iha
international hydropower association

2019

hydropower status report

sector trends and insights

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Cover and inner cover image: The Itaipú hydropower plant on the Paraná River on the border between Brazil and Paraguay. Credit: Itaipu Binacional.

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The Gordon Dam in the south-west of Tasmania, Australia.
Credit: Hydro Tasmania.

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Report methodology

Statistics for the Hydropower Status Report are compiled by IHA using data from published sources, IHA members, government representatives, industry sources and media monitoring.

IHA's database lists more than 13,000 stations in 150 countries. For hydropower generation, statistics are a combination of official government reports and IHA estimates based on averaged capacity factors.

The data is tracked, stored and updated to account for new information as it is received. Data verification exercises are an ongoing process, leading to corrections as and when required.

Advancing sustainable hydropower

The International Hydropower Association (IHA) is a non-profit membership organisation committed to sustainable hydropower.

IHA's vision is a world where water and energy services are delivered to all in a sustainable way.

Our mission is to advance sustainable hydropower by building and sharing knowledge on its role in renewable energy systems, responsible freshwater management and climate change solutions.

We achieve this through monitoring the sector, advancing strategies that strengthen performance, and building an open, innovative and trusted platform for knowledge.

Knowledge building

IHA's programmes increase awareness of hydropower's value to clean energy systems and sustainable development, promoting collaborative, adaptive approaches to river basin development and regional interconnections.

We provide practical advice and support to members on operations and maintenance and have developed tools for dealing with new challenges such as assessing reservoir carbon emissions and building climate resilience.

Sustainability

IHA is a champion of good practices and continuous improvement in the hydropower sector.

We support project assessments and training as the management body for the Hydropower Sustainability Assessment Tools. These tools are used to guide and assess performance against a range of environmental, social, technical and economic criteria.

Find out more:

www.hydropower.org

iha
international hydropower association

Download our 2018-19 Activity and Strategy Report:

hydropower.org/activity2019

Foreword

The Hydropower Status Report is an authoritative guide to key trends in hydropower development, featuring policy insights and latest global capacity and generation data.

The 2019 Hydropower Status Report, published by the International Hydropower Association (IHA), offers insights on hydropower development across all regions of the world.

Now in its sixth edition, this report is compiled by a team of analysts using information provided by our members, industry sources and government representatives, published sources and media monitoring.

Our research found that, during 2018, hydropower projects added almost 22 gigawatts (GW) of installed capacity worldwide. This brought existing capacity to 1,292 GW, resulting in an estimated 4,200 terawatt hours (TWh) in clean electricity generation last year.

Hydropower development today is most active in fast growing economies and emerging markets, with the East Asia and the Pacific region, followed by South America, adding the highest additional capacity last year. The United States, which was previously surpassed by China, has now been eclipsed by Brazil as the second largest hydropower country by installed capacity.

1,292 GW

worldwide hydropower installed capacity in 2018

4,200 TWh

estimated electricity generated from hydropower in 2018

Four years on since the Sustainable Development Goals were agreed at the United Nations in 2015, governments increasingly recognise hydropower as playing a vital role in national strategies for delivering affordable and clean energy, managing freshwater, combatting climate change and improving livelihoods.

We are honoured that five leading government ministers from Canada, Indonesia, Nepal, Uganda and Uruguay, with responsibility for energy, water and infrastructure planning, have shared their perspectives and policy priorities in this report.

In Canada, six out of every 10 homes and businesses are powered by hydroelectricity and the sector is widely recognised for job creation. Writing in these pages, Minister of Natural Resources Amarjeet Sohi welcomes industry efforts to build partnerships with indigenous communities that "create new, long-term economic opportunities" while reducing reliance on diesel in remote communities.

Elsewhere, in countries such as Indonesia, Nepal and Uganda, hydropower holds the potential to accelerate social and economic progress and reduce poverty through widening access to electricity.

"For Uganda to achieve sustainable development," writes Minister of Energy and Minerals Irene Nafuna Muloni, "the hydropower resources that remain untapped will have to be developed so as to bring to fruition plans aimed at increasing access to electricity and per capita electricity consumption."

In line with the Paris Agreement, Indonesia has developed a strategy for hydropower development aimed at boosting industrial growth and reducing carbon emissions. Minister of National Development Planning Bambang P. Soemantri Brodjonegoro explains that his country is committed to reduce GHG emissions by 29 per cent by 2030, through which "increasing and promoting the use of new and renewable energy is critical."

The challenge for many emerging economies and developing countries, however, is to raise the investment capital to build and sustain hydropower projects, while also ensuring national institutions have sufficient capacity to ensure projects are delivered in accordance with good practice on environmental and social performance.

In Nepal, the government is seeking to attract foreign investment in hydropower and is exploring regional energy interconnections as a way of reducing reliance on fossil fuels and increasing off-grid access. Minister of Energy, Water Resources and Irrigation, Barsha Man Pun, writes that his government is considering distributed electricity generation through a mix of hydropower projects, solar, and wind.

In South America, Uruguay has reached close to 100 per cent renewable electricity generation thanks to the contribution of hydropower. Importantly, the government also recognises the "strong complementarity" between hydroelectric and other variable renewable energy forms. Minister of Industry, Energy and Mining Guillermo Moncecchi explains that hydroelectric power has "not only had a relevant role in the past, ensuring the sustainability of the electricity mix, but also in the present, acting as a platform to develop non-conventional renewable energies, redoubling the commitment to comply with the SDGs."

