steady supply for energy, irrigation, and municipal water supply. In times of extreme precipitation, water control infrastructure can reduce the impact of floodwaters.

As the climate gets more volatile, we will need more, not less, water infrastructure. Hydropower facilities provide this infrastructure with the bonus of much-needed low-carbon electricity. Box 1 illustrates one such example in which hydropower facilities provide a steady supply of water for electricity and other uses in Australia.

Additionally, hydropower's ability to generate reliable electricity over the long term as well as the short term should not be ignored. Natural year on year variations in rainfall, wind speeds and cloud cover can all have an effect on generation from the major sources of renewable electricity generation. In India, monsoon rains in 2022 led to above average hydropower generation, in contrast to the low water year of 2021/22. In April, the first month of the rainy period, generation was 40 per cent higher in 2022 than in 2021. This trend continued throughout the six months of the rainy season (see Figure 1).

Drought rarely affects all of a large region at the same time. Although images of ghost villages emerging from reservoirs in Spain in the summer of 2022 were certainly striking, other parts of Europe (Austria, Finland and Greece) experienced higher than average reservoir levels. Equally, although the western U.S. saw its second worse year for drought this century, the region is vast and comprises several climatic sub-regions, with drought rarely hitting all sub-regions at the same time. The Pacific Northwest had above-average surface water levels in 2021/22, and hydropower plants there balanced the lower output from plants in California. In the end, overall hydropower in the region was 84 per cent of its average expected generation.

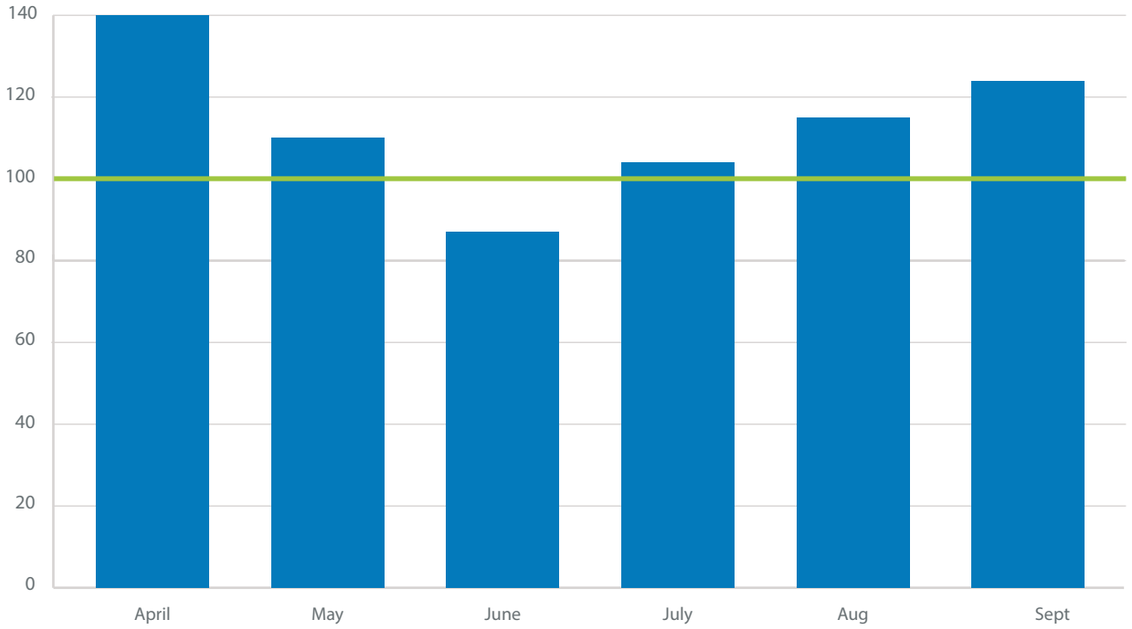
To explore the long-term trend, IHA examined literature on how climate change affects hydropower around the globe and concluded that there is a great diversity, with positive, negative, and/or inconsequential effects. For example, in the western Himalayas, increased flowrates in the winter due to increased glacier melt and precipitation are likely to lead to higher hydropower generation. In contrast, the increased temperature and lower levels of precipitation in Central and South America are likely to reduce the amount of hydropower generation.

In conclusion, "climate change is water change". While there is no doubt that the variability in precipitation

patterns has a direct impact on hydropower generation and infrastructure, the answer should not be less hydropower. The story is more nuanced than what is captured in headlines.

What is clear is that hydropower operators must adapt and develop new strategies to manage uncertainty around future water availability. The Climate Resilience Guide developed by IHA with financial and technical support from the European Bank for Reconstruction and Development, the World Bank Group and its Korea Green Growth Trust Fund, can help hydropower practitioners to manage the risks of climate change by providing good international industry practice.

Figure 1: Hydropower generation in India during the monsoon months of 2022 as a percentage of generation of the same month in 2021. Results greater than 100 per cent represent increased generation from 2022 versus 2021. Generation in April 2022 was almost 40 per cent higher than in April 2021



International Hydropower Association

Box 1

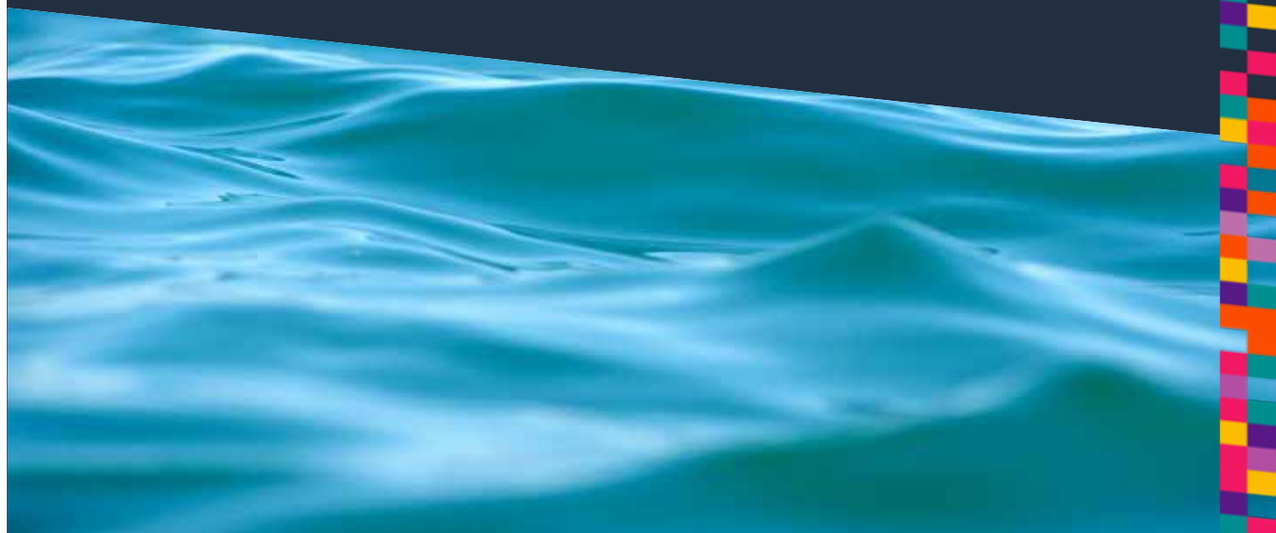
Hydropower mitigating the effects of drought in Tasmania

Hydro Tasmania operates several installations that include a provision for water for irrigation and other commercial uses. It considers the likely water requirements of these uses when periodically reviewing and updating its water release and storage strategy.

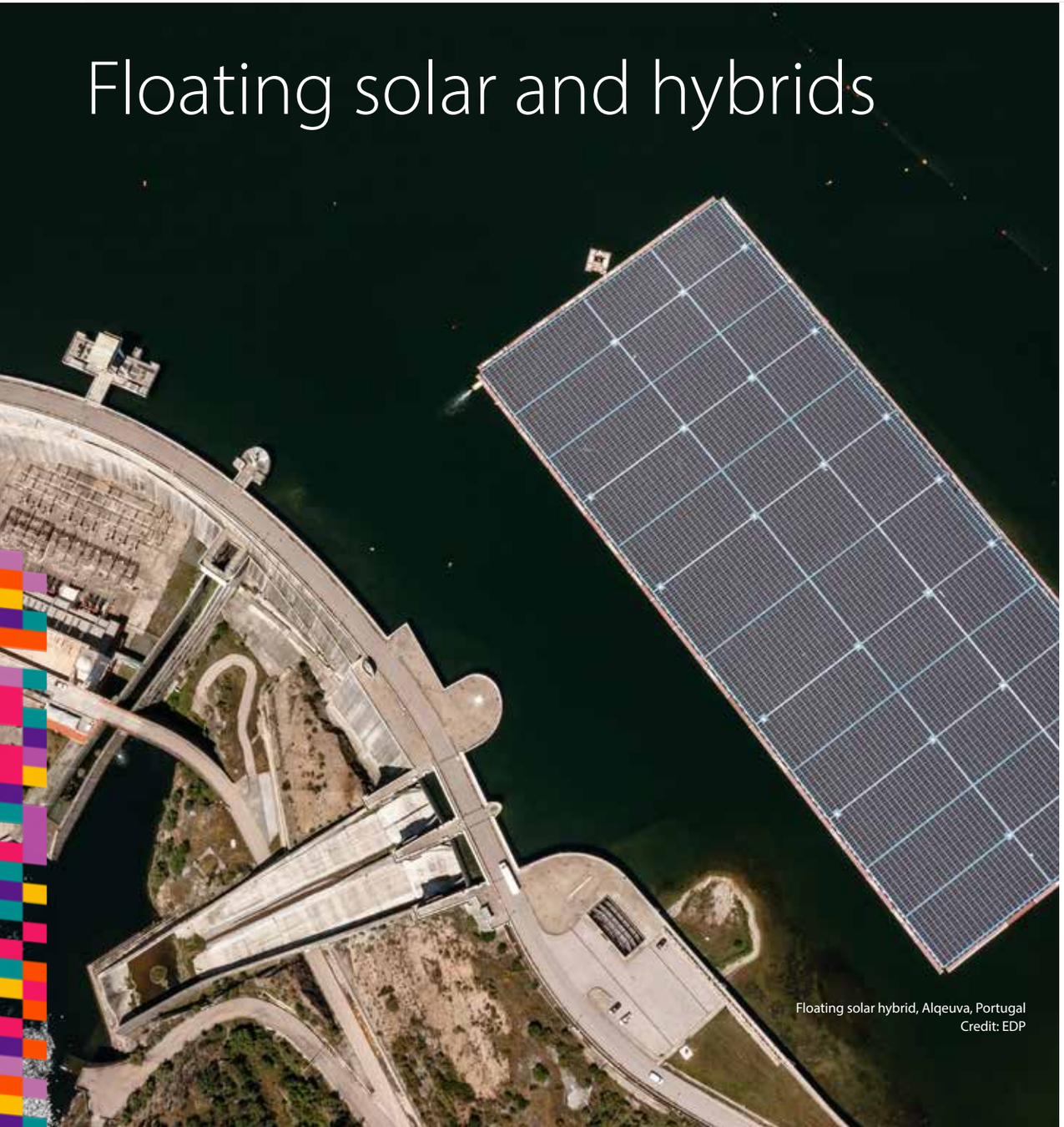
The system worked successfully during extended dry periods in 2006/08 and again in 2015/16. Irrigation schemes serviced by water drawn from hydro storages were able to draw their full allocations; meanwhile, other irrigation schemes in Tasmania experienced restrictions on water availability. Town water supplies and downstream environmental flows from hydropower infrastructure were also maintained. In addition, the inter-annual storage capacity of the larger reservoirs means that there is an increase in energy security during times of drought, as water from wetter years can be stored and used to generate electricity (as well as provide other services such as irrigation) during drier years.

Climate change is expected to result in lower precipitation across some of the Tasmanian agricultural districts which may lead to increased irrigation water demand. Hydro Tasmania is working with government and irrigation entities to determine a pathway that balances future electricity and water supply requirements.

Source: Hydropower providing flood control and drought management services under changing climate scenarios: Case studies



Floating solar and hybrids



Floating solar hybrid, Alqeuva, Portugal
Credit: EDP

Hybrid floating solar has huge potential. Hybrid floating photovoltaics (FPV) hydropower systems have extraordinary capacity to contribute to meeting global energy demands and conserving water without taking up space on land. Globally, it is estimated that there is the potential for between 3 and 7.6 TW of electricity generating capacity from FPV on 400,000 km2 of manmade hydropower reservoirs. In the past decade, floating solar has grown rapidly in capacity, from 70 MW in 2015 to 1,300 MW in 2020.

The rise of FPV is among the latest trends in solar panel expansion in recent years. Installing FPV on existing hydropower reservoirs offers the unique benefit of utilising hydropower's existing grid connections and providing complementary energy production with solar energy available during the day and hydropower available when the sun goes down.

The complementary services don't stop there. When located on an existing hydropower reservoir, floating solar panels do not take up land space, and the panels offer shade to the body of water. This reduces water evaporation from reservoirs which can be useful in areas that are susceptible to droughts, as this can significantly prevent shortages. A rate as high as 60 per cent evaporation reduction has been recorded in some instances. In one study, FPV covering close to 3 per cent of an existing hydropower basin surface resulted in the facility increasing generation by nearly 35 per cent.

The deployment of this buoyant technology that combines hydropower and FPV technologies has increased over the past five years, but its development remains at an early stage.Asia-Pacific is the largest and fastest growing market of hydropower hybrid systems with 1,342 MW deployed or under construction followed by Africa (600 MW), Europe (26 MW) and Latin America (381.8 MW). The map on the next page tracks the installed and under development hybrid systems.

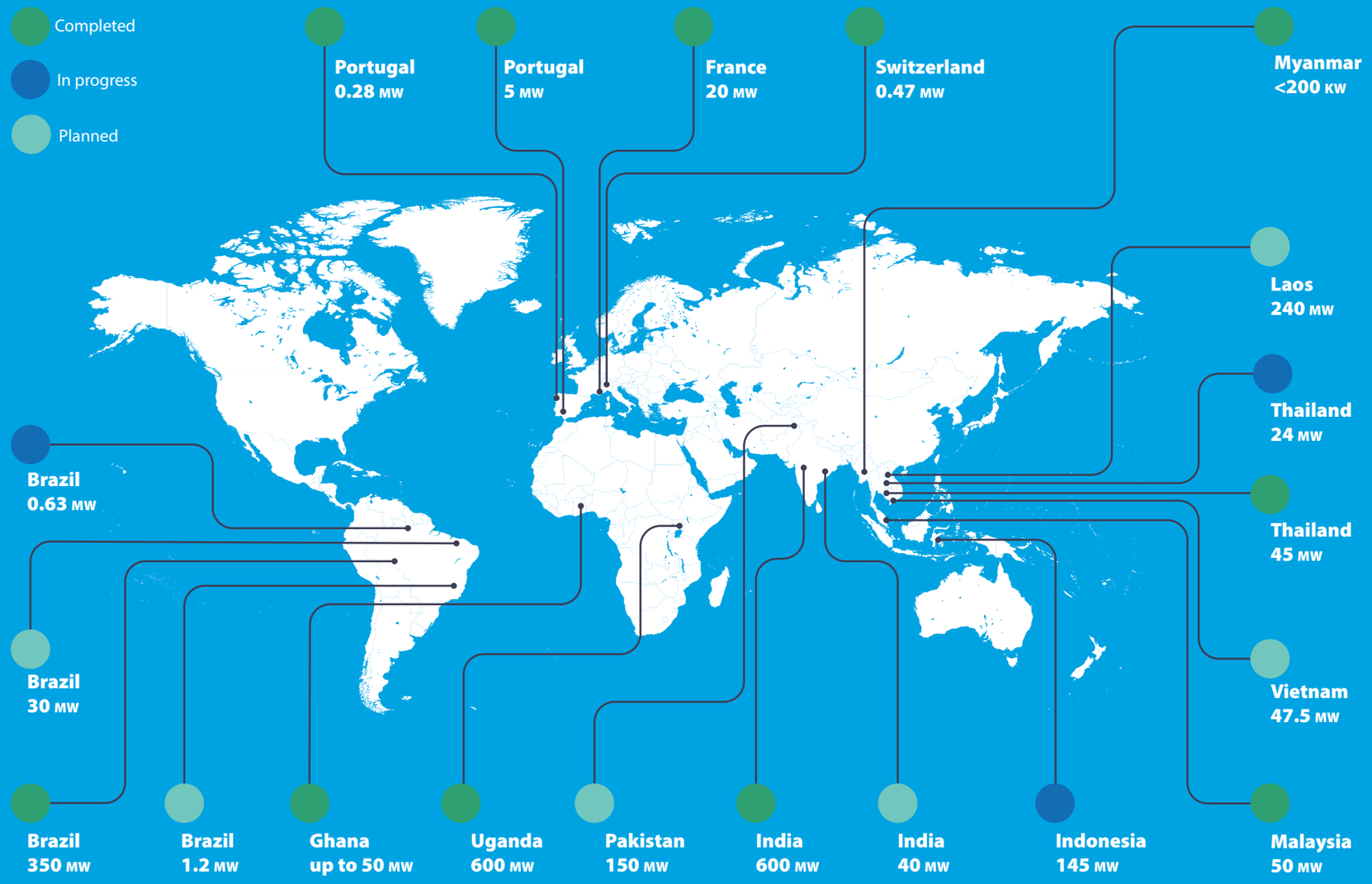
So why is it not more widely adopted?

FPV is an emerging technology and as larger projects have been commissioned (250 MW or more), risks have become apparent that may delay future deployment. FPV has primarily been installed on shallow ponds, quarry lakes and industrial water as opposed to large dam reservoirs. FPV built on large dam reservoirs may be exposed to strong winds and higher and more frequent waves.

Hydropower reservoirs are also subject to greater variations in water levels, requiring a specific design to maintain tension in the mooring cables. This would include fewer and deeper anchors, redundancy of mooring lines, and installation of wave attenuators. Regular monitoring and ease of servicing are crucial to maintaining FPVs.

For those reasons the upfront cost of FPV can be higher than that for ground-mounted PV. However, in the long term there may be savings. Water can cool solar panels so they will not be exposed to similar levels of heating as on the ground, thus meaning greater power and less maintenance. In addition, there are usually lower costs of land acquisition.

Floating Solar around the world



Recommendations

Governments wanting to enable FPV should prioritise the following areas:

- Promote research to further understand the environmental impacts of FPV facilities.
- Develop standards and regulatory guidelines to manage the risks in installation.
- Promote a better regulatory and policy environment to facilitate project development.



The Hydropower Sustainability Standard: Unlocking the full potential of hydropower

Hydropower is a powerhouse when it comes to meeting our energy needs in the transition to a low-carbon economy, but to ensure it delivers net benefits to people, the environment, and the economy it must be developed and operated sustainably and responsibly. Fortunately, systems are in place to harness hydropower's full potential for good, while safeguarding our natural resources for future generations.

The Hydropower Sustainability Standard (HSS) launched at the 2021 World Hydropower Congress, is the first global certification system of its kind in the renewables sector. Governed by the Hydropower Sustainability Council, a multi-stakeholder body, the Standard defines globally accepted Environmental, Social and Governance (ESG) good practice requirements for hydropower. It covers 12 topics and is aligned with international financing institutions frameworks, green bonds carbon credits, and private investor safeguards.