The Fierza Hydroelectric Power Station on the Drin cascade in Albania. Credit: KESH.

Through the pages of this report, we highlight tools, trends and topics of direct interest to hydropower developers, operators, investors, governments and, ultimately, local communities. These subjects range from efforts to assess the benefits of hydropower, through to financing pumped storage projects and adapting operations to new digital technology.

The year 2018 saw the launch of a suite of new sustainability tools by IHA and the Hydropower Sustainability Assessment Council, a multi-stakeholder coalition of representatives of social and environmental NGOs, industry, government and multilateral institutions. These tools include the Hydropower Sustainability Guidelines, which present definitions of good practice in the planning, operation and implementation of hydropower projects, and a new Environmental, Social and Governance Gap Analysis Tool for identifying and address gaps against good practice.

IHA, as a not-for-profit association whose members include public and private companies, national organisations and hydropower professionals, recognises that urgent action is required to deliver clean energy to limit the effects of climate change, and to meet people's basic needs for freshwater and affordable energy.

Our mission is to advance sustainable hydropower by building and sharing knowledge on its role in renewable energy systems, responsible freshwater management and climate solutions. We do this through programmes aimed at lifting the sector's performance and improving understanding on good practices.

We encourage all organisations and individuals that share our vision of a world where water and energy services are delivered to all in a sustainable way to join us in this endeavour.

Richard Taylor
Chief Executive

Ken Adams
President

Executive summary

The Vieux-Emosson dam and reservoir in Valais, Switzerland. Credit: © Alpiq.

Electricity generation from hydropower sources reached record heights in 2018.

Key trends and developments

In 2018, electricity generation from hydropower reached an estimated 4,200 terawatt hours (TWh), setting the highest ever contribution from a renewable energy source.

An estimated 21.8 gigawatts (GW) of hydropower capacity was put into operation last year, including nearly 2 GW of pumped storage, bringing the world's total installed capacity to 1,292 gigawatts (GW).

The East Asia and Pacific region once again held its position as the fastest growing last year, with 9.2 GW of hydropower installed capacity added. It was followed by South America (4.9 GW), South and Central Asia (4.0 GW), Europe (2.2 GW), Africa (1.0 GW) and North and Central America (0.6 GW).

Forty-eight countries added hydropower capacity in 2018. The countries with the highest individual increases in installed capacity were China (8.5 GW) and Brazil (3.7 GW). Among the top five were Pakistan (2.5 GW), Turkey (1.1 GW) and Angola (0.7 GW).

With Brazil reaching 104 GW in installed capacity, the South American nation has now overtaken the United States (103 GW) as the second largest country by hydropower capacity.

See the map on pages 48-51 and the tables on pages 100-101 for data for each country and region.

Understanding hydropower's benefits

Hydropower delivers a range of benefits to society and the environment. Power-related benefits include clean and flexible generation and storage, as well as reduced dependence on fossil fuels and avoidance of pollutants.

More challenging to quantify are the non-power benefits associated with a hydropower project. These include economic improvements to livelihoods and local supply chains, enhanced navigation and transportation, and investment in community services. Freshwater management benefits including supply for homes, industry and agriculture, and mitigation against floods and drought.

With the goal of improving understanding about the underreported benefits of hydropower, IHA is undertaking a global study of projects categorised as either single or multi-purpose, for example providing power generation, water supply, irrigation and flood control.

Multi-purpose hydropower projects predominate in South and Central Asia, whereas South America has the lowest percentage of multi-purpose dams. While most hydropower projects were built for a single purpose, a significant share were constructed to support additional services, or were later recognised to provide these services.

Read more on pages 30-31.

Building resilience to climate change

Hydropower produces almost two-thirds of the world's renewable electricity generation and is making a major contribution to delivering on the ambition of the Paris Agreement and the Sustainable Development Goals. Without this contribution, the objective of limiting climate change to 1.5 or 2 degrees above pre-industrial levels would likely be out of reach.

Hydropower projects offer countries protection against the impacts of by climate change and extreme weather, such as floods and drought, however variable climate conditions also make these projects susceptible to climate risks due to their dependency on precipitation and runoff.

New guidance for the hydropower sector published by IHA will support operators and investors to demonstrate robust ways of achieving climate resilience. This will address the need for international good practice on how to assess climate risks and incorporate resilience into project planning, design, and operations.

To be launched at the 2019 World Hydropower Congress, the Hydropower Sector Climate Resilience Guide has been tested by project operators around the world, with technical and financial support from the European Bank for Reconstruction and Development (EBRD) and the World Bank and its Korea Green Growth Trust Fund.

Read more on pages 32-33.

2018 HIGHLIGHTS

4,200 TWh	1,292 GW	160.3 GW	21.8 GW	1.9 GW
Electricity generated from hydropower in 2018	Global hydropower installed capacity	Global pumped storage installed capacity	Capacity added in 2018, including pumped storage	Pumped storage capacity added in 2018

Turbo-charging the energy transition

Pumped hydropower storage has proven to be an essential component for modern and future clean energy systems. The significant increase in variable renewable electricity sources like wind and solar coupled with their displacement of conventional generators has put increasing pressure on power grids and underlined the need for pumped hydropower 'water batteries'.

While we are witnessing renewed interest in pumped hydropower as the technology evolves to ensure grid stability, markets around the world have been slow to recognise and reward its value, pointing to deficiencies in how liberalised markets are incentivising development.

If pumped hydropower storage is to continue to deliver grid services, either through existing or new projects, the market framework and regulatory treatment of this technology will need to evolve accordingly. Pumped storage should not be seen merely as a back-up generator or a provider of ancillary grid services, but as a resource that provides benefits across a whole spectrum of roles within local and regional water and energy systems.

Read more on pages 36-37.

The digital revolution

The global hydropower fleet is adapting to a new era of digitalised design, operations and maintenance. Digitalisation will be instrumental in helping to bring new efficiencies to clean energy generation.

Read more on pages 34-35.

Regional cooperation in power markets

Integrating electricity markets through regional interconnections helps countries use hydropower and other renewable energy resources more efficiently. The Nordic Power Market offers a blueprint for other world regions to follow.

Read more on pages 38-39.

Local capacity in sustainable hydropower

Capacity-building among local stakeholders and institutions supports the regional development of water and energy services, guided by international good practices in sustainability.

Read more on pages 40-43.

FASTEST GROWING COUNTRIES BY NEW INSTALLED CAPACITY IN 2018

China 8.54 GW

Brazil 3.87 GW

Pakistan 2.49 GW

Turkey 1.09 GW

Angola 0.67 GW

Tajikistan 0.61 GW

Ecuador 0.56 GW

India 0.54 GW

The Rogun hydropower project under construction in Tajikistan. Credit: PA Images.

Regional trends in brief

North and Central America

Hydropower remains the dominant electricity source across North and Central America, although year-on-year growth in hydropower installed capacity is the lowest on a global scale.

In 2018, 575 MW of conventional hydropower capacity was added in Canada, while the United States and Central America added a further 80 MW in 2018.

Canada has four major hydropower projects under construction, which will add another 2,900 MW of capacity over the next five years.

New legislation introduced in the US Congress formally recognises hydropower in the definition of renewable energy and facilitates a timelier process for new project approvals and existing project relicensing. The US Department of Energy has placed increased emphasis on grid reliability and flexibility attributes provided by pumped hydropower.

Several Central American countries, including Costa Rica, Guatemala and Panama, produce the majority of their electricity from renewable sources, largely due to hydropower.

Under the leadership of new President Andrés Manuel López Obrador, Mexico plans on significantly increasing hydropower generation by building new plants and rehabilitating existing facilities.

Read more on pages 52-59.

South America

South America was the second fastest growing region, adding 4,855 MW in installed hydropower capacity in 2018.

Brazil contributed 80 per cent of the region's added hydropower capacity and is the second fastest growing country in the world after China. Brazil has now overtaken the USA as the world's second largest country by installed hydropower capacity.

Climate variability has increased the need for regional interconnections to import electricity from countries with growing surpluses like Bolivia, and diversify renewable energy sources in countries such as Argentina and Chile.

There is increasing need for modernisation of ageing large hydropower infrastructure to extend asset life and boost electricity generation to cope with growing electricity demand.

Initially set to be commissioned in 2018, the 2,400 MW Ituango hydropower plant in Colombia suffered a three-year delay following a series of events in May that resulted in the untimely filling of the reservoir, affecting communities downstream. Steps have been taken to mitigate the damage and Hidroituango is progressing with project works.

In Brazil, a group of hydropower developers and operators formed the Forum for the Development of Midsize Hydropower Plants to strengthen private sector investments in hydropower.

Read more on pages 60-67.

Africa

Africa has the highest percentage of untapped technical hydropower potential in the world. 1,009 MW was added in 2018, bringing total installed capacity to 36.3 GW.

In 2018, Angola commissioned two more power generating units for the 2,070 MW Laúca hydropower station. Once fully operational in 2019, it will provide over 25 per cent of the country's electric installed capacity.

Several modernisation projects were completed in 2018, including the 300 MW Kariba South Bank expansion project in Zimbabwe, the 32 MW Mwadingusha plant in the Democratic Republic of Congo and the 36 MW Nkula project in Malawi.

In Uganda, construction of the 183.2 MW Isimba project was completed and it was commissioned in March 2019.

In Cameroon, the 200 MW Memve'ele project was completed, with the first 80 MW put into operation in April 2019.

Egypt inaugurated the 32 MW New Assiut Barrage project and contracts were signed for the 2,400 MW Ataqa pumped storage project.

The region's total hydropower installed capacity is expected to grow by over 40 GW over the next two to three years due to major new projects coming online.

Read more on pages 68-75.

Europe

As variable renewables continue their rapid growth, hydropower is increasingly recognised in Europe for its flexible services to maintain secure, affordable and sustainable energy supply.

Europe added an estimated 2.2 GW in 2018, including 384 MW of pumped storage, of installed capacity in 2018, bringing the total to 252 GW, including 57.4 GW pumped storage.

Turkey led the region in new installed capacity additions, adding over 1 GW at greenfield sites.

Austria added significant new and innovative pumped storage capacity to support wind and solar and overall system efficiency, including the 360 MW Obervermuntwerk II project.

Norway completed the 370 MW Lysebotn II project, which replaced its 210 MW predecessor. Iceland added 100 MW at the Búrfell II project, utilising existing infrastructure from Búrfell I.

In the Iberian peninsula hydropower generation recovered after a significant period of drought in the previous year.