Here's a closer look at how you can work with the Standard:

- Developers can demonstrate their commitment to sustainability by undergoing an assessment and seeking certification.
- Governments can incorporate the Standard in policy and regulations to secure a responsible sector at the national level.
- Financiers can embed the Standard in their funding models to reduce investment risks.
- Manufacturers can pledge to supply only hydropower projects that are certified by the Hydropower Sustainability Standard.
- Civil society can join the Hydropower Sustainability Council and shape the future of the HSS and hydropower.

How to get a hydropower project certified:

1. Assess your project – by hiring an Accredited Assessor to conduct a third-party assessment.
2. Publish the report – and address public comments during a consultation period.
3. Apply for certification – and get the label.
4. Showcase your project – and demonstrate your commitment to sustainability.

A Standard backed by the best:

- Sustainability initiative RE100 endorses the Standard as a recommended certification system for sustainable hydropower.
- In its ESG Risk Framework, re/insurance company Swiss Re, encourages companies to adhere to the HSS to demonstrate sustainability performance and attract investment.
- The Hydropower Sustainability Standard is aligned with the safeguards of key lenders, such as the International Finance Corporation (IFC) the World Bank and CBI.
- WWF recommends that insurers require systems like the Standard to be applied by projects, according to their Insurer's Guide to Hydropower.



Case study: The Sebzor hydropower project – the world's first project certified using the Hydropower Sustainability Standard

The Sebzor hydropower project, an 11 MW hydropower project owned by Pamir Energy in Tajikistan, was the world's first hydropower project to be certified against the Hydropower Sustainability Standard. Pamir Energy worked closely with a team of independent accredited assessors for a period of two years to identify their sustainability gaps and implement a plan to address them. Pamir Energy earned certification against the Standard in March 2023 (preparation stage) and has set the bar for the industry to follow. Sebzor's certification comes as the industry faces rising pressure to substantiate sustainability claims, making a robust and credible certification system like the Hydropower Sustainability Standard more important than ever.

Equality in the Hydropower sector



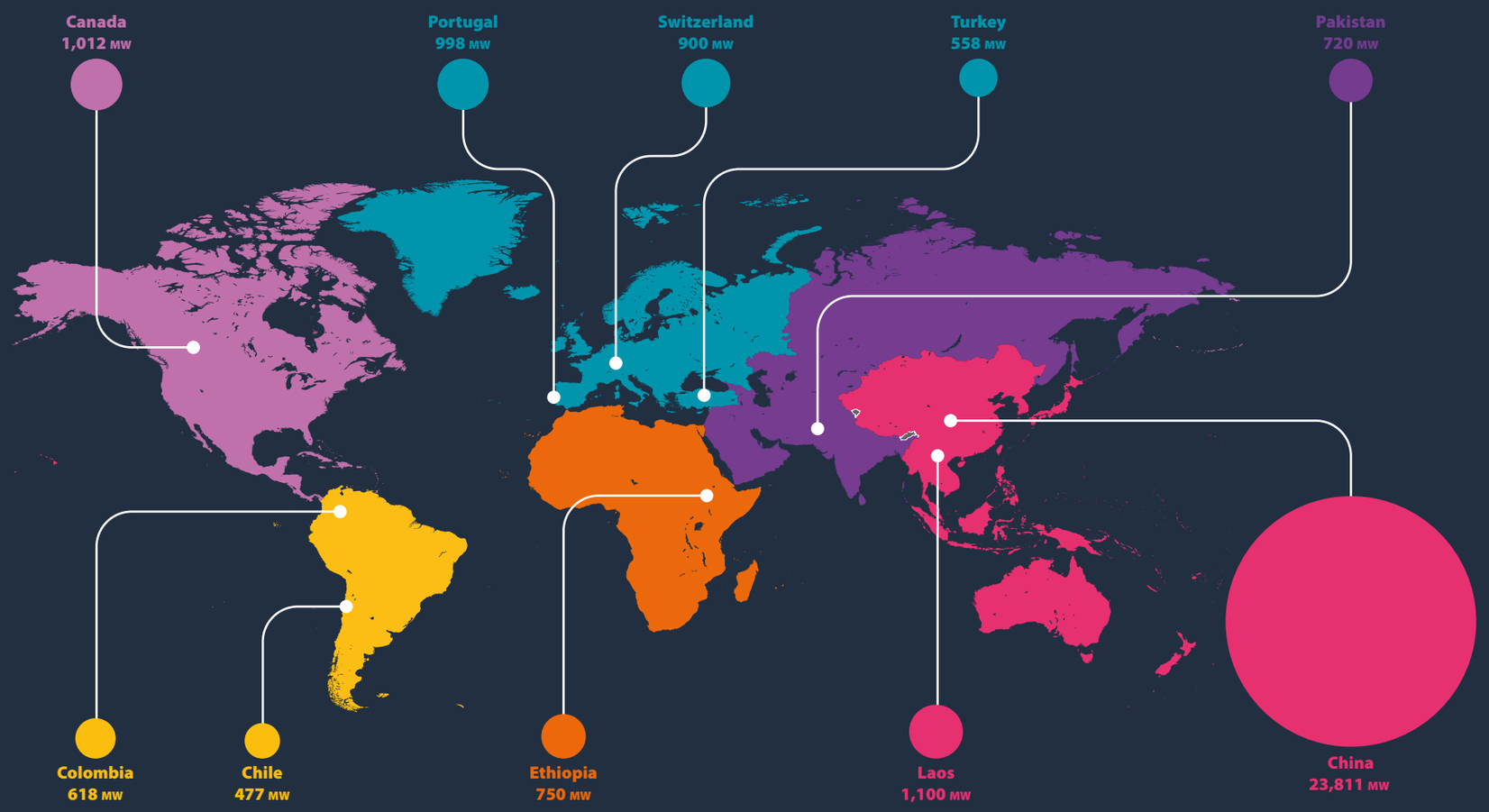
Hydropower Cahora Bassa, an Accredited Assessor and the HS Secretariat

If hydropower is to fulfil its crucial role in the transition to low-carbon energy systems, the sector must be able to draw upon the broadest possible pool of talent. The hydropower industry, in common with many others in the energy sector, has traditionally been male dominated. To gain insight into why this is, the World Bank's Energy Sector Management Assistance Program (ESMAP) commissioned IHA and the Global Women's Network for the Energy Transition to report on women's employment across the sector and provide concrete recommendations.

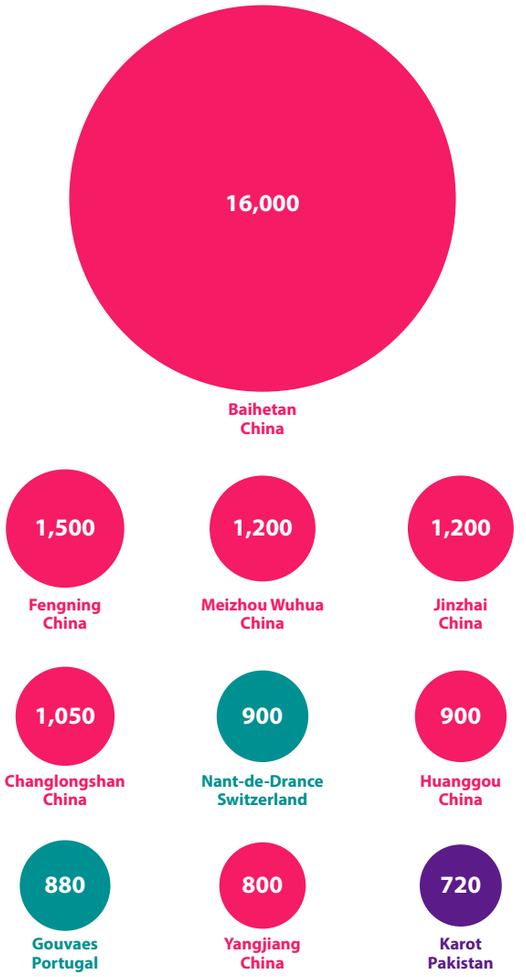
Throughout 2022, the team met with many stakeholders and raised awareness about the gender gaps and barriers that inhibit women's inclusion in the sector. The recommendations that came out of this initiative include solutions that encourage more women to study science, technology, engineering, and mathematics (STEM), enacting policies to close gender gaps, and providing mentoring and role models for women.

Closing gender gaps in the hydropower sector requires the efforts of many stakeholders within and beyond hydropower companies, including industry associations, NGOs, academia and governments. IHA is working to improve the perception about hydropower, which can only help the sector become more attractive to a generation that actively wants to contribute to solutions to limit global warming.

Global trends

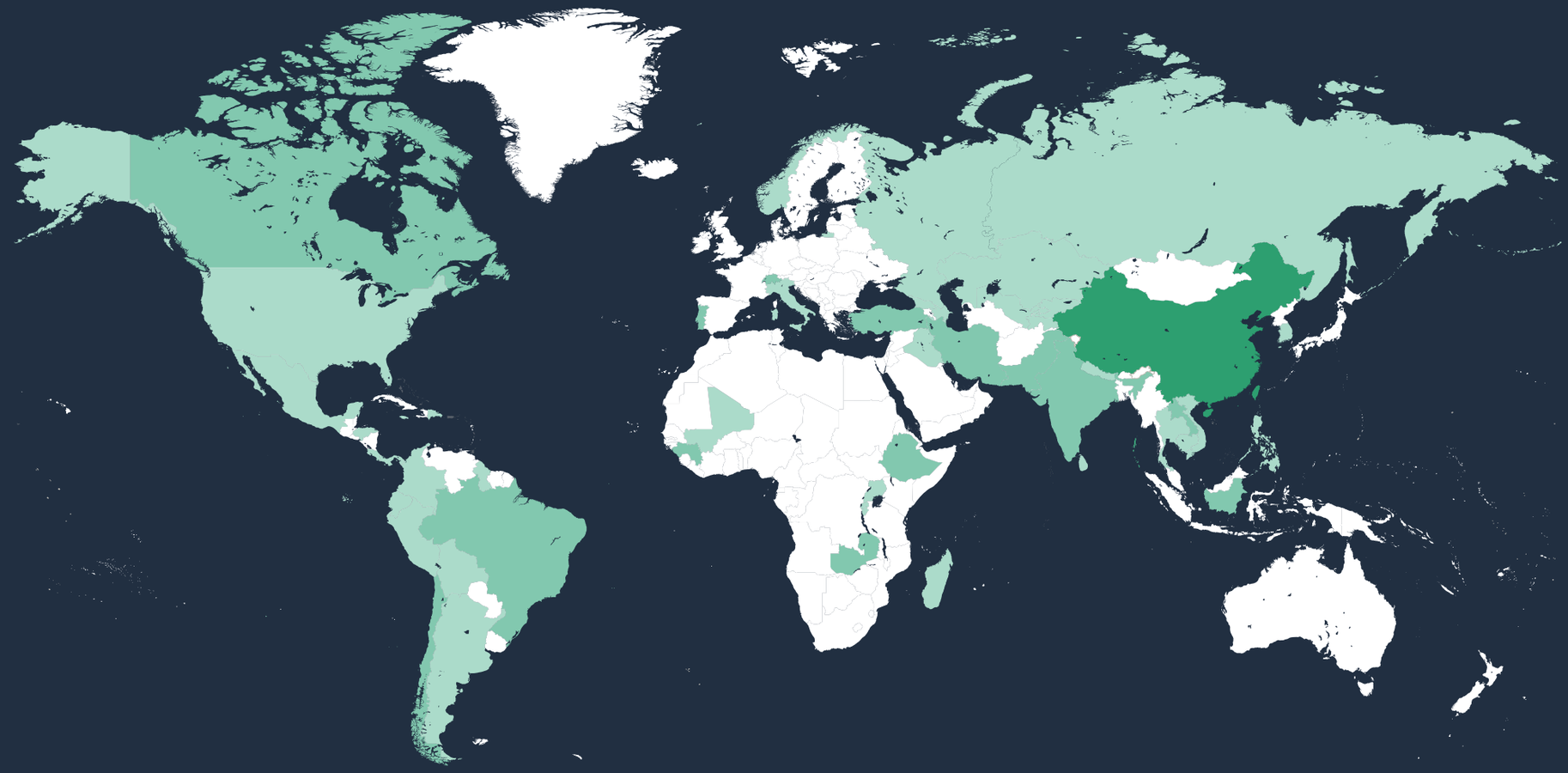


Top 10 countries by new installed capacity in 2022 (MW)



Projects completed in 2022 (MW)

Where was capacity added in 2022

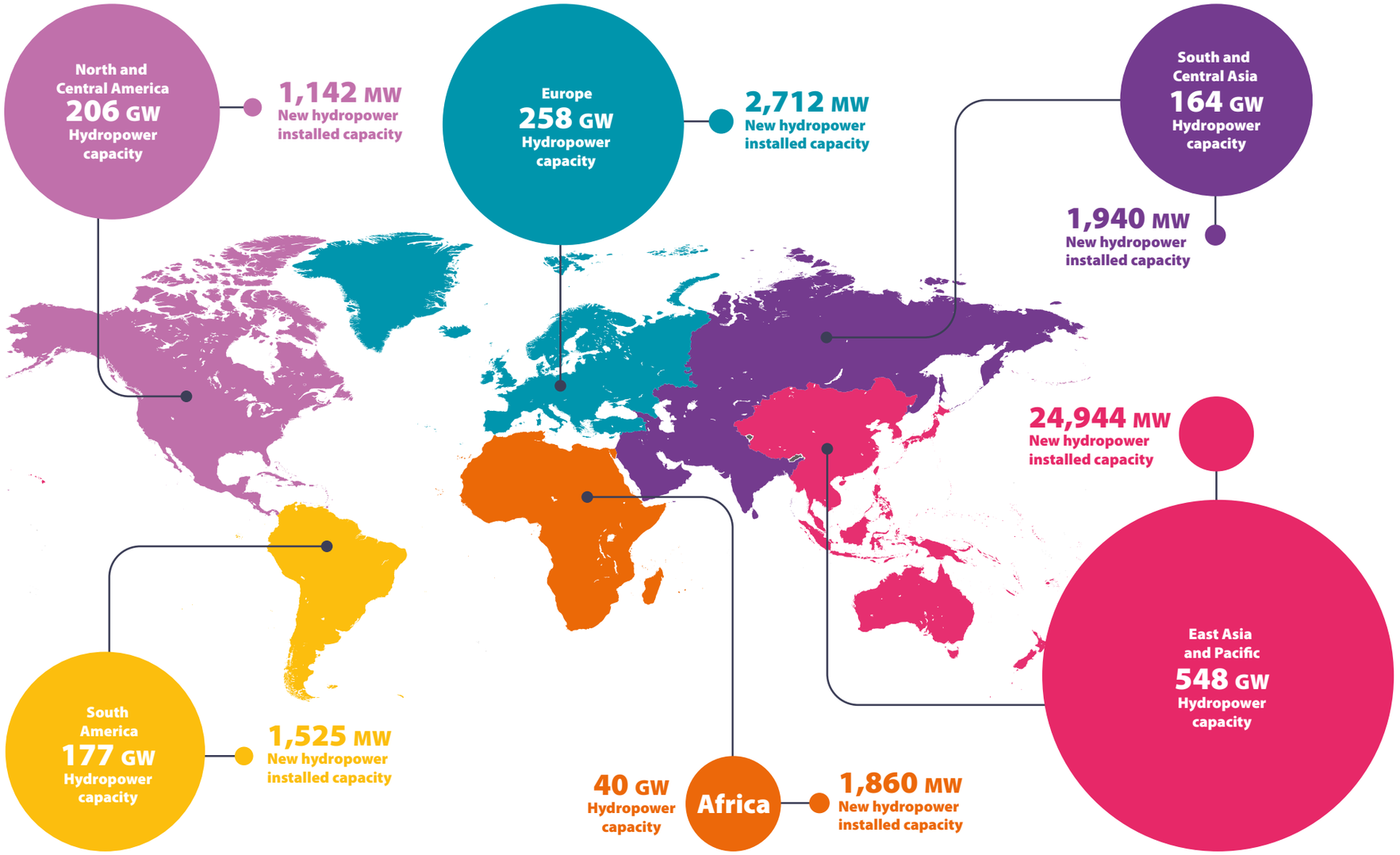


Key

- No new additions
- 199 MW and below
- 200 MW to 1,999 MW
- 2,000 MW to 9,999 MW
- 10,000 MW and over

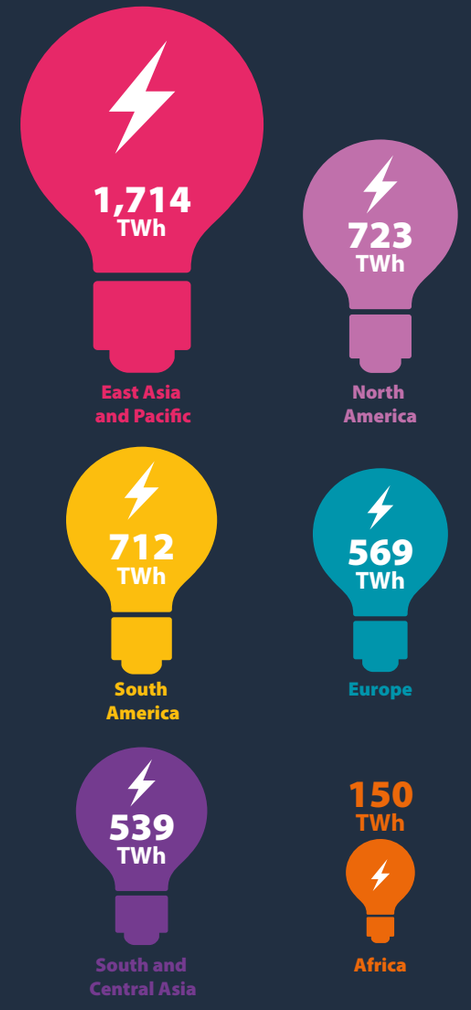
Ranking	Country/Territory	Capacity added (MW)
1	China	23,811
2	Laos	1,100
3	Canada	1,012
4	Portugal	998
5	Switzerland	900
6	Ethiopia	750
7	Pakistan	720
8	Colombia	618
9	Türkiye	558
10	Chile	477
11	Guinea	450
12	Zambia	450
13	India	434
14	Iran	356
15	Brazil	332
16	Nepal	174
17	Norway	163
18	Russia	145
19	Mali	140
20	USA	96
21	Austria	89
22	Ecuador	84
23	Kyrgyzstan	60
24	Tajikistan	40
25	Panama	34
26	Viet Nam	33
27	Madagascar	28
28	Uganda	22
29	Burundi	15
30	Argentina	14
31	Rwanda	6
32	Azerbaijan	5
33	Italy	4
34	Iraq	3
35	Sri Lanka	2

Hydropower capacity by region in 2022

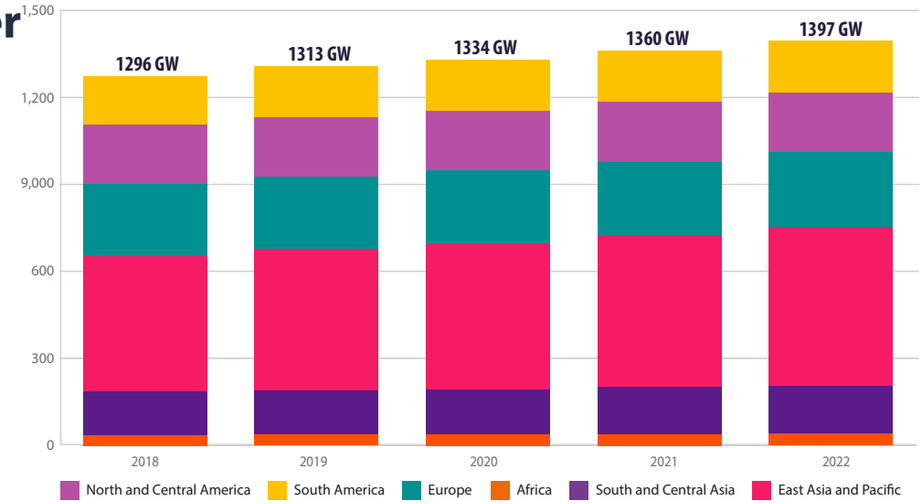


International Hydropower Association

Hydropower generation by region in 2022 (TWh)