In France, major projects under construction include the 92 MW Romanche-Gavet hydropower plant, and the 330 MW La Coche pumped storage plant, which will add a 240 MW turbine.

Read more on pages 76-83.

South and Central Asia

Installed hydropower capacity in South and Central Asia grew by almost 4 GW in 2018, continuing the growth trajectory from 2017.

India categorised large hydropower projects as renewable energy, which along with supporting measures, signifies a major step forward in national policy.

Pakistan's installed hydropower capacity grew by over 25 per cent in 2018 alone, as large-scale projects came online boosting grid supply capacity.

Tajikistan passed an important milestone with the construction of the Rogun hydropower project, as the first 600 MW unit entered into operation.

Across Central Asia, there is growing interest in regional interconnections and power markets for hydropower development, including bilateral agreements signed between BBIN countries (Bhutan-Bangladesh-India-Nepal) in South Asia, and construction of the CASA 1000 cross-border transmission project.

Modernisation programmes at large, older stations continued across Russia, Georgia and other Central Asian countries, with some rehabilitated units coming back into service in 2018.

Read more on pages 84-91.

East Asia and Pacific

East Asia and the Pacific again saw the highest annual increase in hydropower installed capacity in 2018.

9.2 GW was added last year, bringing total installed capacity across the region to over 480 GW. The region also accounted for over a third of the world's total hydropower generation.

Over 90 per cent of the added capacity came from China, including 1.5 GW from pumped storage, which increased its total installed capacity to 352 GW.

Significant activity took place in Myanmar where, after some delay, the government issued a notice to proceed for both the 1,050 MW Shweli 3 and the 60 MW Deeoke projects.

Cambodia took an important step forward in achieving its energy goals with the commissioning of the 400 MW Lower Sesan II project, the country's largest hydropower project.

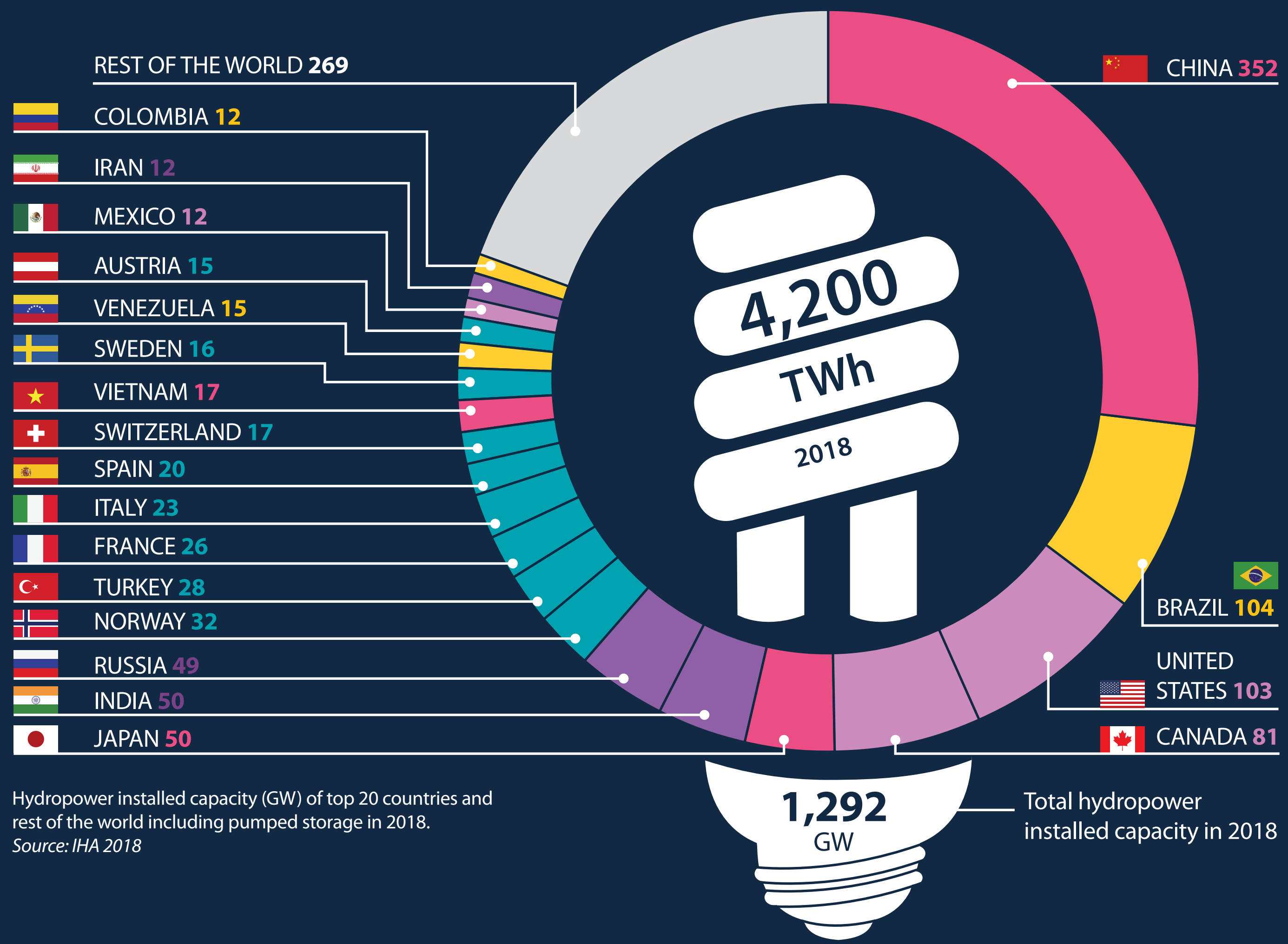
Australia continued to progress with the development of several pumped storage projects, with Snowy Hydro's 2,000 MW 'Snowy 2.0' project receiving the green light to proceed in early 2019.

Across the Pacific, in Fiji, the Solomon Islands and Samoa, a number of small hydropower projects are under active development.

Read more on pages 92-99.

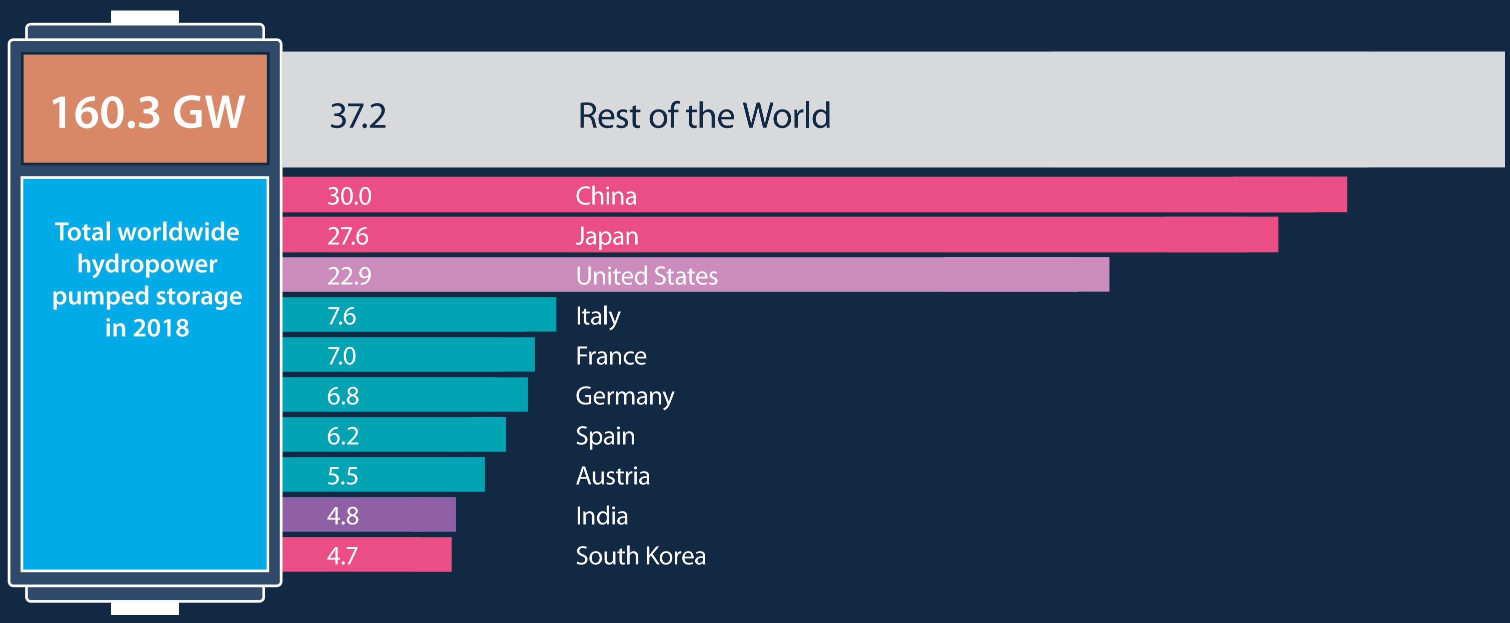
The Cambambe power station in Angola. Credit: Voith Hydro.

HYDROPOWER INSTALLED CAPACITY WORLDWIDE



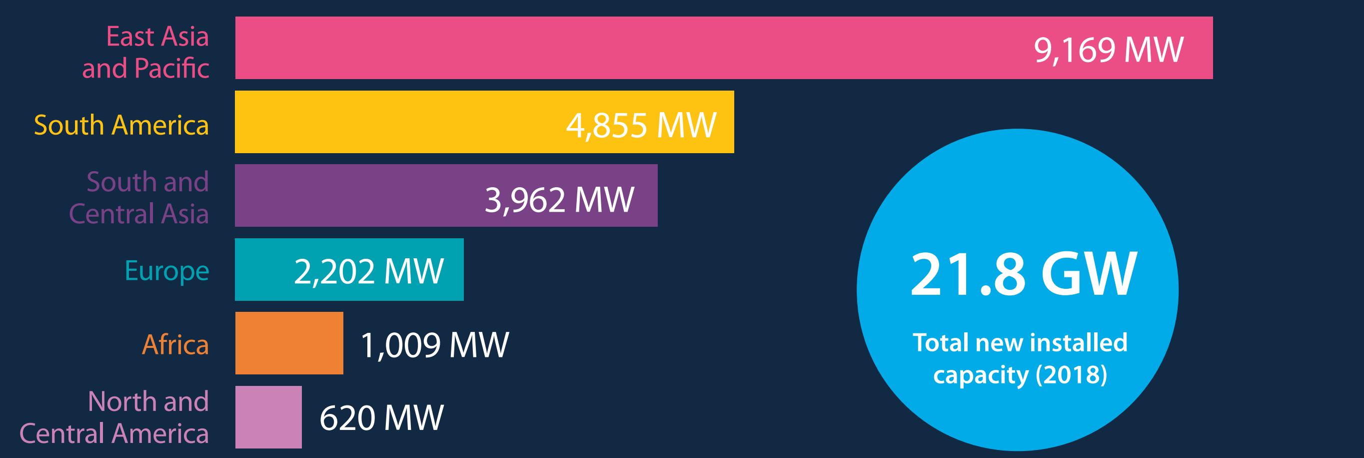
Hydropower installed capacity (GW) of top 20 countries and rest of the world including pumped storage in 2018.
Source: IHA 2018