Hydropower installed capacity growth, 2018-2022

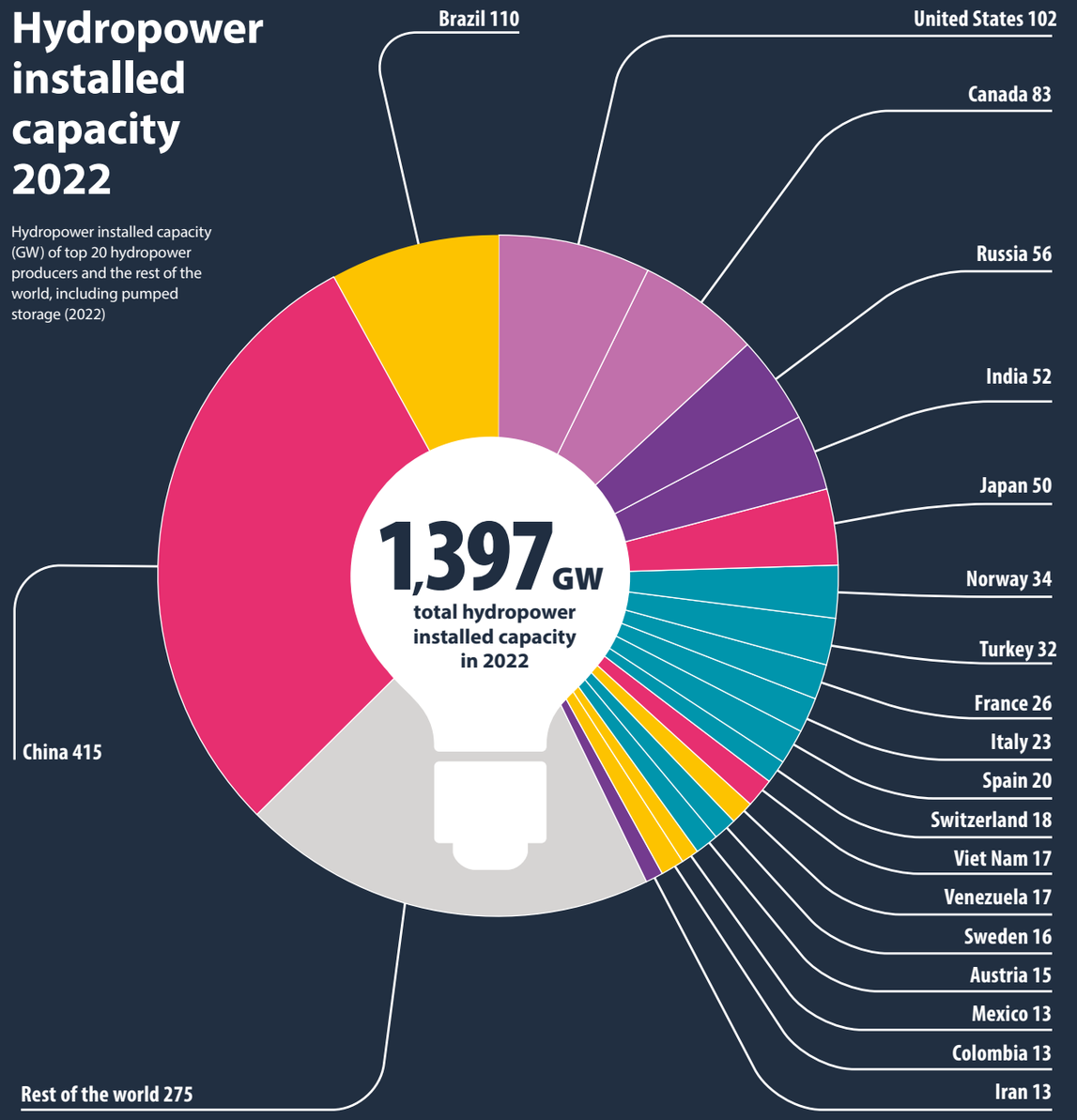




Kaplan Manufacture
Credit: Voith

Hydropower installed capacity 2022

Hydropower installed capacity (GW) of top 20 hydropower producers and the rest of the world, including pumped storage (2022)



Europe

Generation by hydropower
569 TWh

Total installed capacity*
258 GW

Capacity added in 2022*
2,712 MW

Pumped storage installed capacity
56 GW

Pumped storage capacity added in 2022
1,780 MW

*Including pumped storage

Europe's journey towards a renewable energy future is significantly powered by its hydropower sector. The potential lies not only in making the most of its geographical resources but also in modernising existing facilities, pioneering innovative small-scale and run-of-river projects, and advancing pumped storage for grid stability.

The success of this journey is contingent on supportive policy frameworks that incentivise investment in hydropower. As the intermittent share of Europe's power mix increases, hydropower's role as a flexibility provider supporting other renewable growth becomes ever more critical. To ensure grid stability, it is essential that electricity markets renumerate the ancillary services flexibility and the dispatchability that modernised hydropower facilities can provide.

With this potential in mind, 2022 was an exciting year for hydropower development in Europe. Notable projects in Switzerland (Nant-de-Drance), Portugal (Tâmega) and Türkiye (Ysufeli Dam), contributed to an overall added capacity of 2,712 MW of hydropower including 1,780 MW of PSH.

The year also saw investment in small hydro with Edison's Palestro programme in Italy, a crowdfunded project that involved the local community. In Norway, 25 small hydropower plants were commissioned in 2022 for a total capacity of 163 MW and expected annual production of 530 GWh.

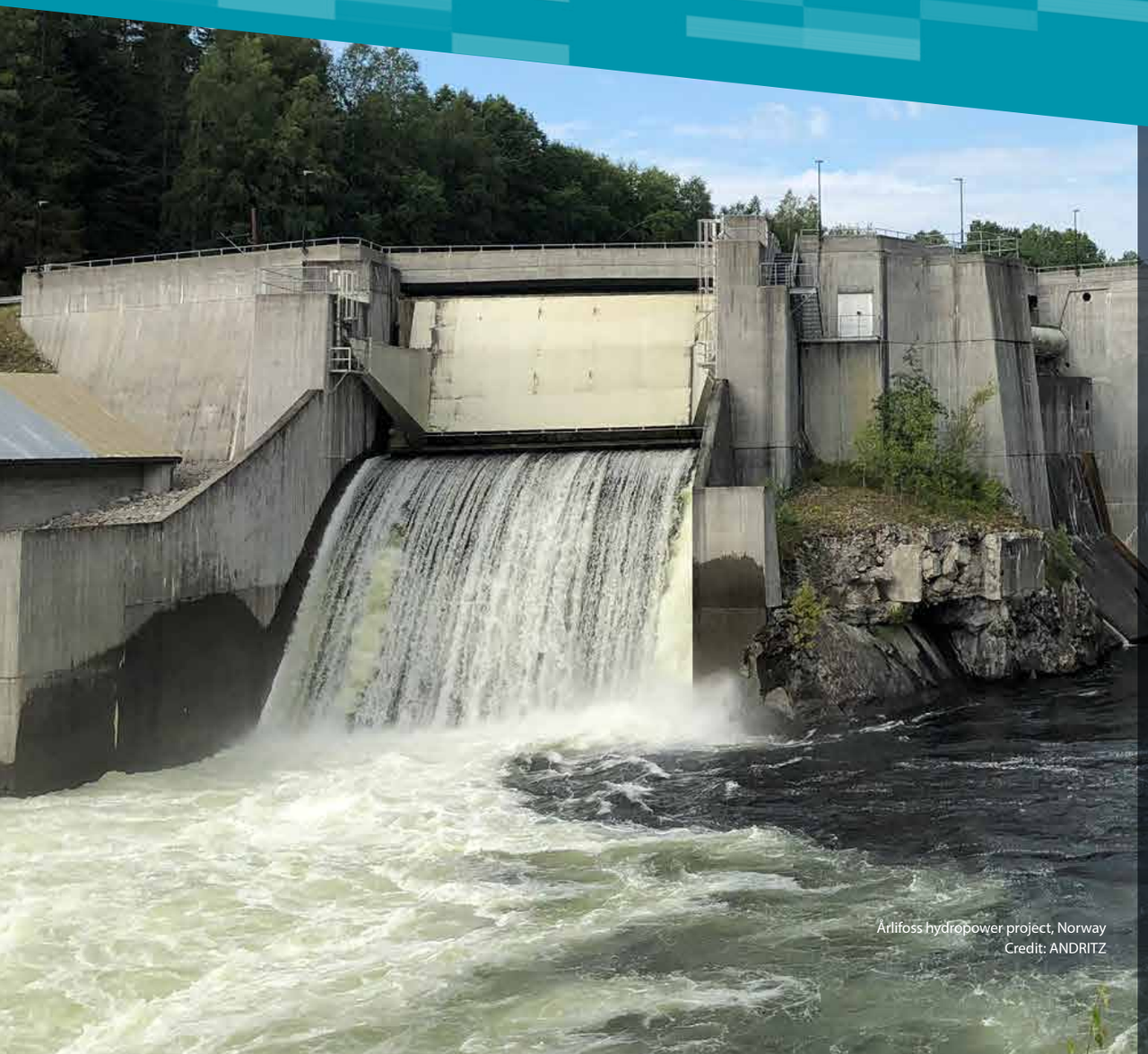
In Austria, the Gemeinschaftskraftwerk Inn power plant has become a milestone on ways to achieve the goals of the European and regional energy strategies. It is the largest newly built run-of-river power station in the Alpine region and supports the integration of wind and solar.

We also see some early signs of positive policy development on a national level for PSH. As contributions by wind and solar continue to grow, national authorities are more focused on their PSH potential with policy and regulatory developments in the UK, France and Poland.



Foyers Hydro Power Station, located on the shores of Loch Ness, Scotland
Credit: SSE RENEWABLES

Europe



Årlifoss hydropower project, Norway
Credit: ANDRITZ

This development comes on the back of some of the worst droughts Europe has experienced and the energy crisis, brought on by the war in Ukraine. Regional electricity prices increased to levels that in certain occasions were 10 times higher than those recorded in 2020. This has resulted in lengthy discussions across Europe about price volatility and security of supply and the EU sought ways to optimise the electricity market design to tackle price volatility, further accelerate investments in renewables, and enhance the flexibility and resilience of the power system. This included the REPowerEU plan of May 2022 which worked to diversify energy supplies and reduce dependence on foreign fossil fuels, make energy savings, and accelerate the rollout of renewables. As part of this plan the EU increased its 2030 renewable energy consumption targets to 45 per cent and introduced a revenue cap on inframarginal electricity generators whenever wholesale electricity prices exceed €180/MWh. The drought experienced during the latter half of 2022 led to reduced hydropower production, particularly in southern Europe, (~15 per cent); however, hydropower continued to play an important role throughout the continent, including providing water to agriculture, and responding to increases in unmet electricity demand due to a reduction in supply from nuclear power.

The EU is seeking ways to optimise the electricity market design to tackle price volatility, further accelerate investments in renewables, and enhance the flexibility and resilience of the power system.

The EU Commission launched a research programme in 2022, ETIP Hydropower, whose goal is to provide consensus-based strategic advice to the European Commission covering analysis of market opportunities, research & development funding needs, biodiversity protection and ecological continuity. This project will ensure that the voice of the sector will be heard and represented at the European level.

Europe latest developments

Austria

The Gemeinschaftskraftwerk Inn power plant was created as a joint project between the Swiss municipality of Valsot and the Austrian municipality of Prutz. The dam offers 89 MW of installed capacity located on the river Inn and generates almost 440 GWh/yr of electricity while supporting the integration of wind and solar. It is the largest newly built run-of-river power station in the Alpine region and cost €600m. Financing included contributions from the European Investment Bank (€150m) and KfW IPEX-Bank (€90m).

France

The French government has recently carried out an extensive consultation to support PSH projects. In November 2022, one of the Pelton runners of the Grand'Maison power plant was replaced, the third out of four to be replaced. The new runners have been upgraded from 156 MW to 170 MW, providing around 9 per cent more power generating capacity.

Italy

Built on an existing water barrage created to regulate the water flow in the rice fields of Northern Italy at a cost of €10m, the Palestro project has been developed by Edison using a crowdfunding programme involving local communities, a first for Italy. With an installed capacity of 3.6 MW on the Sesia river; and generation of 13.5 GWh. This is an interesting example of how retrofitting non-powered dams can create new sources of renewable electricity with strong community buy-in.

Ireland

EU Member States have given the green light to invest €602m of EU funds in eight cross-border energy infrastructure projects. In Ireland, the Silvermines hydropower plant will receive €4.3m for researching and setting up a pumped storage facility at a historic mining site that will help reduce price volatility, contribute to market stabilisation and increase the flexibility resource of the island's electricity system.

Norway

25 small hydropower plants were commissioned during 2022 for a total capacity of 163 MW and expected annual production of 530 GWh. The two most significant planned plants are Smibelg (33 MW) and Tokajjelet (27 MW).

Poland

In March 2023, the Polish Government introduced a new law to make it easier for PSH development, as they recognised there were barriers making investment harder. The new law allows PSH to be integrated into decisions across multiple permitting authorities, and to make PSH a 'public purpose' investment. Supported by the new streamlined authorisation process in Poland, the Polish utility PGE and the National Fund for Environmental Protection and Water Management are



Credit: Natel Energy

Europe latest developments



Sauerbrunn Hydro, Austria
Credit: Natel Energy

cooperating on the construction of a US$1.14bn project offering 750 MW at the Mloty pumped storage power plant in a drive to support the national grid's resilience and reliability.

Portugal

Construction continues to complete the Alto Tâmega power plant, which is part of the Tâmega Giga Battery project. The reservoir filling operations are expected in October 2023. This is the last stage prior to completion expected in mid-2024 of the Tâmega Giga Battery project.

The project includes the construction of three power plants: Daivões, Gouvães and Alto Tâmega with a total installed capacity of 1,158 MW. Daivões was inaugurated in July 2022 and is a 118 MW Storage Plant. Gouvães was inaugurated in July 2022 and is an 880 MW pump storage plant. Finally, Alto Tâmega with a cost of circa €1.5bn, will have a storage capacity of 20 GWh and is expected to eliminate 1.2 million tonnes of CO2 emissions annually.

Romania and Bulgaria

Romania announced in 2022 that talks would resume with Bulgaria on building the Turnu Măgurele Nikopol hydropower plant on the Danube River. With this project the two countries would have 420 MW of installed capacity each.

Switzerland

In Switzerland, the recently commissioned Nant de Drance (pumped storage) owned by Alpiq, provides a total of 900 MW installed capacity. It has six Francis pump turbines with variable speed technology and 20 GWh storage (equivalent to 400,000 car batteries) with a total cost of circa US$2bn. Unlike many of the plants that preceded it, Nant-de-Drance uses variable speed pump-turbines. It is one of the most flexible assets in the world and power from this 900 MW facility can be available within two minutes. Due to its central location, it will be a key asset to stabilising the European grid.

Türkiye

Construction on the Ysufeli Dam began in 2013 and it was inaugurated in November 2022, with full commercial operations starting in summer 2023. Standing at 275 metres, it is the tallest dam in Türkiye and ranks among the top ten worldwide. It offers a total installed capacity of 558 MW and houses three 180 MW Francis turbine-generator units.

Europe latest developments

Ysufeli Dam's annual production is 1,900 GWh and which provides US$269m added value a year to the Turkish economy and meets the energy needs of 2.5 million households at a cost of US$1.8bn.

United Kingdom

In August 2022, the UK Government followed up its consultation on Large-scale Long Duration Energy Storage, by concluding that it has "an important role to play" but faces significant barriers to deployment under the current market framework. They indicated they would develop policies to enable investment by 2024 to ensure sufficient long duration energy storage.

A proposal for PSH (Cruachan) was submitted for an expansion of an existing asset (+600 MW) in 2022. Owners Drax are awaiting approval from local authorities on expansion. The total new PSH capacity, if approved, would be 1,040 MW.

SSE is providing a £100m investment boost to the Coire Glas PSH project which is expected to require a capital investment of over £1.5bn. The project, which received planning consent from the Scottish Government in 2020 will be capable of delivering 30 GWh (circa 1,500 MW).

Gilkes Energy has unveiled scoping plans for its 900 MW Earba Pumped Storage Hydro Project in Scotland with a 33 GWh storage capacity. The developer is now starting public consultations on their plans.

International Hydropower Association



Régua Hydro Power Plant, Portugal
Credit: EDP

Europe

Case study: Vogelgrun hydropower plant

The Vogelgrun HPP, managed by EDF, is located on the Rhine River and it has been the target of a pilot study on BESS hybridisation under the framework of the EU research project XFLEX HYDRO.

The approach taken was to reduce the amount of wear and tear caused by the provision of Frequency Containment Reserve (a grid ancillary service that requires a maximum power response time of 30s), which requires continuous management of the operating point of the 50-year-old Kaplan unit, minimising the battery size to limit the capital investment required.

The installation included an adaptation of the Smart Power Plant Supervisor designed to optimise the state of charge of battery and support the turbine in the provision of a Frequency Containment Reserve.

Follow xflexhydro.com to find out more about the XFLEX Hydro project.