PUMPED HYDROPOWER STORAGE WORLDWIDE



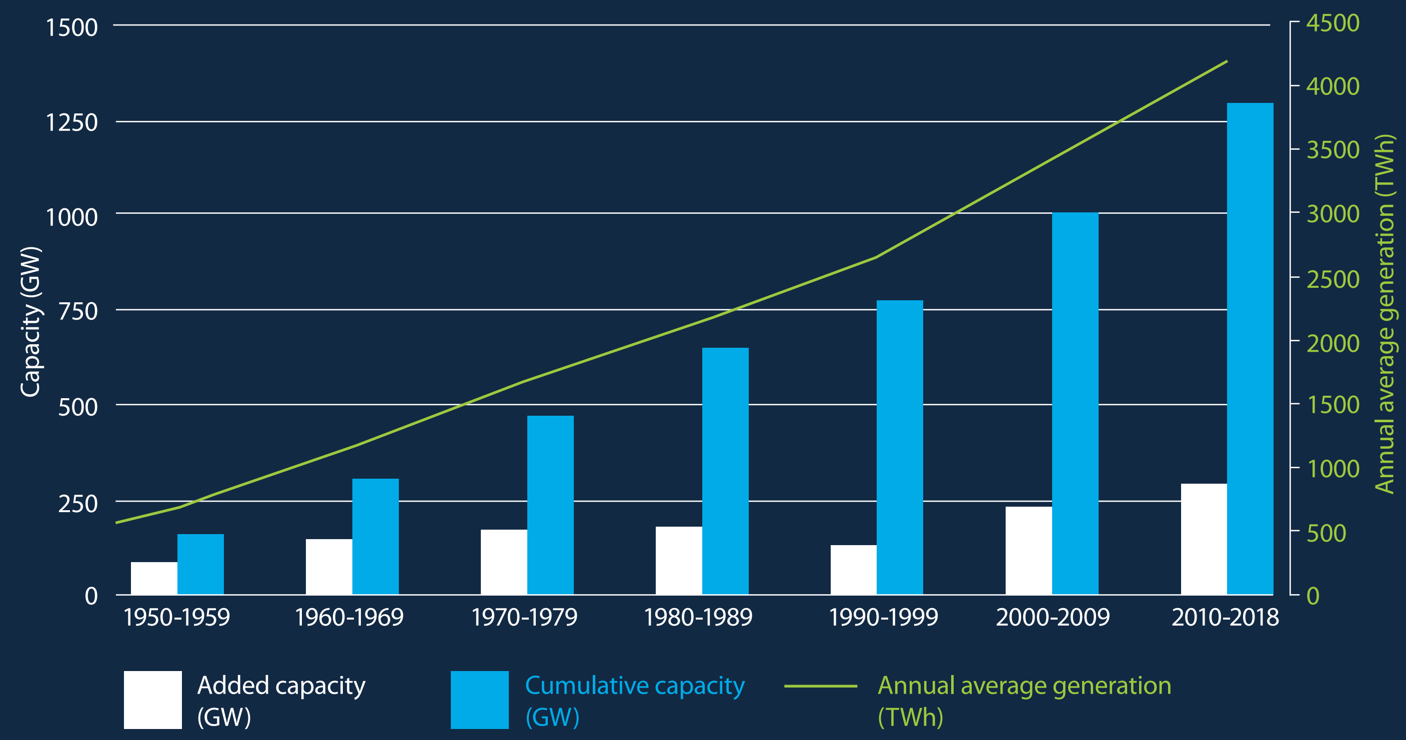
Pumped hydropower storage capacity (GW) of top 10 countries and rest of the world in 2018.
Source: IHA 2018.

NEW INSTALLED CAPACITY BY REGION (MW)



NEW INSTALLED CAPACITY BY COUNTRY (MW)

HYDROPOWER GROWTH THROUGHOUT THE DECADES



HYDROPOWER BENEFITS

Affordable and reliable energy
Hydropower is the lowest cost source of electricity generation in many markets, with a global weighted average cost of USD 0.05 per kWh for new hydropower projects (IRENA 2018).

Enabling solar, wind and other renewables
Hydropower supports growth in variable renewables such as wind and solar, meeting demand when these sources are unavailable.

Protecting from floods and drought
The storage infrastructure provided by a hydropower reservoir mitigates against the risks posed by climate change, including extreme weather events such as floods and drought.

Managing freshwater responsibly
Hydropower provides a vital means of safely managing freshwater, providing water supply for homes, businesses and agriculture.

Boost to economic growth and jobs
The hydropower industry employs a reported 1.8 million workers worldwide, and many more in connected supply chains (IRENA 2018).

Avoiding pollutants and emissions
Hydropower is a low-carbon technology which helps to offset the carbon emissions and pollutants caused by fossil fuels.