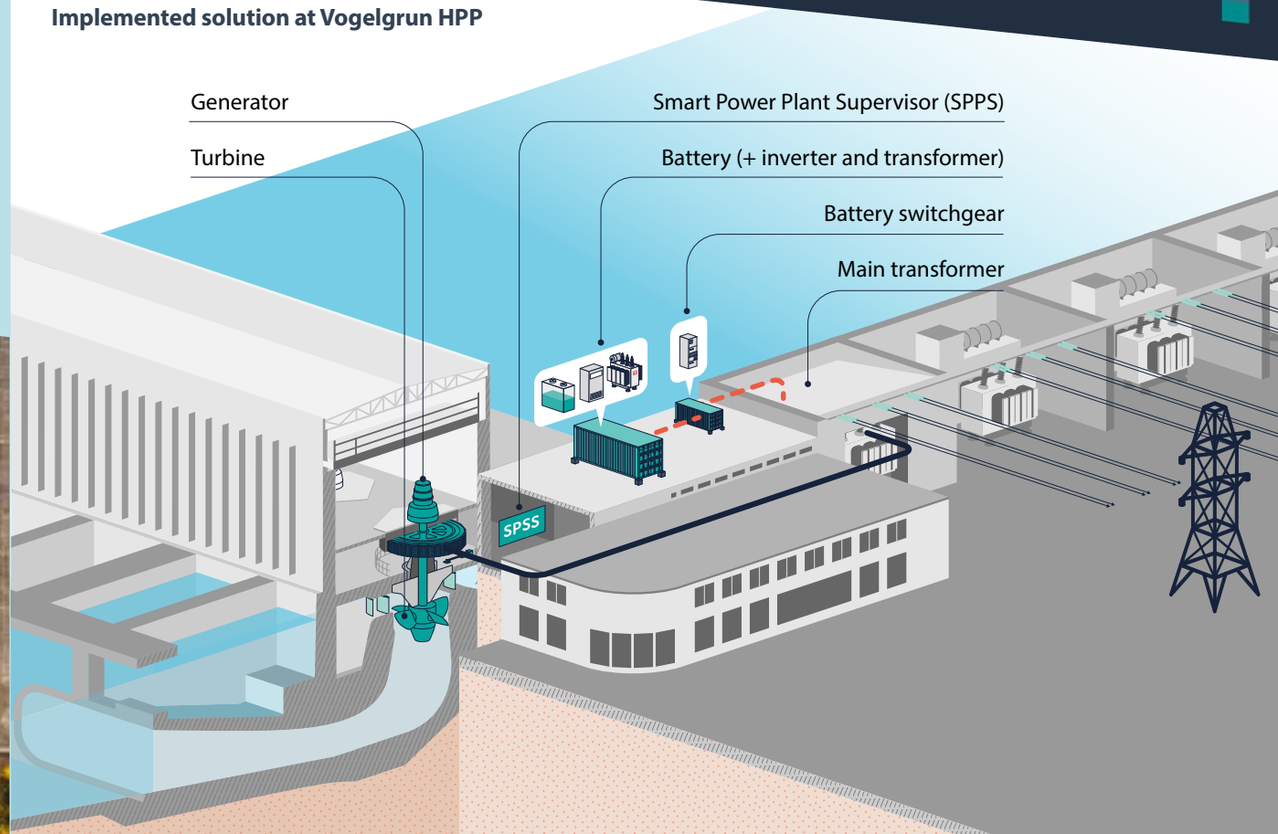


Interesting fact

Battery storage hybridisation of existing hydropower plants is a technology that has seen some interesting developments in Europe over the last few years. The first cases identified by IHA date back to 2018-19. Since then, several additional installations were commissioned in numerous European sites.

Despite the relatively small size of the battery installed at Vogelgrun, initial results have demonstrated that thanks to the battery systems, the power response of the plant was enhanced. Additionally, the mileage of critical components (the Runner Blade Bearing) was substantially reduced, indicating between 40 per cent and 50 per cent movement reduction of the Runner Blade Bearing. This has an associated reduction of wear and tear of circa 55 per cent with an expected life span extension of circa 50 years.

Implemented solution at Vogelgrun HPP

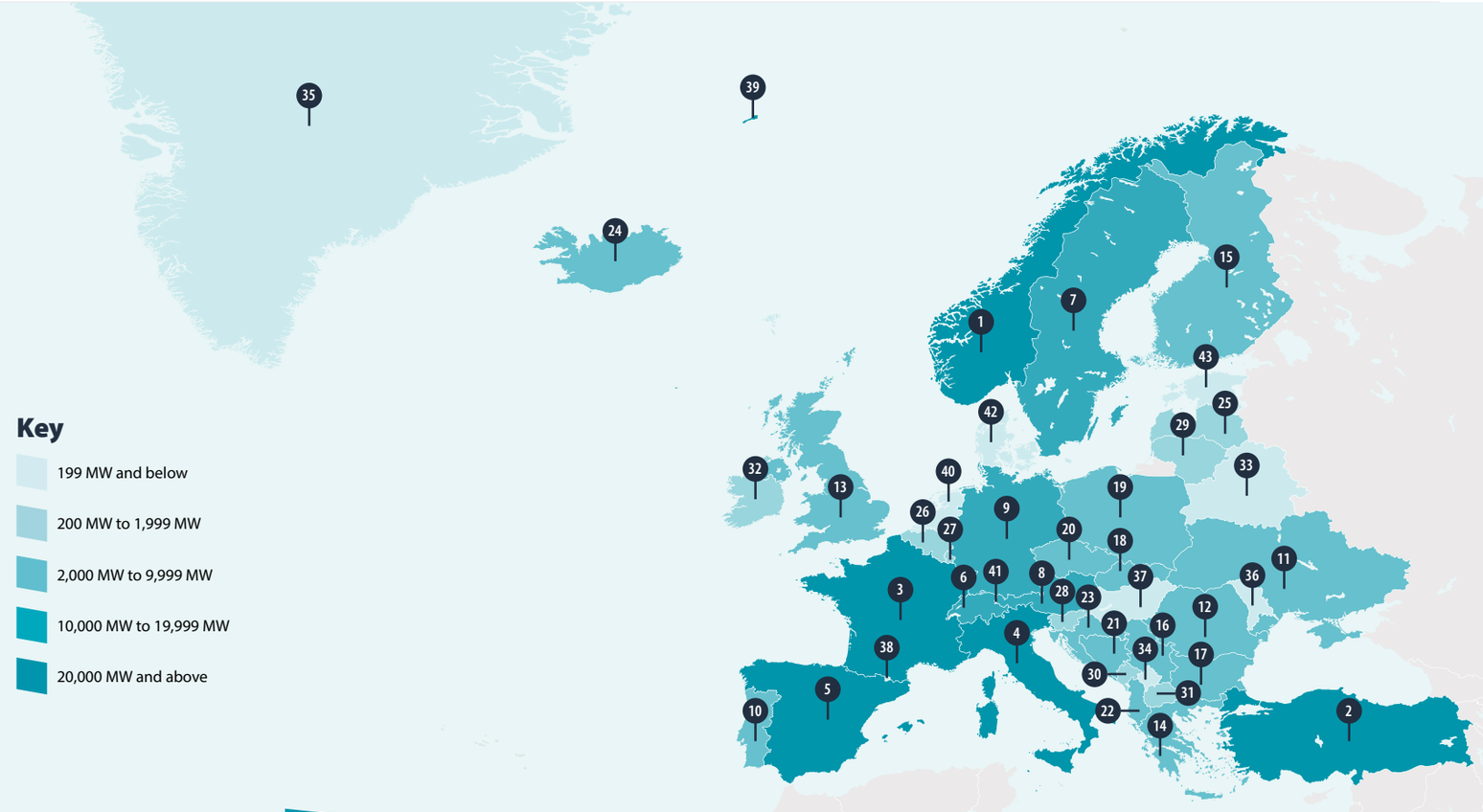


Europe

Ranking by total installed hydropower capacity

Rank	Country/Territory	Installed capacity (MW)*
1	Norway	33,807
2	Türkiye	32,130
3	France	25,669
4	Italy	22,635
5	Spain	20,425
6	Switzerland	17,756
7	Sweden	16,391
8	Austria	14,836
9	Germany	11,471
10	Portugal	8,252
11	Ukraine	6,317
12	Romania	6,229
13	United Kingdom	4,723
14	Greece	3,421
15	Finland	3,246
16	Serbia	3,166
17	Bulgaria	2,916
18	Slovakia	2,476
19	Poland	2,376
20	Czechia	2,290
21	Bosnia and Herzegovina	2,230
22	Albania	2,203
23	Croatia	2,155
24	Iceland	2,086
25	Latvia	1,588
26	Belgium	1,493
27	Luxembourg	1,332
28	Slovenia	1,307
29	Lithuania	1,028
30	Montenegro	649
31	Macedonia	644
32	Ireland	508
33	Belarus	96
34	Kosovo	92
35	Greenland	91
36	Moldova	64
37	Hungary	58
38	Andorra	45
39	Faroe Islands	39
40	Netherlands	38
41	Liechtenstein	35
42	Denmark	7
43	Estonia	4

*including pumped storage



Top 5 countries by capacity added in 2022

- 1st Portugal 998 MW
- 2nd Switzerland 900 MW
- 3rd Türkiye 558 MW
- 4th Norway 163 MW
- 5th Austria 89 MW

North and Central America

Generation by hydropower
723 TWh

Total installed capacity*
1,142 GW

Capacity added in 2022*
1,011 MW

Pumped storage installed capacity
22 GW

Pumped storage capacity added in 2022
96 MW

*Including pumped storage

The hydropower industry has had encouraging boosts this year in North and Central America, with policy changes that will further unlock the potential to develop and modernise hydropower. North America's substantial hydropower potential is predominantly concentrated within Canada, the United States, and Mexico. Mexico, with its varied topography and extensive river systems, holds an estimated 20 GW of exploitable hydropower potential. Canada, rich in water resources, has an estimated technical hydropower potential of 160 GW and the U.S. has an estimated exploitable potential at over 65 GW. In 2022, 1 GW of hydropower was developed, continuing with previous years' development. Most notably, the U.S. Inflation Reduction Act (IRA) and Canada's 2023 budget will both incentivise hydropower development through innovative tax credit schemes.

There was also an increase across countries to modernise existing hydropower projects, which expanded their capacity and increased their expected lifespan, to continue providing renewable energy to communities and power systems for longer.

To develop North and Central America's sustainable hydropower projects, investment in the industry needs to follow the policy announcements. The path forward requires innovative technical solutions, inclusive and respectful engagement with indigenous communities, a strong commitment to environmental sustainability, and regulatory streamlining.



Malpaso dam and spillway, Mexico
Credit: ANDRITZ

North and Central America latest developments

Canada

Hydropower provided Canada with approximately 61 per cent of the country's total annual electricity generation and represents more than half of its total generation capacity. The 2023 Canadian Budget introduces a Clean Electricity Investment Tax Credit, which is a 15 per cent refundable tax credit for eligible investments in non-emitting electricity generation systems including hydropower (regardless of scale) and PSH, with new projects and refurbishment of existing projects to be eligible.

The Keeyask power plant in Manitoba (695 MW), the last two of seven generating units were placed in service and the Romaine 4 power plant (245 MW) in Québec reached completion. The last unit came on-line, completing the commissioning of the four-plant cascade system, totalling its generation capacity to 1,550 MW.

The Champlain Hudson Power Express is a ground breaking high-voltage direct current underwater and underground power cable project that will transfer 10.4 TWh of hydropower from Québec to New York City, expected to be commissioned in 2026.

Canadian TC Energy Corporation is the owner and developer of two pumped hydropower storage projects. The Ontario Pumped Storage Project (1 GW) is expected to become operational in 2030 and will create more than 3,800 jobs. Alberta will host TC Energy's other project, the 75 MW Canyon Creek Pumped Hydro Energy Storage Project, which will provide up to 37 hours of on-demand, flexible, clean energy and ancillary services to the electricity grid.

Newfoundland and Labrador Hydro have proposed to expand the 604 MW Bay d'Espoir hydroelectric generating station, which began operating more than 50 years ago and includes seven generating units in two powerhouses.

In British Columbia, construction of the 1.1 GW Site C hydro project in Peace River, is ongoing, with the installation of the first turbine runner in 2022 and is expected to be operational in 2025.

The Independent Electricity System Operator (IESO) in Ontario released two reports in 2022: the Pathways to Decarbonization (P2D) and the Annual Planning Outlook, both of which emphasise the need to take action to realise the potential of long-lead time hydropower projects. The IESO has highlighted that permitting and approvals must be streamlined, and Indigenous community participation is essential for success. The P2D assumes an additional 2,000 MW of long-duration storage will be added in the late 2030s to meet adequacy needs.



Jean-Lesage generating station, Canada
Credit: Hydro-Québec

North and Central America latest developments

Honduras

Honduras is projected to add 200 MW from hydropower plants by 2025, supplying electricity to at least 120,000 homes across the country.

Mexico

Hydropower provides approximately 11 per cent of Mexico's total annual electricity generation and continues to grow in the country, with the government investing directly in the modernisation of existing fleets and developing new projects. Mexico's federal power company Comisión Federal de Electricidad (CFE) has recovered 261 MW of capacity so far as part of its plan to overhaul its aged hydroelectric generation portfolio. Modernising the units has allowed the company to draw 31 per cent more power from them.

Mexico's CFE is advancing several projects including modernising 13 hydroelectric units and the construction of three new generators, as well as the operation of six combined cycle units the company awarded to Siemens and Mitsubishi. In 2022 CFE announced that on the Grijalva River basin, optimising water management had led to a 41% increase year on year in electricity generation.

International Hydropower Association

Nicaragua

Empresa Nicaraguense de Electricidad, the state-owned utility, is modernising two power plants and is seeking financing for two hydropower projects that would add nearly 50 MW to the company's generation capacity.

Panama

A group of Panamanian lawmakers submitted a draft bill to the national assembly that would declare a 15-year moratorium on granting permits and concessions for new hydroelectric projects in the Chiriquí province. This region is home to most of the country's hydropower plants, among them the country's largest – the 300 MW Fortuna plant. Hydropower has been beneficial to the country, but greater regulations need to be implemented ahead of further construction.

United States of America

There were significant policy announcements in the U.S. which are expected to spur investment in both new and existing hydropower. See case study for details.

While droughts have made headlines in the past year in the U.S., researchers from the Pacific Northwest National Laboratory found that even during the most severe droughts observed in the last two decades, hydropower has sustained 80 per cent of average power generation, which is approximately 20 per cent of electricity demand across the West. The U.S. Department of the Interior and the Bureau of Reclamation have both stated that improving the systems across the U.S. is a priority.

A brand-new small hydropower project at the University of Notre Dame, Indiana, U.S., will power an estimated 7 per cent of the electricity for the campus. The 2.5 MW state-of-the-art facility started generating power in May 2022 and has operated at about 70 per cent capacity. This project is offsetting 9,700 tons of carbon dioxide annually, benefitting the University and the surrounding community.



Main transformers, Malpaso, Mexico
Credit: ANDRITZ

North and Central America

Case Study

The United States made several major investment announcements in 2022 that will positively impact the hydropower sector. Following the success of the Infrastructure Investment and Jobs Act (commonly known as the Bipartisan Infrastructure Law) signed in November 2021, the US$370bn Inflation Reduction Act (IRA) adopted in 2022 is the nation's most significant climate legislation to date. The landmark measure recognises that hydropower plays a critical role in accelerating the transition to a more reliable, clean energy grid. The tax credits created by the IRA will provide investment certainty upgrades at existing hydropower facilities, incentivise development of new pumped storage facilities, retrofits of non-powered dams with hydropower generation and new marine energy and hydrokinetic generation by creating a 10-year investment tax credit and production tax credit framework for these projects.

The tax credits provided by the IRA will be equivalent to other renewable technologies such that a megawatt of electricity produced from hydropower receives the same level of federal tax support as a megawatt produced from other zero-carbon resources.

Additionally, earlier in the year, the U.S. Department of Energy (DOE) announced US$8m for technologies to increase hydropower flexibility. The following projects were awarded the money:

- General Electric's research to develop a cost-effective and easy-to-implement method to increase hydropower units' ability to ramp electricity generation.
- Littoral Power Systems Inc's Turbine and Generator upgrade system that designs, builds, and field tests a rapidly deployable upgrade system for existing hydropower plants.
- Oregon State University's Hybrid Hydropower-Storage Units that demonstrates and quantifies the value of a hybrid hydroelectric-storage generation units.

Fundamentally, the framework established by the IRA and the DOE could help the hydropower industry by supporting billions of dollars in investment in building new projects as well as maintaining and enhancing existing infrastructure.

Interesting fact:

One cannot speak about hydropower in North America without invoking the concerns of Indigenous rights.

In the United States, the 'Uncommon Dialogue' initiative launched in 2021 set the blueprint for Native American tribes, environmentalists, and the hydropower industry to reach a deal in 2022 on a proposed legislative package that could boost clean energy as well as river conservation. This will give tribes the authority to put conditions on permits for things like protection of tribal cultural resources and fish passage.

In neighbouring Canada, a settlement was reached with West Moberly First Nations, BC Hydro and the Canadian government regarding financial benefits, contracting opportunities and jointly developed recommendations for land management measures over provincial Crown lands for the Site C hydro project in British Columbia.

In addition, the Québec portion of the CHPE line to bring hydropower to New York City will be co-owned by the Mohawk Council of Kahnawà:ke (MCK), representing the Indigenous people whose community lies close to the start of the line. As noted by the MCK, "this project demonstrates that collaborating with an Indigenous community can prove to be mutually beneficial for industry and Indigenous communities alike".



Undergroud Power house,
Angostura, Mexico
Credit: ANDRITZ

North and Central America

Ranking by total installed hydropower capacity

Rank	Country/Territory	Installed capacity (MW)*
1	United States	102,009
2	Canada	83,312
3	Mexico	12,614
4	Costa Rica	2,331
5	Panama	1,845
6	Guatemala	1,513
7	Honduras	849
8	Dominican Republic	623
9	El Salvador	572
10	Nicaragua	159
11	Puerto Rico	98

Rank	Country/Territory	Installed capacity (MW)*
12	Haiti	78
13	Cuba	65
14	Belize	55
15	Jamaica	30
16	Guadeloupe	11
17	Dominica	7
18	Saint Vincent And The Grenadines	6

*including pumped storage



Top 5 countries by capacity added in 2022

- 1st Canada 1,012 MW
- 2nd United States 96 MW
- 3rd Panama 34 MW
- 4th Nicaragua <1 MW
- 5th Puerto Rico <1 MW

South America

Generation by hydropower
712 TWh

Total installed capacity*
180 GW

Capacity added in 2022*
1,525 MW

Pumped storage installed capacity
994 MW

Pumped storage capacity added in 2022
0 MW

*Including pumped storage

South America experienced a significant increase in hydropower development in 2022, with over 1.5 GW capacity installed and 17 projects getting commissioned or coming online. Countries in this region are making considerable advances in implementing policies and setting targets to increase renewable energy production, specifically hydropower, since there is an abundance of this natural resource. Brazil leads with a total hydropower potential estimated at 260 GW, predominantly located in the Amazon Basin.

In the Andean region, both Colombia and Peru exhibit substantial exploitable hydropower capacities exceeding 50 GW each, supported by their abundant water resources and conducive geographical features. Argentina, with a technical hydropower potential of 130 TWh/yr, has harnessed only a quarter, indicating considerable opportunity for growth.

In 2022, rainfall levels were higher than average in Chile and Colombia, boosting the hydropower output compared to previous years, which experienced drought. In Chile specifically, the year-on-year increase for August 2022 was 87 per cent. Similarly, in Brazil, water was spilled from five dams on the Rio Grande River basin, which had not happened since March 2011. In December 2022, the level of water in the reservoirs of Brazil's southeast/centre-west hydroelectric system was at about 50 per cent of capacity, double what it was a year ago. The recovery of the hydro reservoirs is a result of higher rainfall in 2022 compared with 2021, when Brazil faced its worst drought in 91 years.



Itaipu, Brazil
Credit: Voith Hydro

South America latest developments



Itaipu, Brazil
Credit: Gemma Regniez

Brazil

In 2022, Brazil added approximately 300 MW of hydropower after commissioning over 15 hydropower plants, the largest of which was the São Roque plant at 141.9 MW installed capacity.

Due to socio-environmental considerations, the feasible exploitation is reduced to around 68 GW, highlighting the necessity of a sustainable approach in balancing power generation with ecological conservation. This includes the use of less invasive run-of-river systems, comprehensive socio-environmental impact assessments, and ensuring enhanced community participation in decision-making processes.

Chile

Chile is ramping up their investment in renewable technologies including hydropower. The country's hydropower capacity increased by 477 MW, mainly due to the commissioning of the Las Lajas and the Alfalfal II power plants, both part of the same developer, Alto Maipo.

The Ocean Renewable Power Company is installing the country's first commercial river hydrokinetic system in the municipality of Chile Chico. This type of system generates electricity without the need for dams or impoundments. The electricity delivered from ORPC devices would displace diesel fuel in the market. This fits in the municipality's larger plan of expanding its usage of renewable energy by expanding electric vehicle charging networks and tourist traveller services, adding public lighting in off-grid areas in the community and creating additional electrical capacity to support sustainable community development.

Colombia

Empresas Públicas de Medellín (EPM) launched the commercial operation of the first two turbine-generator units of its 2.4 GW Ituango Hydropower plant. The plant is delivering continuous electricity supply from 600 MW of capacity to the national grid and once completed in 2024 will provide 17 per cent of Colombia's electricity demand from its eight units.

Five other hydropower projects came online in 2022, cumulatively adding total generation capacity of over 600 MW.

South America latest developments

Ecuador

Hydropower provided 73 per cent of Ecuador's electricity, and in 2022, two new plants began operation, Sarapullo (49 MW) and Sabanilla (36 MW) hydropower plants.

The government of Ecuador has announced a plan to offer public-private partnerships for 10 new hydropower projects with a combined total capacity of 640 MW and investment of US$1.52bn.

French Guyana

Voltalia is a Brazilian company developing a 2.9 MW run-of-river hydropower station in French Guyana. It is expected to produce 12.7 GWh/yr, which will replace the current diesel generators used in the community and will reduce the carbon footprint of the municipality by more than 18,000 tonnes of CO2 per year.

Peru

RC Hydro has begun initial construction work on the 40 MW Churo run-of-river hydro project in the Lima region of Peru, with an expected cost of US$60 million and completion date in 2024. The electricity produced will be used to supply the national grid. According to the country's National Interconnected System Financial Operation Committee, Peru will add 650 MW of hydropower in 2023.

International Hydropower Association



Empresas públicas de Medellín project , El Buey Columbia
Credit: Victoria Cardenas

South America

Case Study

Hidroituango also referred to as Ituango, is a hydropower plant located in Antioquia, Colombia, which will provide 17 per cent of the country's electricity demand when completed in 2024. Ituango is a project of the Ituango Hydrolectric Company, made up of the majority partners Instituto para el Desarollo de Antioquia, the Government of Antioquia and Empresas Públicas de Medellín who is the main contractor and operator.

The project's completion had been delayed due to severe weather conditions. Between April and May in 2018, Antioquia experienced heavy rains which caused large landslides. These events coupled with geological characteristics, resulted in the premature filling of the reservoir. A sudden unblocking of one of the diversion tunnels caused flooding downstream of the dam and an evacuation of the surrounding communities.

A year later, Colombia's National Disaster Risk Management Unit declared that the 600 families that were evacuated could safely return to their homes. In 2021, a report warned that the decision to abort the project would pose a greater socio-environmental threat than finishing it. The Colombian licensing authority ANLA provided a series of recommendations for the safe completion of the dam and powerhouse. These recommendations were implemented and since late 2022, Ituango has been supplying continuous electricity from 600 MW capacity to the national grid.

The project is undergoing an assessment under the Hydropower Sustainability Standard to certify its compliance and demonstrate its alignment with performance standards. This assessment is undergoing public consultation with an expected completion in June 2023.

Once Ituango is fully completed in 2024, it will have a total installed capacity of 2,400 MW and will represent a reduction in emissions of 4.4 million tons of CO2 per year.

Interesting fact

Around the world, the countries that are using almost 100 per cent renewable energy to generate electricity are Albania, the Democratic Republic of Congo, Iceland, Paraguay, Costa Rica and Norway. These countries have made significant strides in implementing renewable energy sources such as solar, wind, and hydropower and have set ambitious targets for continuous growth. The Itaipu Dam, located on the Paraná River, is one of the largest hydroelectric power plants in the world and generates about 95 per cent of Paraguay's electricity helping Paraguay generate all its electricity from renewable sources.



Itaipu, Brazil
Credit: Gemma Regniez

South America

Ranking by total installed hydropower capacity

Rank	Country/Territory	Installed capacity (MW)*
1	Brazil	109,778
2	Venezuela	16,829
3	Colombia	12,563
4	Argentina	11,359
5	Paraguay	8,810
6	Chile	7,289
7	Peru	5,515

Rank	Country/Territory	Installed capacity (MW)*
8	Ecuador	5,191
9	Uruguay	1,538
10	Bolivia	759
11	Suriname	180
12	French Guiana	119
13	Guyana	3

*including pumped storage



Top 5 countries by capacity added in 2022

- 1st Colombia 618 MW
- 2nd Chile 477 MW
- 3rd Brazil 332 MW
- 4th Ecuador 84 MW
- 5th Argentina 14 MW

Africa

Generation by hydropower
150 TWh

Total installed capacity*
40 GW

Capacity added in 2022*
1,860 MW

Pumped storage installed capacity
3.4 GW

Pumped storage capacity added in 2022
0 MW

*Including pumped storage

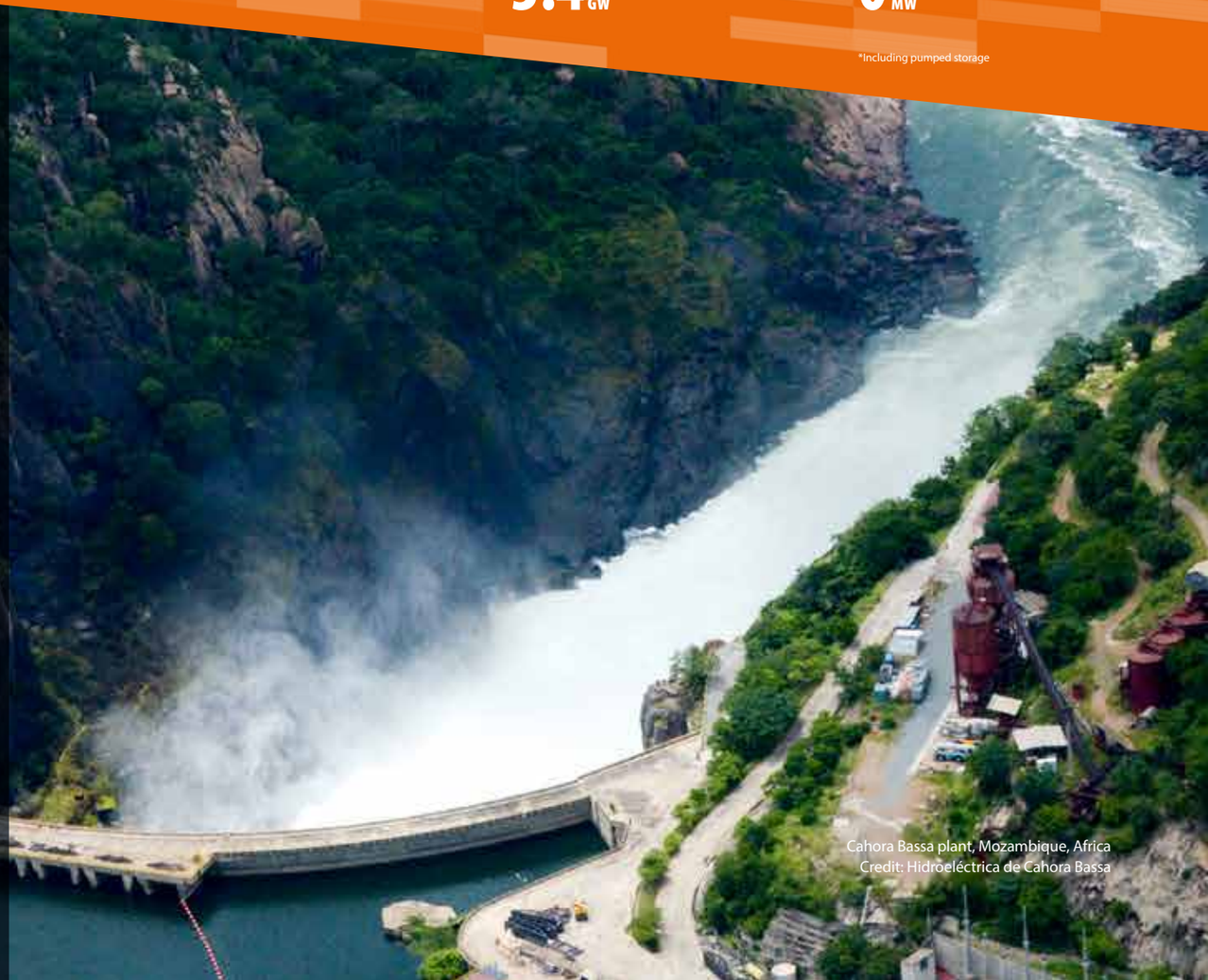
Africa has the world's fastest growing population, yet access to clean, secure, and affordable, energy services has not kept pace with the continent's expanding needs despite the continent having the largest percentage of untapped hydropower potential in the world. The Democratic Republic of Congo (DRC), Ethiopia, Angola, Sudan, Congo and Madagascar, have all been identified as having substantial untapped potential.

Hydropower, among other renewables, could support Africa's energy sector expansion in a way that is compatible with both the continent's own development goals and global demand for renewable energy and reach climate objectives. Indeed, the huge increase in solar power in particular, Africa has 60 per cent of the world's solar potential and the technology could provide 30 per cent of its power by 2050, will increase the demand for energy storage to make the most efficient use of this valuable resource.

Africa had a significant year in terms of hydropower development, over 1 GW of hydropower capacity was installed in nine countries across the continent and large-scale projects are underway to provide affordable and dispatchable electricity.

60 per cent of the hydropower installed capacity in the region is over 20 years old so modernisation efforts are important to maintain and where possible, improve access to clean and reliable energy. To help address this, the AfDB has implemented the Africa Hydropower Modernisation Program, supported by IHA. This programme provides significant market opportunity for rehabilitation of Africa's existing hydropower plants and to increase generation capacity at a low cost, and with relatively short lead times and minimal environmental impact.

Foreign investment has been instrumental to the development of new projects in the region, from countries such as China, Canada, the United Kingdom and Norway. Within the continent, the private sector is beginning to finance projects for the first time, as seen in Uganda, Gabon and Cameroon. While this is an encouraging trend, unlocking more finance for sustainable hydropower remains key to Africa's energy future.



Cahora Bassa plant, Mozambique, Africa
Credit: Hidroeléctrica de Cahora Bassa

Africa



Removal of generator top covers, Jebba Hydropower Plant, Niger
Credit: Mainstream Energy Solutions Ltd

Angola

The Caculo Cabaça hydropower project is a 2 GW run-of-river hydroelectric facility under construction in the Kwanza Norte Province of Angola. The project is being developed by Angola's Ministry of Energy and Water and is expected to be commissioned in 2024. Upon completion, Caculo Cabaça is expected to be the biggest hydroelectric facility in Angola, surpassing the Laúca hydroelectric power station. Chinese foreign investment helped finance the project, providing a US$4.1bn loan. Currently, Angola's exploitable potential is 12 GW, of which only 4 GW is currently harnessed, is a focus for government infrastructure plans aimed at addressing increased electricity demand.

Burundi

An additional 15 MW of power was added to Burundi's electricity grid by the Ruzibazi hydropower plant, which was handed to the government of Burundi by the Chinese company Sinohydro.

Burundi's Jiji and Mulembwe Hydropower Plant Development Project is set to be completed in 2025 with a capacity of 48 MW, which will double the energy power generation in the country. Additionally, the Burundian government approved a project to build two hydroelectric power stations on the Mulembwe and Ruvyironza rivers. These facilities will inject 10.65 MW into the local electricity grid and will be built by Songa Energy.

Cameroon

In 2022 the first private hydroelectric power plant under 5 MW was commissioned in the village of Mbakou in Cameroon, funded by the French Global Environment Fund. This project is part of a bigger plan aimed to unlock the potential for smaller independent power producers in Cameroon.

Cameroon will see significant hydropower development once the 420 MW Nachtigal hydroelectric power plant in Nachtigal is operational in 2024, which is projected to increase the country's electricity production by 30 per cent. The Nachtigal Hydro Power Company is implementing the project with a consortium made up of Electricité de France, IFC and the State of Cameroon.

Africa latest developments

Additionally, British firm Savannah Energy has signed an agreement with the Cameroon government to develop the 75 MW Bini a Warak Hydroelectric Project (the 'Bini Project') in the country's northern region. It is expected to increase current on-grid electricity generation capacity in northern Cameroon by over 50 per cent.

Côte d'Ivoire

The AfDB has approved finance for the Singrobo Hydropower project (44 MW) in Côte d'Ivoire. The project will include a 3.5 km transmission line and substation to connect the power generated to the existing grid. This project will contribute to the country's net zero ambition, as it is projected to reduce Côte d'Ivoire's emissions by 109,561 tonnes of CO2.

The Democratic Republic of the Congo

The Democratic Republic of Congo (DRC), Ethiopia, Angola, Sudan, Congo and Madagascar, have all been identified as having substantial untapped potential. The DRC, enriched by the Congo River, holds an exploitable hydropower potential of around 100 GW. However, various political and economic challenges have restricted exploitation to 3 per cent. The Government of the DRC has ambitious plans for the Inga III dam project; if this vision materializes, the DRC could transform into a key player in Africa's electricity industry.

Egypt

Egypt has a large undertaking in the coming years as it plans to replace 19 turbines at the Aswan High Dam and Aswan Low Dam, as Ethiopia starts producing electricity from the Grand Ethiopian Renaissance Dam, which itself is situated on a main tributary of the Nile River. The cost of rehabilitating the stations is estimated at US$48m, which will be financed through a loan from the German Ministry for Economic Cooperation and Development under an agreement signed with the German Development Bank.

Ethiopia

As of August 2022, Ethiopia's Grand Ethiopian Renaissance Dam (GERD) began generating electricity from its second turbine, which has a capacity of 275 MW, bringing the dam's current operational capacity to 750 MW. Once completed, it will have 13 operating turbines, with an expected capacity of 5 GW, making it the largest power plant in Africa. Ethiopia's exploitable potential is over 30 GW, with roughly 10 per cent being developed, with the GERD as the leading project to be developed.

Eswatini

The Eswatini Electricity Company plans to conduct an environmental and social impact assessment and the associated environmental and social mitigation plan for the 10 MW expansion of the existing Maguga Hydropower plant (10 MW).

Gabon

To scale up clean energy production capacity in Gabon, IFC, the Government of Gabon, Meridiam Infrastructure Africa Fund FIPS, Meridiam Infrastructure Africa Parallel Fund FIPS and the Fonds Gabonais d'Investissements Stratégiques, with the support of the Government of Canada, announced a financing package for the Kinguele Aval hydropower plant, the first independent power producer in Gabon.

The Kinguele Aval hydropower plant has an installed capacity of 35 MW and is expected to bring a low-cost clean power generation capacity to Gabon's capital Libreville. IFC expects the project to generate 203 GWh of electricity, amounting to approximately 9 per cent of the country's current total output, enough to serve 32,000 customers.

Guinea

Guinea has doubled its hydropower production in the nation after the Souapiti hydroelectric facility commissioned the roller-compacted concrete gravity dam equipped with four turbines, totalling 450 MW. The project is co-owned by the Ministry of Energy and Environment of the Republic of Guinea and the operator Société de Gestion et d'Exploitation de Souapiti (SOGES).

Kenya

The planned Kerio Valley will be a 60 MW hydropower project on the Arror river basin in Elgeyo-Marakwet, Kenya. The project is currently in the permitting stage and is expected to be developed in a single phase with a commission date in late 2023.

Namibia

The proposed 600 MW Baynes Dam on the border between Angola and Namibia received additional support from the AfDB. The AfDB is funding further technical assistance to engage an independent panel of experts to review and validate all the design work according to international standards.

Africa latest developments



Engaging lifting beam, Jebba Hydropower Plant, Niger
Credit: Mainstream Energy Solutions Ltd

Nigeria

Mainstream Energy Limited was selected as the concessionaire for the 700 MW Zungeru hydropower plant in Nigeria. In another development, the National Council of Privatisation an external restructuring scheme proposed by KEPCO Energy Resources Nigeria Limited, the core investor in Egbin power plant. The approval enables the entity to boost its capacity to raise the required capital to double the existing capacity of the plant to 2.6 GW.

Malawi

A joint venture between Norway's Norfund, Scatec, Electricité de France and British International Investment will develop a 350 MW Mpatamanga hydropower plant in Malawi. The project will increase security of supply, reduce energy shortages, and help secure the country against floods. Mpatamanga will supply electricity to approximately two million people and create 180,000 jobs. This joint venture will also develop the first tri-national Public-Private Partnership in Africa (Ruzizi III HPP) and Malawi's largest power plant (Mpatamanga HPP) among others.

Mali

The Gouina hydroelectric power plant in Mali has been commissioned by the Senegal River Basin Development Organisation, an organisation formed by Mali, Senegal, Guinea and Mauritania that jointly manages the Senegal River and its drainage basin. 85 per cent of the US$460m 140 MW run-of-river project was funded by the Export-Import Bank of China.

Mali currently has 756 MW of hydropower capacity under development.

Madagascar

In Madagascar, the 28 MW Farahantsana hydroelectric power station was commissioned by the project developer, Tozzi Green Madagascar, and is the largest facility to date in the country. It is operational and the facility provides 6 per cent of Madagascar's installed capacity, with its four 7 MW Francis turbines.

Madagascar has a technically feasible hydropower potential of 180,000 GWh, yet less than one per cent has

Africa latest developments

been developed so far. Right now, 162 MW of installed hydropower capacity is producing 61 per cent of the nation's electricity. Sahofika is a 192 MW hydropower project that it still on its permitting stage with an expected commission date in 2024. It is planned to be located on Onive river/basin in Antananarivo. The power plant, including the associated 220 kV transmission line, are being financed by the AfDB.

Morocco

Another 350 MW hydroelectric facility will be built in Morocco. The Abdelmoumen PSH power plant (350 MW) will be developed by the Office National de l'Electricité et de l'Eau Potable, with Vinci Construction and Andritz Hydro. It is expected to be commissioned in 2023.

Reunion

Andritz has signed a contract with Electricité de France to rehabilitate two horizontal Francis turbines in the 20 MW Takamaka I hydropower plant on the island of La Réunion, set to be commissioned by June 2024.

Rwanda

The Mushishito-Rukarara V Hydropower Plant was inaugurated in June 2022, adding 5.5 MW to Rwanda's electricity grid. Omnihydro developed the US$31.1m project that will connect over 175,000 homes with clean energy and will contribute to the country's ambition of 100 per cent electricity for all.

Tunisia

Tunisian utility, Société Tunisienne de l'électricité et du gaz is planning to build a 400-600 MW PSH plant, for a 2029 commissioning date. Robust studies are being conducted on the topographical, geotechnical, environmental, social impact and grid connection before the development of the project. The cost of the studies is covered by the French Development Agency, the European Investment Bank, and the German Development Bank.

Tanzania

In Tanzania, there are several hydropower developments under development. The largest project is the Julius Nyerere hydropower facility with an expected capacity of 2 GW which will increase the country's installed capacity to 3.7 GW.

In addition, other smaller hydropower plants are in the planning stages but are expected to produce 600 MW and after these plants are developed, hydropower will contribute over 4 GW to Tanzania's energy mix.

Uganda

Two hydropower plants were commissioned in Uganda, adding 21.8 MW of power to the country's energy mix. Serengeti Energy's run-of-river Nyamwamba II power plant produces 7.8 MW and Kikagati Power Company Ltd. developed the Kikagati Hydropower Plant producing 14 MW.