Improving infrastructure and waterways
Hydropower development delivers greater regional connectivity in distribution and transport networks.

Enhancing cooperation between countries
Long distance electricity transmission across national boundaries promotes strong inter-governmental cooperation.

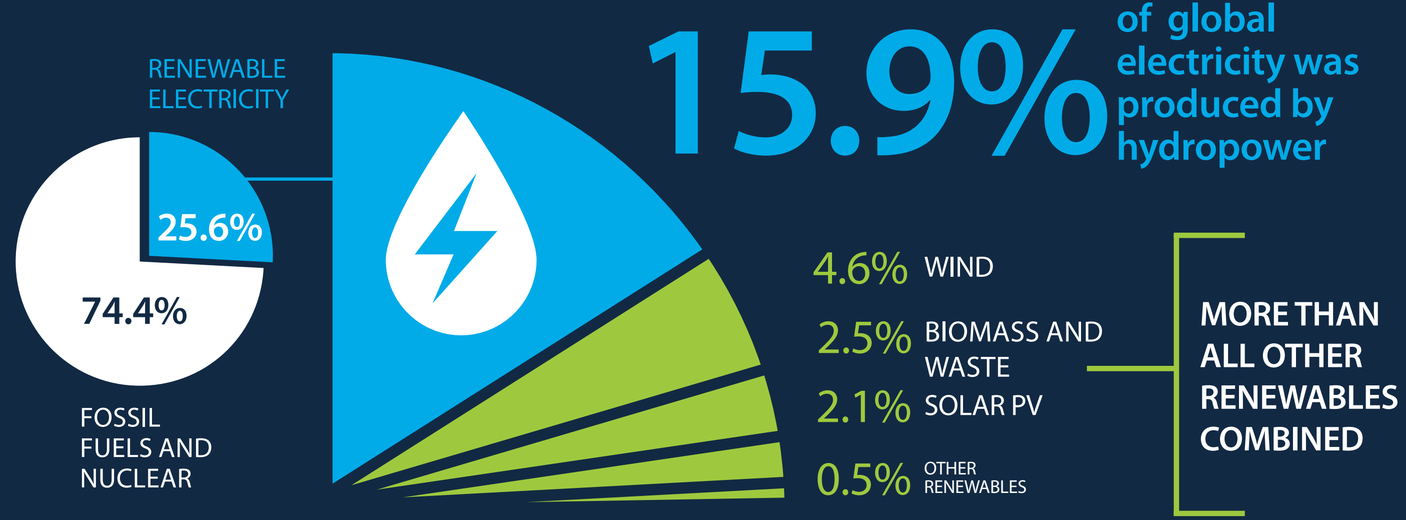
Community investments in rural areas
Hydropower development can bolster investment in local communities, including education, healthcare and other services.

Recreational activities and tourism
Hydropower reservoirs can offer regional development through the creation of tourism, recreational activities and fisheries.