The Ugandan government agreed to create a new, state-run company called the Uganda National Electricity Company Limited to manage the generation, transmission, and distribution segments of the electricity sector, consequently not renewing the contracts with Eskom. The government states this is an effort tprovide national control.

Zambia

The final three units of the Kafue Gorge Lower Hydropower Station in Zambia have been commissioned, with a total capacity of 750 MW. The five turbines were completed in different stages, with the final turbine becoming operational in March 2023. Built by PowerChina's subsidiary, Sinohydro, the station is the first of its size in the country and is currently the biggest single infrastructure construction project in Zambia.

During construction, the project created 15,000 jobs for locals and drove the development of industries across Zambia. Now that is it operational, it will supply power to Zambians, as well as exporting electricity to Malawi, Zimbabwe, South Africa and Namibia.

Africa latest developments

Case study: Africa Hydropower Modernisation Programme; Continent-wide Mapping of Hydropower Modernisation Needs

In Africa, nearly 50 per cent of installed hydropower capacity is over 40 years old, and 60 per cent is over 30 years old. As part of its Africa Hydropower Modernisation Programme, the African Development Bank (AfDB) commissioned the International Hydropower Association (IHA) to map the status of existing hydropower plants in the continent and identify targets needing modernisation. IHA investigated the conditions of 87 hydropower projects across Africa, using surveys and follow-up interviews with their operators and owners to provide a holistic idea of the development opportunities across the continent.

Modernisation projects across the continent were categorised based on varying degrees of rehabilitation need: low, medium and high.

The study concluded that 66 plants out of 87 are in medium and high need of modernisation, of which 30 currently require urgent intervention. Modernising the existing fleet will help secure the availability of over 14.7 GW installed capacity, increase project flexibility, reduce maintenance costs, enhance water management, and enable safer operations, all while being less cost-intensive than developing green field projects.

IHA estimated that to secure reliable, efficient and safe electricity generation from the plants in the high-need category, approximately US$2.1 billion will need to be invested. As for the medium-need projects, a US$4.7 billion investment will be required.

As part of the Africa Hydropower Modernisation Programme, the AfDB is currently finalising the selection of projects that it will support by providing grant funding for relatively simple rehabilitation activities as well as funding for studies required to identify detailed scope and cost of more complex modernisation projects.

The report's public version will be released on the 22 June 2023 and available for download from www.ahmpafrica.org.

Interesting fact: Democratic Republic of the Congo

Sister Alphonsine Ciza spends her day with a team of nuns and engineers to supervise the micro hydroelectric plant she built in her town of Miti in eastern Democratic Republic of Congo. Ciza built the plant to overcome daily electricity cuts in her town and provide power to the residents. The micro plant is responsible for keeping the lights on in the convent, the church, two schools and a clinic free of charge. Without the plant, residents would only have electricity two or three days a week for a few hours.



Jebba Hydropower Plant, Niger
Credit: Mainstream Energy Solutions Ltd

Africa

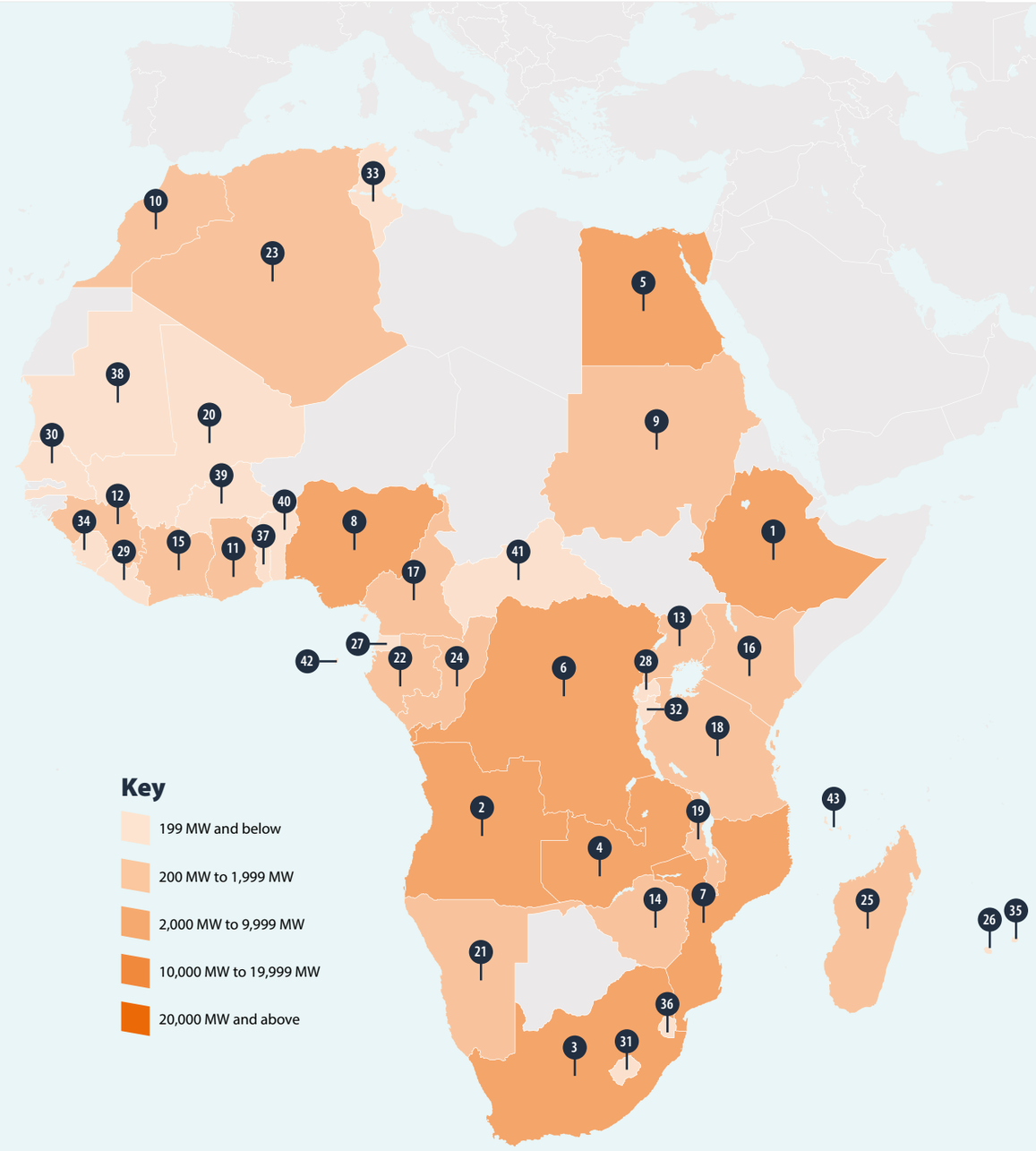
Ranking by total installed hydropower capacity

Rank	Country/Territory	Installed capacity (MW)*
1	Ethiopia	4,824
2	Angola	3,836
3	South Africa	3,600
4	Zambia	3,153
5	Egypt	2,876
6	Democratic Republic of the Congo	2,760
7	Mozambique	2,216
8	Nigeria	2,111
9	Sudan	1,923
10	Morocco	1,770
11	Ghana	1,584
12	Guinea	1,156
13	Uganda	1,095
14	Zimbabwe	1,081
15	Cote D'Ivoire	879
16	Kenya	837
17	Cameroon	822
18	Tanzania	562
19	Malawi	391
20	Mali	360
21	Namibia	347
22	Gabon	331
23	Algeria	269
24	Congo	218
25	Madagascar	214
26	Reunion	134
27	Equatorial Guinea	128
28	Rwanda	117
29	Liberia	93
30	Senegal	81
31	Lesotho	73
32	Burundi	72
33	Tunisia	66
34	Sierra Leone	64
35	Mauritius	61
36	Eswatini	61
37	Togo	49
38	Mauritania	48
39	Burkina Faso	34
40	Benin	33
41	Central African Republic	19
42	Sao Tome And Principe	2
43	Comoros	1

*including pumped storage

Top 5 countries by capacity added in 2022

- 1st Ethiopia 750 MW
- 2nd Guinea 450 MW
- 2nd Zambia 450 MW
- 3rd Mali 140 MW
- 4th Madagascar 28 MW



South and Central Asia

Generation by hydropower
539 TWh

Total installed capacity*
164 GW

Capacity added in 2022*
1,940 MW

Pumped storage installed capacity
7.7 GW

Pumped storage capacity added in 2022
0 MW

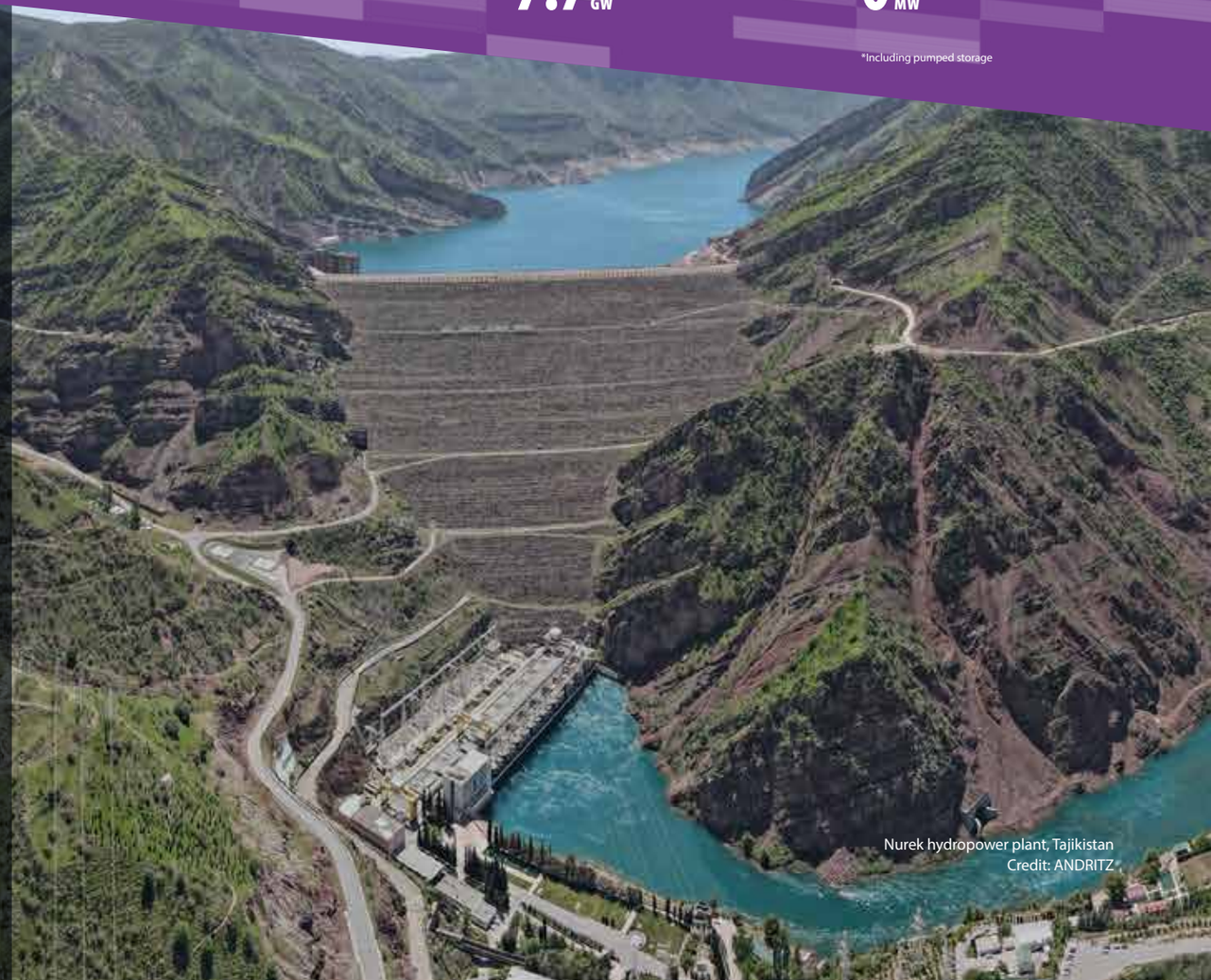
*Including pumped storage

In South and Central Asia, hydropower presents significant opportunities for the region's development. With several countries experiencing rapid population growth and increasing energy demands, harnessing untapped hydropower resources can contribute to energy security and economic growth. The optimisation of this potential requires a balance between advancing hydropower generation, preserving environmental integrity, and maintaining geopolitical equilibrium. The Himalayas, serving as Asia's water tower, present a remarkable but fragile opportunity for hydropower expansion, which demands the strengthening of transnational cooperation, particularly among countries such as China, India, Bhutan, and Bangladesh that share the Brahmaputra – the world's largest transboundary river basin. The successful exploitation of hydropower potential in South and Central Asia demands a strategic, environmentally conscious, and collaborative approach, underscoring the importance of international cooperation in this area.

In 2022, the entire region saw nearly 2 GW of new hydropower installed, with many large-scale projects nearing completion and set to be commissioned in 2024-2025. This is due to many governments in the region making commitments and prioritising financial incentivisation policies, as well as creating targets for renewables (including hydropower), across 2022 and early 2023. As well as regional partnerships which have begun to take shape across countries as governments encourage the development of hydropower.

Notably, the Energy Ministers from Kyrgyzstan, Uzbekistan and Kazakhstan signed a roadmap agreement for the construction of the Kambar-Ata-1 hydropower project. The 256 m rockfill dam will have an installed capacity of 1.8 GW when built. The governments of Nepal and India announced an agreement to build the 695 MW Arun IV project, on the Arun River and to improve power transmission to raise the electricity import and export capacity from 600 to 800 MW.

India also finalised its "Guidelines for Pumped Storage Hydropower Projects in Country" in April 2023, which is a landmark document that will incentivise further hydropower development. This region has significant potential to expand its hydropower development which will result in a massive economic boost as well as energy security for local communities.



Nurek hydropower plant, Tajikistan
Credit: ANDRITZ

South and Central Asia latest developments

Azerbaijan

Azerbaijan inaugurated a cascade of three small hydropower projects that increased the country's overall installed capacity by 5 MW.

Bhutan

Bhutan is close to commissioning four projects which would together add an additional 2.9 GW of installed capacity, which would more than double the current installed capacity in the country.

Georgia

A new scheme has been developed in cooperation between the Government of Georgia and the International Monetary Fund to facilitate the use of renewable energies and attract investment to Georgia. The energy support scheme includes incentives to develop 800 MW of hydropower within the large initiative to promote renewable investment.

In December 2022, Georgian Prime Minister announced they would be resurrecting the Soviet era Khudoni 702 MW hydropower project, which if built will become the second largest hydropower plant in the country.

India

India saw an increase in installed capacity with approximately 434 MW new capacity added over the period, with one of the largest projects being the 180 MW run-of-river Bajoli Holi in Himalchal Pradesh. The country also saw a tremendous increase in generation due to the high increase in monsoon rains. The 1.5 GW Nathpa Jhakri hydropower station set the highest single day generation record in July 2022.

Two large-scale PSH projects were announced in India in 2022. The Gandhisagar (or Gandhi Sagar) 1,440 MW pumped storage project will use an existing reservoir and have an energy storage capacity of 10 GWh. In the Maharashtra state, JSW Neo Energy announced that they will develop a 960 MW pumped storage project.

Iran

Iran saw a year-on-year increase in installed hydropower capacity from 12,193 MW in 2021 to 12,543 in March 2022, an increase of 356 MW.

Israel

The 344 MW Kokhav Hayarden PSH plant, located near the city of Beit She'an and some 120 km from Tel Aviv, is nearing completion. The project is being built by Power Construction Corporation of China and will become the largest pumped storage power plant in Israel. This will more than double the country's installed pumped storage capacity.

Kazakhstan

Kazakhstan set ambitious goals for the development of renewable energy including hydropower. Achieving these goals requires overcoming its dependence on cheap domestic coal and addressing its lack of flexible generating capacity, which provides ample opportunity for foreign hydropower investments.

Kyrgyzstan

In October, the President of Kyrgyzstan took part in the ceremony celebrating construction commencing at Kulanak hydropower project, and in March 2023 the European Bank for Reconstruction and Development (EBRD) agreed to contribute financially to the project. Additionally, EBRD agreed to finance modernisation of hydropower projects in Kyrgyzstan, with Chakan GES, the state-owned hydropower operator of nine small hydro power plants, to receive a financial package of US$13.8m. The money will help finance the rehabilitation and modernisation of the Lebedinovskaya project, which has an installed capacity of 7.6 MW.

Nepal

Nepal had an increase of 174 MW of installed hydropower capacity. This is due to the many smaller hydropower projects becoming operational, with the largest being the 28 MW run-of-river Lower Likhu project.

The Nepalese government has endorsed hedging regulation in a bid to attract more foreign investment in the country. This provision that will help minimise the potential financial risk emanating from fluctuating asset price including reservoir or semi-reservoir hydropower projects with at least 100 MW of capacity.

Pakistan

The Karot 720 MW run-of-river project was commissioned in summer 2022. This project, built by China Three Gorges Corporation (CTG), is the first hydropower project to be completed as part of the China – Pakistan Economic Corridor initiative. Karot

South and Central Asia latest developments



Upper Chuwa Headworks area, Humla District, Nepal
Credit: Er. Krishna Bahadur Kumal, Bizbell

will provide stable and affordable energy to Pakistan to meet the electricity demand of roughly 5 million residents, will reduce CO2 emissions by an estimated 3.5 million tons per year and effectively alleviate Pakistan's power shortage.

CTG provided scholarships for more than 20 public welfare projects to promote development of surrounding communities. In addition, the project can provide more than 4,500 direct and indirect local jobs each year.

Following a blockage found in a tunnel in July 2022, the Neelum-Jehlum hydropower project became non-operational for safety reasons. The tunnel collapsed in November, but in March 2023 it was reported that the 969 MW project will be operational in July 2023.

The monsoon period saw substantial increases in generation across the region, however this led to flooding and some projects were heavily impacted. The flooding of the 4,320 MW Dasu hydropower project required a rushed diversion to be constructed to mitigate impacts and to allow further building of the main dam.

The Pakistan Water and Power Development Authority confirmed its ambition to double its current installed capacity by adding 10 GW by 2030 through the phased completion of its under-construction projects. Contributing to the increase is the 800 MW Mohmand dam project, with expected completion date in 2026, with recent financial support announced by the Saudi Fund for Development.

Sri Lanka

Resus Energy has connected the eighth smallest hydropower project in Sri Lanka to the national grid, providing an installed capacity of 2.4 MW and expected to produce 8 GWh annually. The development of hydropower in Sri Lanka is part of the bigger plan to achieve 70 per cent of their electric generation from renewables by 2030.

Russia

There has been a great deal of modernisation to increase capacity at existing hydropower projects across the country. The Volzhskaya hydropower project increased by 63 MW, the Irkutsk hydropower project increased by roughly 25 MW and the

South and Central Asia latest developments

Votkinskaya hydropower project increased by 15 MW. Refurbishments increased Russia's hydropower capacity by nearly 145 MW in 2022.

The Russian Prime Minister announced that to increase its renewable energy mix, approximately 7,000 MW of new hydropower projects will be constructed. This is in addition to a plan to commission 128 MW of small hydropower projects by 2025

Tajikistan

In Tajikistan, the Nurek hydropower project's rehabilitation progressed after operation began of the first unit rehabilitated. The completion of the unit – the first of nine expected to be rehabilitated – was a major milestone. The new turbine extends the economic life of the unit by 35 years and increased the installed capacity by 40 MW to 375 MW. The Nurek HPP, with an installed capacity of over 3,000 megawatts, generates about 50 per cent of total annual energy demand in Tajikistan.

The World Bank approved US$15m in grant financing for the Technical Assistance for Financing Framework for the Rogun hydropower project in late 2022. This comes six months after the European Investment Bank expressed interest in financing the 'world's tallest dam.' The World Bank grant will include hiring of experts in dam safety and environmental and social frameworks, and the Rogun project will have a benefit-sharing mechanism to ensure that socio-economic programs receive a portion of the revenues.

Uzbekistan

It was announced that 250 micro-hydropower projects would be completed in the coming years. The Government anticipates there are 17 projects with a total capacity of 197 MW scheduled to be commissioned in 2023. There are 50 micro-hydropower projects with a capacity of 438 MW set to commence shortly. Construction of the Yavan Hydropower project has begun with a ceremony that was attended by the Presidents of Tajikistan and Uzbekistan for the 140 MW new project.



Karot Hydropower Station, Pakistan
Credit: CTG

South and Central Asia

Case Study

The Government of India published its long-anticipated "Guidelines to Promote the Development of Pumped Storage Projects (PSP)". The Guidelines recognise the value of PSH when it comes to integrating variable renewable energy sources to the energy grid. With PSH expected to play a key role in grid stabilization, meeting peak power demand and benefitting the economy, the government formulated special guidelines to promote its development.

Currently, PSH is not adequately monetised, and unfairly taxed. The Guidelines share recommendations for market, policy and safe development to encourage promote the development of pumped storage projects:

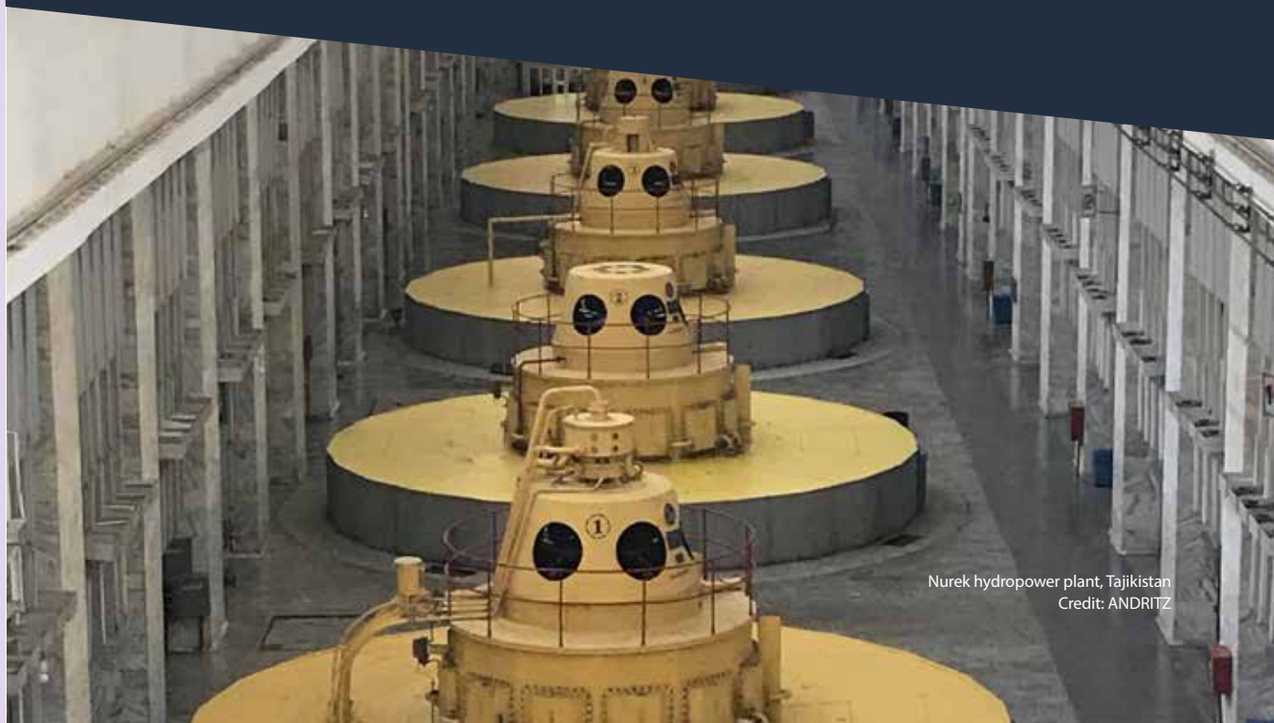
- Monetising PSH's ancillary services to meet critical electricity market measures.
- Reimbursing the State Goods and Services Tax or exempting land to be acquired for off-river PSH and should not have to face an upfront premium for project allocation.
- Identifying and safely developing exhausted mines for prospective sites and that concessional climate finance could be used to support the development of PSH.

India estimates that it will need at least 18.8 GW of PSH to support the integration of wind and solar into India's grid by 2032, and the potential is much higher. Additionally, the Central Electricity Authority recently revised estimates show that the on-river pumped storage potential alone is 103 GW in India, with many sites for off-river pumped storage potential also available.

Interesting fact

In January, a failure in Pakistan's national grid caused an electrical outage that left people without power for more than 12 hours across the country. It was reported that the blackout was caused by voltage fluctuations. The only way to regain power in the country if the entire national grid loses power is to restart individual power stations. This process is known as a "Black start," which means that smaller power sources start larger ones, and the domino effect continues until the entire country is powered up again. Some of the first power sources to turn on were hydropower plants in northern Pakistan because hydropower does not require electricity to start-up in the same way that other generation does. Hydropower reservoirs hold enough water to power turbines during a black start operation and they can be restarted fast with minimal station power.

WAPDA reported that Tarbela, Mangla, Ghazi Barotha and Warsak were successfully re-connected to the grid, essentially marking the start of the restoration as electricity from these power plants was sent to other plants so that they could reboot and resume operations until the grid was completely restored the following morning of the incident.



Nurek hydropower plant, Tajikistan
Credit: ANDRITZ

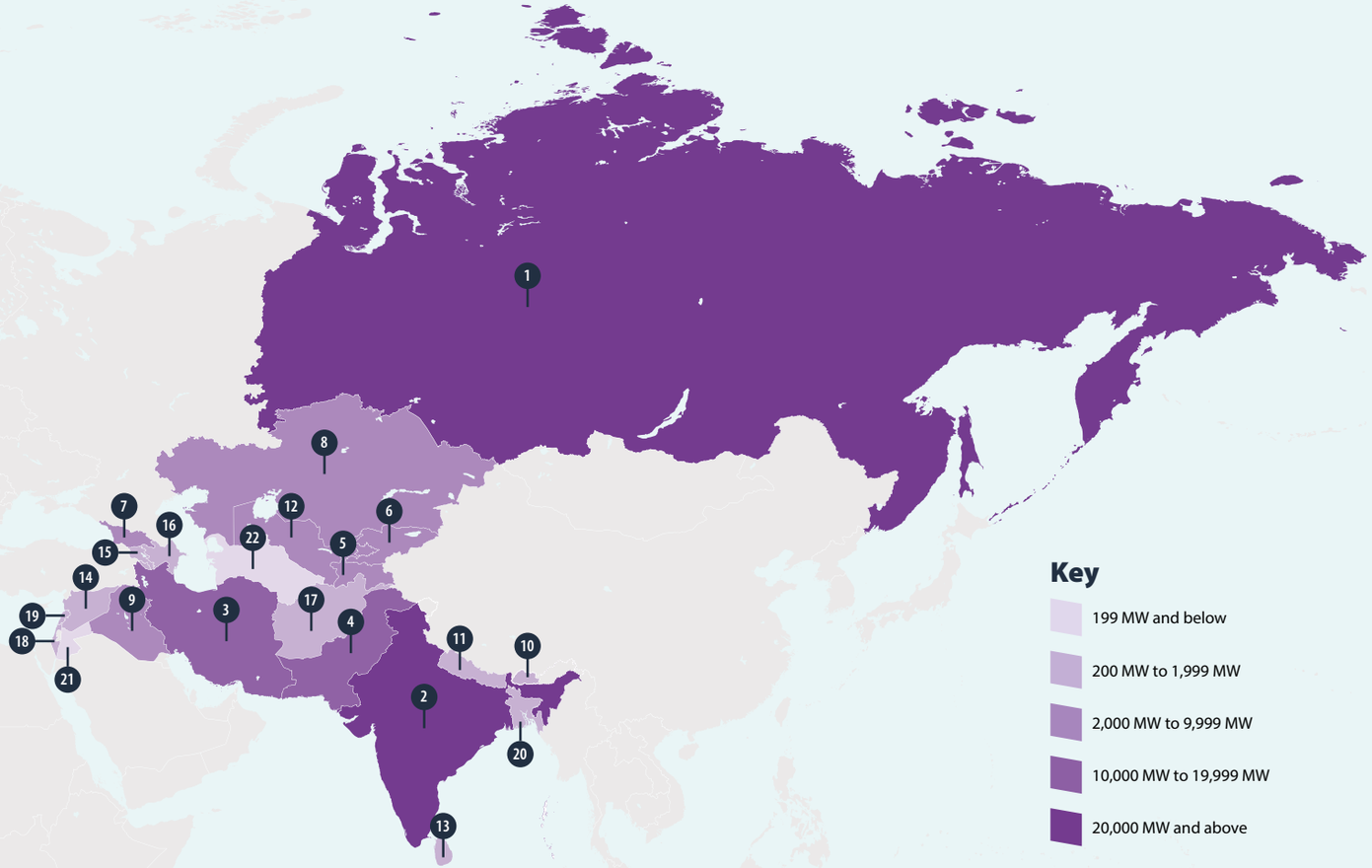
South and Central Asia

Ranking by total installed hydropower capacity

Rank	Country/Territory	Installed capacity (MW)*
1	Russia	55,819
2	India	51,786
3	Iran	12,543
4	Pakistan	10,649
5	Tajikistan	6,484
6	Kyrgyzstan	3,952
7	Georgia	3,459
8	Kazakhstan	3,087
9	Iraq	2,756
10	Bhutan	2,335
11	Nepal	2,162

Rank	Country/Territory	Installed capacity (MW)*
12	Uzbekistan	2,081
13	Sri Lanka	1,859
14	Syria	1,505
15	Armenia	1,324
16	Azerbaijan	1,155
17	Afghanistan	461
18	Israel	307
19	Lebanon	282
20	Bangladesh	230
21	Jordan	12
22	Turkmenistan	5

*including pumped storage



Top 5 countries by capacity added in 2022

- 1st Pakistan 720 MW
- 2nd India 434 MW
- 3rd Iran 356 MW
- 4th Nepal 174 MW
- 5th Russia 145 MW

East Asia and Pacific

Generation by hydropower
1,714 TWh

Total installed capacity*
548 GW

Capacity added in 2022*
24,944 MW

Pumped storage installed capacity
84 GW

Pumped storage capacity added in 2022
8,741 MW

*Including pumped storage



Semangka, Indonesia
Credit: Voith Hydro

This region stands at the forefront of the global hydropower landscape. China, as the world leader, has an exploitable hydropower capacity ranging between 400-700 GW, largely attributed to its conducive geographical features, especially in the southwestern regions. Political stability permitting, Myanmar, with an estimated exploitable capacity of around 100 GW, has the potential to become a significant hydropower exporter. In the heart of Southeast Asia, Indonesia is estimated to have a technical hydropower potential of approximately 80 GW, of which around 38 GW is considered economically feasible. This is primarily on the islands of Sumatra, Java, and Sulawesi. Malaysia and Laos, each with approximately 20 GW, also offer substantial hydropower resources.

Harnessing hydropower in the East Asia and Pacific region can significantly decrease regional fossil fuel reliance, contributing to carbon emission reduction, and fostering sustainable economic growth.

China has made huge commitments on PSH and hybrid solar-hydropower plants. Elsewhere in the region, investment in PSH is evident with development of large PSH facilities across the region. Australia is developing the Queensland's Pioneer-Burdekin pumped hydro project and in French-Polynesia, the Fa'atauti'a is undergoing modernisation.

East Asia and Pacific latest developments

Australia

Australia continues to promote clean energy and to phase out coal capacity, with energy storage playing a critical role in its push towards a renewable energy future in the country. The Queensland Premier has allocated another A$13m in the state budget to accelerate key technical studies to enable a final investment decision to advance the 1 GW/24 GWh Borumba PSH project near Gympie in the state's south-east.

Queensland's mid-coast is set to provide 5 GW of storage – enough to supply half of Queensland's entire energy needs. Stage one of the Pioneer-Burdekin pumped hydro project, said to be part of the largest pumped hydro energy storage scheme in the world (according to Queensland's premier), was announced in September 2022 and is estimated to be completed in 2032, with the final stage operational by 2035.

China

In 2022, China added over 15 GW to its conventional hydropower capacity and a further 8.7 GW of PSH. Furthermore, the National Energy Administration published their mid-term and long-term plans from 2021 to 2035 for PSH development which would see installed PSH capacity at least 62 GW in 2025, and around 120 GW in 2030, from the present 44.7 GW.

The 16 GW Baihetan hydropower station, now the second largest hydropower project in the world in terms of total installed capacity, became fully operational in December 2022.

Finally, Yalong Hydropower is building a 1 GW solar park, Kela Photovoltaic Power Station that will be connected to an operational 3 GW Lianghekou hydropower facility on the Yalong River in Southwestern China. Upon completion, this new hybrid PV-hydropower complex will be the world's largest power plant of its kind. The hydropower side of the project has an adjustable capacity of up to 6.56bn cubic metres of water.

French Polynesia

In French Polynesia, planning for the modernisation of the Fa'atauti'a 2 hydroelectric power plant in 2024 and 2025 is a key priority. It was built and commissioned in 1984, with a capacity of 960 kW. With a total production since its commissioning of 128 GWh and an average of 3.5 GWh per year, this plant alone ensures an annual production equivalent to the consumption of the island of Nuku Hiva.



Right bank main power house of Baihetan hydropower project, China
Credit: CTG

East Asia and Pacific latest developments



Penstock inspection in progress, Bakun HEP, Malaysia
Credit: Sarawak Energy

Laos

Laos added 1,100 MW to its hydropower capacity. The Nam Theun 1 Hydropower Project started commercial operation with a 177m dam located on the Nam Kading River in Bolikhamxay Province. The dam has a total installed capacity of 650 MW, of which a total of 520 MW will be exported to Thailand and 130 MW will be for domestic consumption. The Nam Theun 1 is the last project to be developed in the Nam Theun-Nam Kading hydropower cascade scheme in Laos.

The Nam Theun 1 Power Company project is a joint venture between Phonesack Group (32 per cent), Chaleun Sekong Energy Company (28 per cent), Electricity Generating Public Company of Thailand (25 per cent), and Electricité du Laos (15 per cent). China's state-owned Sinohydro Bureau 3 was also engaged in civil works for the project. The cost of the project is estimated at US$1,335m with major financing provided by Bangkok Bank, Export-Import Bank of Thailand, Siam Commercial Bank and TISCO Bank.

Philippines

Filipino Infrastructure developer Prime Infra is in the pre-development stage of the 500 MW Wawa PSH project in the Rizal province, with construction due to start in 2023. This project has an estimated investment cost of US$1bn and is seen as one of the Philippines' most strategically important power generation assets in terms of ensuring the immediate reduction of power prices. Wawa is intended to help support the Philippine government's push toward tripling the country's green energy generating capacity by 2030 by providing grid stability.

In 2022, the Filipino Government increased its original energy target for the share of renewable energy to 35 per cent by 2030 and 50 per cent by 2040. Additional targets including a 12 per cent reduction in CO2. The Laguna PSH project was announced in October 2022, with a capacity of 800 MW and a cost of US$1.3bn.

East Asia and Pacific

Construction is expected to be completed by the end of 2026 and will generate an average annual energy supply of 1,523 GWh.

Thailand

In Thailand, the Electricity Generating Authority of Thailand is focusing on expanding its pumped storage capacity to increase the security of the system during peak demand and allow for the greater integration of variable renewable energy. It currently operates three facilities totalling 1.53 GW and is reviewing the feasibility of six further projects including the proposed 900 MW Vajiralongkorn pumped storage project in Kanchanaburi Province. The main goals of this feasibility study include conducting geotechnical and geological investigations of the project site and developing a high-level conceptual design for the PSH plant. The planned open-loop project is currently projected to be developed between 2029 and 2036 at an estimated cost of Baht 32bn (US$938.4m).

Malaysia The Sustainable Energy Development Authority (SEDA) in Malaysia has set an ambitious target to attract new investments and create more jobs in Malaysia's renewable energy sector. SEDA announced a feed-in tariff quota application for small hydropower resources. In 2022 it was announced that 127 MW of small hydropower projects became qualified for the scheme.

The 1,285MW Baleh Hydroelectric Project has been commissioned for completion in 2027. The hydropower facility is being developed by Sarawak Energy Berhad Power. The main civil works are being jointly conducted by China Gezhouba Group Company Ltd and local firm Untang Jaya Sdn Bhd.

Vietnam

Hydropower sources in Vietnam have the potential to produce up to 40 GW of electricity. The total capacity of hydropower, including small hydroelectricity plants, is expected to reach almost 30 GW by 2030.

In 2022, the country added 33 MW installed capacity for conventional hydropower with the completion of the Dak Di 1 Hydro Power Plant.

According to the newly published "Power Development Plan VIII", the Vietnamese Government is prioritising multi-purpose and PSH projects.

Case Study

The State Grid Corporation of China announced the operation of the 3.6 GW Fengning Pumped Storage Power Station in 2022. The station is likely to be the world's biggest pumped storage project (despite healthy competition from Queensland). It was developed in two phases with a 1.8 GW capacity per phase, by the State Grid Xinyuan Company, a directly managed subsidiary of the state-owned State Grid Corporation of China. State Grid Xinyuan Company manages and operates the facility. Fengning is reportedly the first hydroelectric facility in China to integrate variable speed technology for efficient power generation.

Not only is it the world's biggest pumped storage project, but it also has 190 caverns, making it one of the largest underground factories in the world. It is also one of the world's first pumped storage power stations connected to the flexible DC grid, due to a connection made to the Zhangbeirou DC converter station. The plant's first operational units provided 600 MW of capacity to Beijing and Zhangjiakou, the host cities of the Winter Olympics.

Interesting fact

As the world's largest archipelago, Indonesia has over 600 lakes, dams and reservoirs which could potentially be used for floating PV farms. Deploying floating PV systems on these water bodies will not only help conserve the country's land resources but can also offer additional benefits such as preserving water quality and protecting these ecosystems from rising temperatures and water evaporation.

Work has begun on the construction of up to 60 floating PV plants in Indonesia. Cirata Floating Solar plant is one of these, with a capacity of 145 MW on a 250-hectare plot of the 6,200-hectare Cirata Reservoir in the West Java region, it is reported to become the biggest in Southeast Asia.

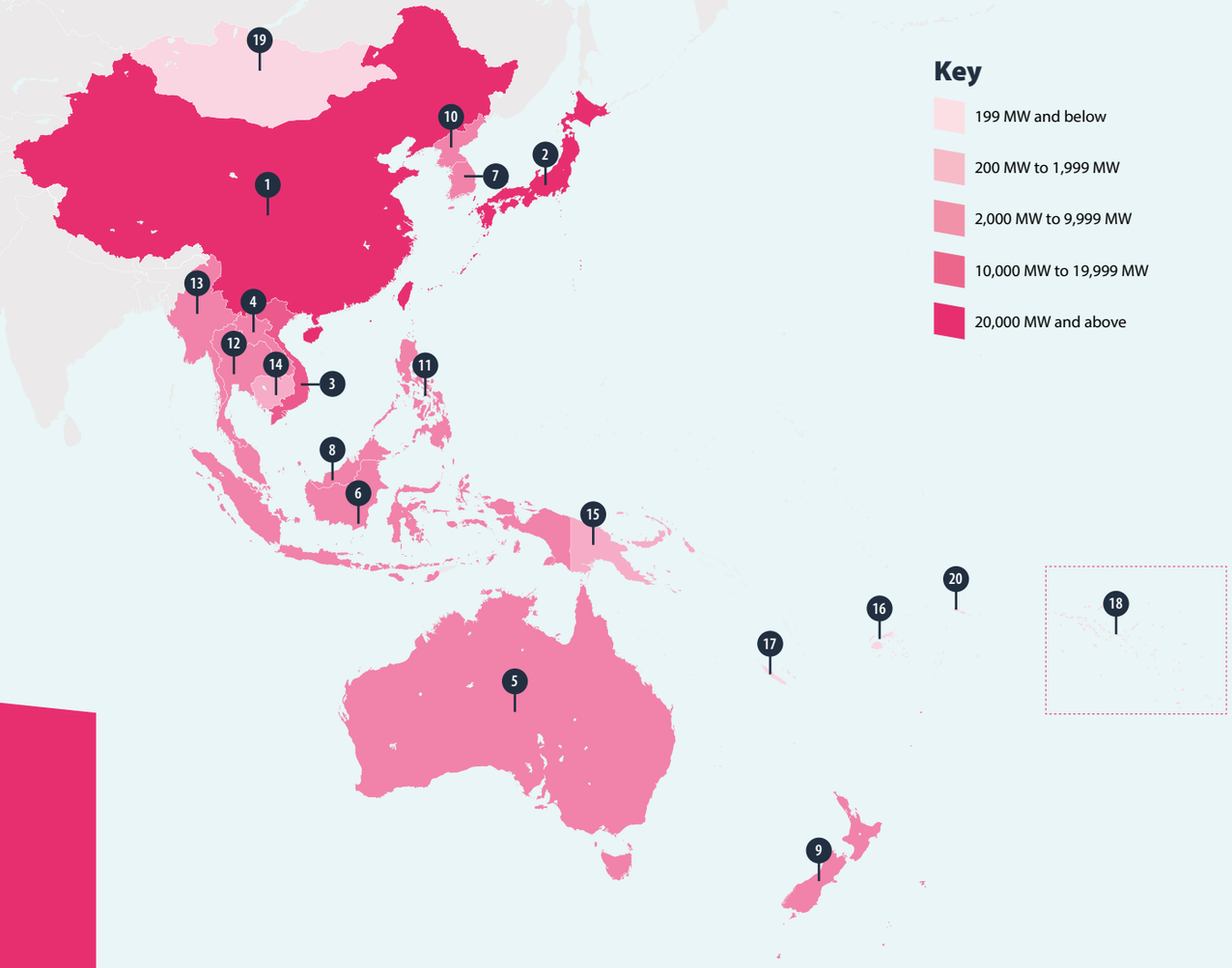
East Asia and Pacific

Ranking by total installed hydropower capacity

Rank	Country/Territory	Installed capacity (MW)*
1	China	414,811
2	Japan	49,643
3	Vietnam	17,366
4	Laos	9,208
5	Australia	8,576
6	Indonesia	6,602
7	South Korea	6,541
8	Malaysia	6,372
9	New Zealand	5,342
10	North Korea	5,010

Rank	Country/Territory	Installed capacity (MW)*
11	Philippines	4,520
12	Thailand	4,515
13	Myanmar	3,331
14	Cambodia	1,332
15	Papua New Guinea	234
16	Fiji	125
17	New Caledonia	82
18	French Polynesia	48
19	Mongolia	23
20	Samoa	12

*including pumped storage



Top 5 countries by capacity added in 2022

1st China 23,811 MW

2nd Laos 1,100 MW

3rd Vietnam 33 MW

Practical solutions for the future development of sustainable hydropower

This section summarises the policy recommendations provided throughout Outlook.

Three key aspects associated with hydropower development that are urgent for today's energy policies to focus on:

Incentivise sustainable hydropower development through financial and market mechanisms that reward flexibility. To meet the objectives of the Paris Agreement and the UN Sustainable Development Goals, IEA estimates that investment in hydropower needs to double to US$100bn a year. This cannot happen without appropriate financial and market frameworks to incentivise new investment.

Accelerate the development of renewables through streamlined permitting and licensing. Hydropower planning and approval processes typically take more than five years before a project can even begin construction. Meanwhile, the default option is often to fall back on fossil fuels. The massive deployment of renewables needed to meet global climate goals through sustainable development should be accelerated by streamlining these processes wherever possible.

Embed hydropower sustainability practices in government regulation. Accelerating development does not mean cutting corners. Application of the Hydropower Sustainability Standard, built and governed through multi-stakeholder consensus, should be integrated into regulatory frameworks to maximise the benefits of projects and mitigate any negative impacts.

Hydropower Potential:

There is more than enough hydropower potential to achieve the net zero targets set by IEA and IRENA for 2050. More importantly, around half of the economically feasible hydropower potential remains untapped. This potential can be achieved through four broad actions:

- developing new hydropower,
- developing PSH,
- modernising existing infrastructure, and
- retrofitting non-powered dams.

Governments can encourage development by:

Ensuring regulatory and licensing regimes are fit for purpose and do not disincentivise investment by station owners or operators;

Ensuring that electricity markets remunerate the flexibility and the dispatchability that modernised hydropower facilities can excel in providing, to safeguard grid stability;

Providing long term visibility of revenues including through long term contracts, that will further incentivise investment.

Pumped Storage Hydropower recommendations:

Comprehensive Planning. Policymakers must anticipate long-term clean electricity requirements, considering the need for storage to support the integration of a high share of variable renewables into the energy mix.

Site Identification. A systematic mapping and assessment of existing and potential hydropower sites suitable for PSH is necessary to guide sustainable infrastructure development and inform energy policy decisions.

Financial Frameworks. Policymakers must construct robust financial policy mechanisms that incentivise PSH and enable long-term revenue visibility. Electricity markets should reward grid stability contributions provided by PSH. PSH could also be included in green finance initiatives.

Sustainability Assessment. Rigorous sustainability evaluations using internationally recognised assessment tools should be integrated into development processes.

Non-powered dams recommendations:

Support research and development of innovative technologies which could help to lower the costs of retrofitting non-powered dams.

Improve existing processes to streamline hydropower licensing, relicensing, and license surrender, making them more efficient and responsive to the needs of retrofitting non-powered dams.

Increase financial support for dam rehabilitation and retrofitting projects. This could be facilitated through greater budget allocations, tax incentives, or low-interest loans specifically designed for these initiatives.

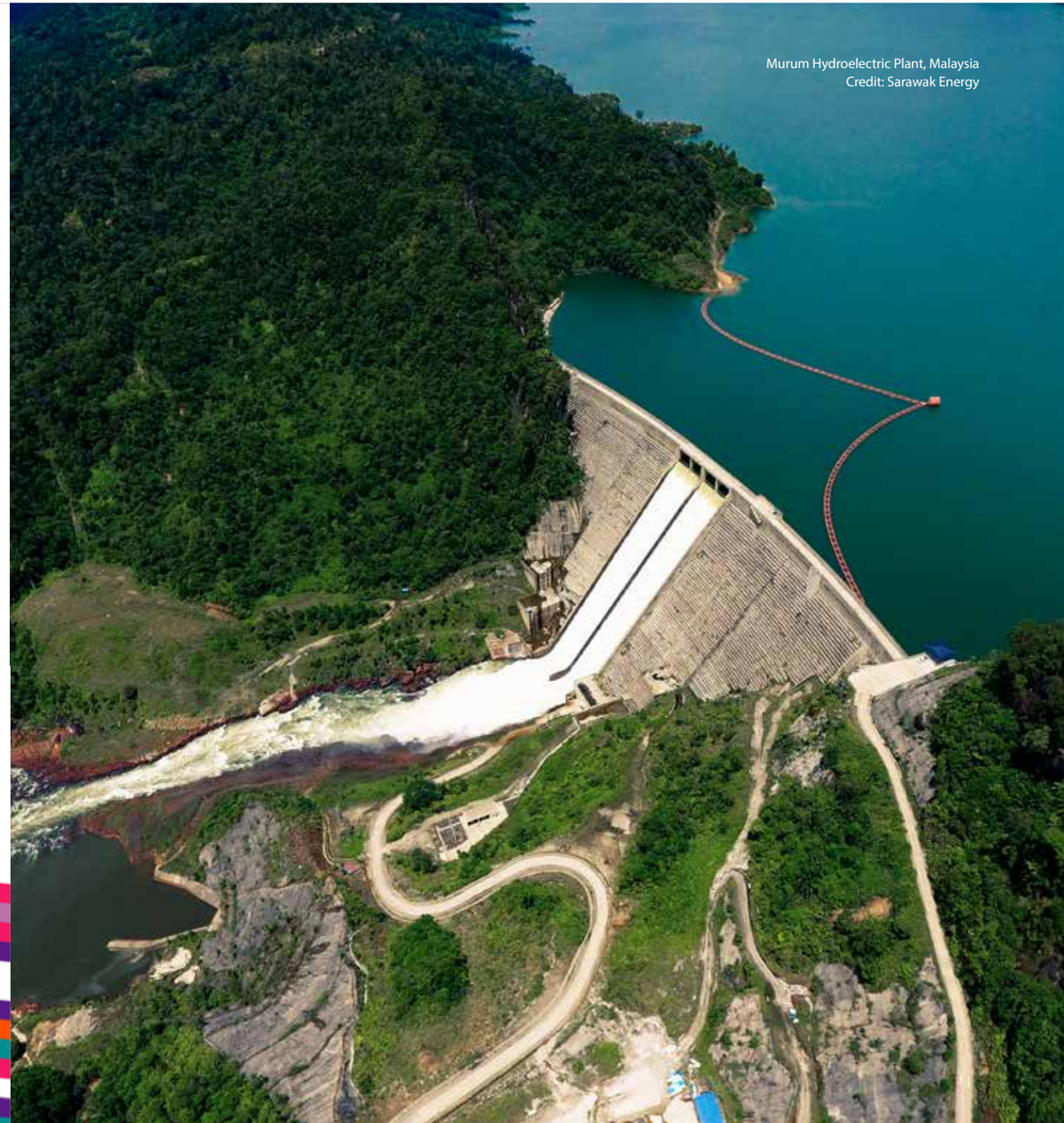
Floating Solar recommendations:

Governments wanting to enable FPV should prioritise the following areas:

Promote research to further understand the environmental impacts of FPV facilities.

Develop standards and regulatory guidelines to manage the risks in installation.

Promote a better regulatory and policy environment to facilitate project development.



Murum Hydroelectric Plant, Malaysia
Credit: Sarawak Energy

Installed capacity and generation 2022

North and Central America

Country/Territory	Total installed capacity including pumped storage (MW)	Pumped (MW)	Generation (TWh)
Anguilla	0	0	0
Antigua and Barbuda	0	0	0
Aruba	0	0	0
Bahamas	0	0	0
Barbados	0	0	0
Belize	55	0	<1
Bermuda	0	0	0
Canada	83,312	177	392
Cayman Islands	0	0	0
Costa Rica	2,331	0	9
Cuba	65	0	<1
Dominica	7	0	0
Dominican Republic	623	0	1
El Salvador	572	0	2
Grenada	0	0	0
Guadeloupe	11	0	0
Guatemala	1,513	0	7
Haiti	78	0	<1
Honduras	849	0	4
Jamaica	30	0	<1
Martinique	0	0	0
Mexico	12,614	0	35
Montserrat	0	0	0
Nicaragua	159	0	<1
Panama	1,845	0	8
Puerto Rico	98	0	0
Saint Bartholemy	0	0	0
Saint Kitts And Nevis	0	0	0
Saint Lucia	0	0	0
Saint Pierre And Miquelon	0	0	0
Saint Vincent And The Grenadines	6	0	0
Trinidad And Tobago	0	0	0
Turks And Caicos Islands	0	0	0
United States	102,009	22,008	262
Virgin Islands, British	0	0	0
Virgin Islands, U.S.	0	0	0
Total	**206,175**	**22,185**	**723**

South America

Country/Territory	Total installed capacity including pumped storage (MW)	Pumped (MW)	Generation (TWh)
Argentina	11,359	974	31
Bolivia	759	0	3
Brazil	109,778	20	423
Chile	7,289	0	20
Colombia	12,563	0	64
Ecuador	5,191	0	25
French Guiana	119	0	1
Guyana	3	0	0
Paraguay	8,810	0	41
Peru	5,515	0	30
Suriname	180	0	1
Uruguay	1,538	0	6
Venezuela	16,829	0	68
Total	**179,933**	**994**	**712**

Africa

Country/Territory	Total installed capacity including pumped storage (MW)	Pumped (MW)	Generation (TWh)
Algeria	269	0	<1
Angola	3,836	0	11
Benin	33	0	<1
Botswana	0	0	0
Burkina Faso	34	0	<1
Burundi	72	0	<1
Cameroon	822	0	6
Cape Verde	0	0	0
Central African Republic	19	0	<1
Chad	0	0	0
Comoros	1	0	0
Congo	218	0	1
Cote D'Ivoire	879	0	3
Democratic Republic of the Congo	2,760	0	15
Djibouti	0	0	0
Egypt	2,876	0	14
Equatorial Guinea	128	0	<1
Eritrea	0	0	0
Eswatini	61	0	<1
Ethiopia	4,824	0	14
Gabon	331	0	2
Gambia	0	0	0
Ghana	1,584	0	7
Guinea	1,156	0	2
Guinea-bissau	0	0	0
Kenya	837	0	4
Lesotho	73	0	<1
Liberia	93	0	<1
Libya	0	0	0
Madagascar	214	0	1
Malawi	391	0	1
Maldives	0	0	0
Mali	360	0	<1
Mauritania	48	0	<1
Mauritius	61	0	<1
Morocco	1,770	465	2
Mozambique	2,216	0	14
Namibia	347	0	1
Niger	0	0	0
Nigeria	2,111	0	8
Reunion	134	0	0
Rwanda	117	0	0
Sao Tome And Principe	2	0	0
Senegal	81	0	<1
Seychelles	0	0	0
Sierra Leone	64	0	<1
Somalia	0	0	0
South Africa	3,600	2,912	6
South Sudan	0	0	0
Sudan	1,923	0	8
Tanzania	562	0	2
Togo	49	0	<1
Tunisia	66	0	0
Uganda	1,095	0	4
Western Sahara	0	0	0
Yemen	0	0	0
Zambia	3,153	0	15
Zimbabwe	1,081	0	5
Total	**40,349**	**3,377**	**150**

Europe

Country/Territory	Total installed capacity including pumped storage (MW)	Pumped (MW)	Generation (TWh)
Albania	2,203	0	7
Andorra	45	0	<1
Austria	14,836	5,596	36
Belarus	96	0	<1
Belgium	1,493	1,308	<1
Bosnia and Herzegovina	2,230	440	5
Bulgaria	2,916	1,404	4
Croatia	2,155	281	5
Cyprus	0	0	0
Czechia	2,290	1,172	2
Denmark	7	0	0
Estonia	4	0	0
Faroe Islands	39	0	<1
Finland	3,246	0	13
France	25,669	5,050	50
Germany	11,471	6,414	17
Gibraltar	0	0	0
Greece	3,421	699	5
Greenland	91	0	<1
Hungary	58	0	<1
Iceland	2,086	0	14
Ireland	508	292	<1
Italy	22,635	7,891	30
Kosovo	92	0	<1
Latvia	1,588	0	3
Liechtenstein	35	15	<1
Lithuania	1,028	900	<1
Luxembourg	1,332	1,296	<1
Macedonia	644	0	1
Malta	0	0	0
Moldova	64	0	<1
Monaco	0	0	0
Montenegro	649	0	1
Netherlands	38	0	<1
Norway	33,807	1,441	129
Poland	2,376	1,591	2
Portugal	8,252	3,754	9
Romania	6,229	92	14
San Marino	0	0	0
Serbia	3,166	642	9
Slovakia	2,476	1,017	3
Slovenia	1,307	180	3
Spain	20,425	6,164	19
Sweden	16,391	91	70
Switzerland	17,756	4,419	34
Türkiye	32,130	0	66
Ukraine	6,317	1,488	11
United Kingdom	4,723	2,833	5
Total	**258,324**	**56,470**	**569**

South and Central Asia

Country/Territory	Total installed capacity including pumped storage (MW)	Pumped (MW)	Generation (TWh)
Afghanistan	461	0	<1
Armenia	1,324	0	2
Azerbaijan	1,155	0	2
Bahrain	0	0	0
Bangladesh	230	0	<1
Bhutan	2,335	0	11
Georgia	3,459	0	11
India	51,786	4,746	175
Iran	12,543	1,040	15
Iraq	2,756	240	7
Israel	307	300	0
Jordan	12	0	0
Kazakhstan	3,087	0	10
Kuwait	0	0	0
Kyrgyzstan	3,952	0	12
Lebanon	282	0	<1
Nepal	2,162	0	3
Oman	0	0	0
Pakistan	10,649	0	36
Qatar	0	0	0
Russia	55,819	1,385	219
Saudi Arabia	0	0	0
Sri Lanka	1,859	0	7
Syria	1,505	0	<1
Tajikistan	6,484	0	21
Turkmenistan	5	0	0
United Arab Emirates	0	0	0
Uzbekistan	2,081	0	7
Total	**164,253**	**7,711**	**539**

East Asia and Pacific

Country/Territory	Total installed capacity including pumped storage (MW)	Pumped (MW)	Generation (TWh)
American Samoa	0	0	0
Australia	8,576	2,461	17
Brunei	0	0	0
Cambodia	1,332	0	6
China	414,811	44,741	1354
Taiwan (China)	4,689	2,596	7
Cook Islands	0	0	0
Fiji	125	0	<1
French Polynesia	48	0	<1
Guam	0	0	0
Hong Kong	0	0	0
Indonesia	6,602	0	19
Japan	49,643	27,470	99
Kiribati	0	0	0
Laos	9,208	0	38
Macau	0	0	0
Malaysia	6,372	0	16
Marshall Islands	0	0	0
Micronesia, Federated States Of	0	0	0
Mongolia	23	0	<1
Myanmar	3,331	0	8
Nauru	0	0	0
New Caledonia	82	0	<1
New Zealand	5,342	0	24
Niue	0	0	0
North Korea	5,010	0	13
Papua New Guinea	234	0	<1
Philippines	4,520	735	9
Samoa	12	0	36
Singapore	0	0	0
Solomon Islands	0	0	0
South Korea	6,541	4,790	8
Thailand	4,515	1,531	7
Timor-leste	0	0	0
Tonga	0	0	0
Tuvalu	0	0	0
Vanuatu	0	0	0
Vietnam	17,366	0	53
Total	**548,381**	**84,324**	**1714**

World

	Total installed capacity including pumped storage (MW)	Pumped (MW)	Generation (TWh)
Total	**1,397,415**	**175,060**	**4,408**

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