ELECTRICITY GENERATION

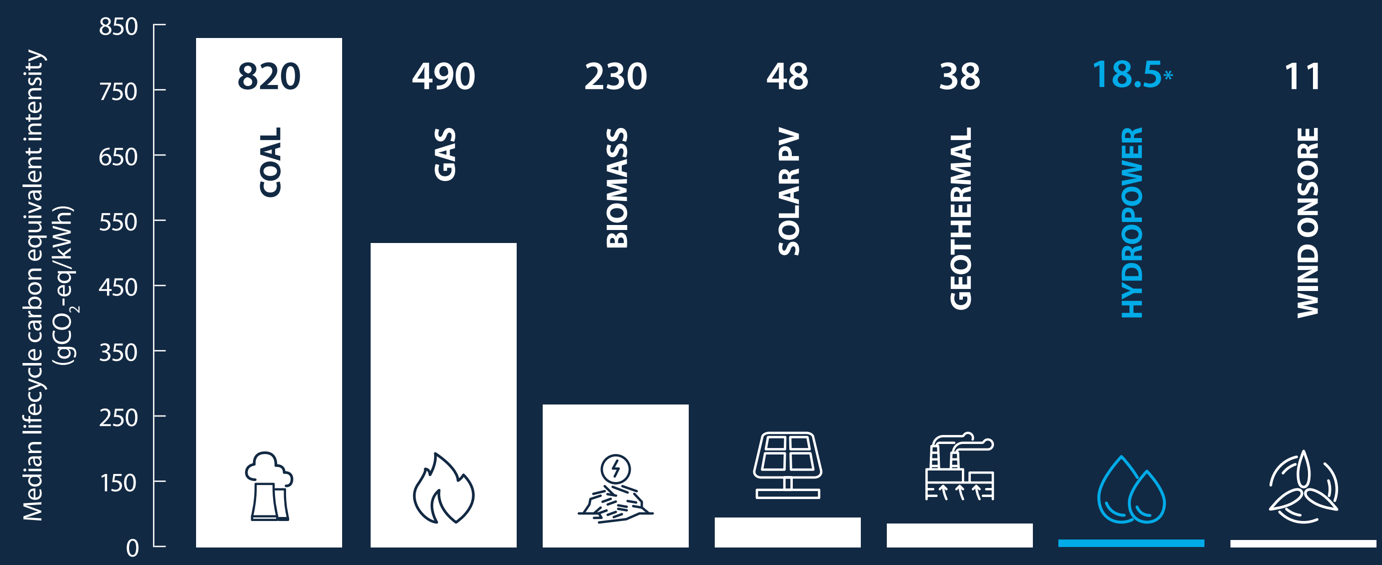
Source: IEA 2019

Hydropower is the world's largest source of renewable electricity generation



REDUCING EMISSIONS

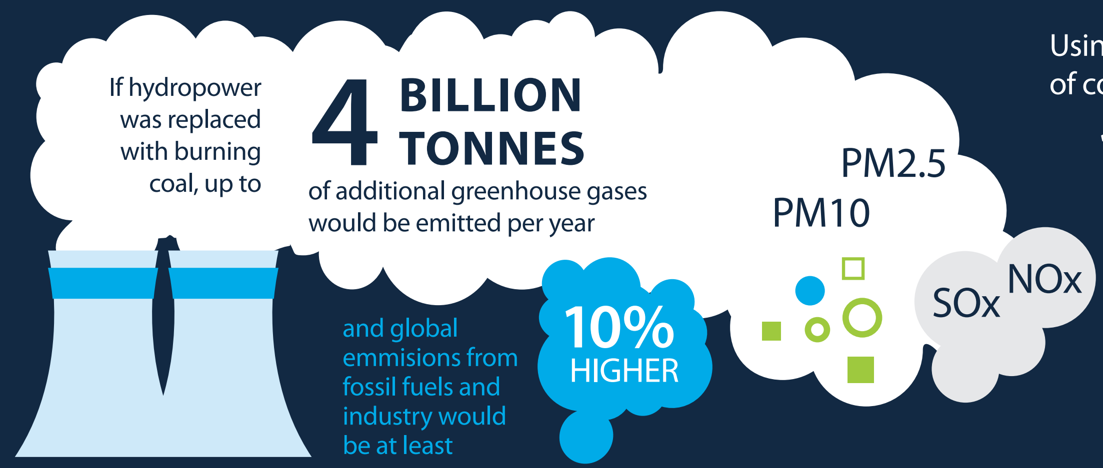
Source: IPCC 2014 / *IHA 2018



Hydropower has one of the lowest lifecycle GHG emissions per kilowatt hour among all energy sources

AVOIDING POLLUTION

Source: IHA 2018



Using hydropower instead of coal each year avoids:

148 million tonnes of particulates
62 million tonnes of sulfur dioxide
8 million tonnes of nitrogen oxide

View from Canada

Canada's clean energy priorities need hydropower

The Canadian government will work with international partners to promote opportunities for hydropower, eliminate barriers for renewable energy, and share best practices and benefits around the world, writes the Honourable Amarjeet Sohi, Minister of Natural Resources.

White Dog Falls Generating Station, Ontario.
Credit: OPG.

Caribou Falls Generating Station, Ontario.
Credit: OPG.

With its vast landmass and diverse geography, Canada has an abundance of renewable energy sources that are helping power our communities. That is part of Canada's natural advantage; we not only have abundant resources, we have the expertise and experience to develop those resources – sustainably and competitively.

Hydropower is a great example of that advantage. For close to 140 years, Canada has been developing its water resources to produce clean, sustainable, reliable and affordable electricity.

Hydropower generates tremendous economic opportunities and provides thousands of jobs in communities across the country – all the while helping to ensure low electricity prices for Canadians. In fact, six out of every 10 Canadian homes and businesses are powered by hydropower.

The industry has also built new partnerships by developing projects with indigenous communities that create new, long-term economic opportunities from coast to coast while helping to reduce reliance on diesel fuel in off-grid, rural and remote communities.

Hydropower is at the forefront of our energy transformation

In 2017, our government launched Generation Energy, a nationwide conversation on Canada's energy future. More than 380,000 individuals participated, including experts, industry stakeholders, and indigenous people. Their views were heard and included, and the final report outlines four clean energy paths to Canada's energy future – including the use of more renewable energy like hydropower.

Canada is well on its way to realising this vision and hydropower is at the forefront of our energy transformation. Currently, six Canadian provinces and territories generate more than 94 per cent of their electricity from renewable sources. This creates opportunities for more trade in clean electricity between provinces and territories, while boosting our economy, creating jobs and protecting our environment.

We are also using technologies that improve the reliability, resiliency and flexibility of our new renewables-sourced energy systems. This technology will allow us to increase our energy security and provide consumers with a wider range of energy choices.

For all of these reasons, our government sees a bright future for Canada's hydropower industry – at home and abroad. We will continue with international partners to promote these opportunities, eliminate barriers for renewable energy, and share best practices and benefits around the world.

View from Indonesia

Indonesia promotes hydropower to create the demand for industrial development

The Indonesian government's strategy for hydropower development aims at boosting industrial growth, reducing carbon emissions and achieving energy independence, writes Honourable Bambang P. Soemantri Brodjonegoro, Minister of National Development Planning.

Electricity infrastructure plays a pivotal role in development. It provides and conveys energy for increasing prosperity and encouraging economic activities. Indonesia's National Long-Term Development Plan 2005-2025 mandates the fulfilment of reliable and efficient electricity supply according to needs and increased access to equitable energy services.

The National Energy Policy (NEP) 2014-2050 underlines the principles of fairness, sustainability and environmental protection in achieving national energy independence and security. The government targets at least 23 per cent in 2025 – and 31 per cent in 2050 – the portion of new and renewable energy in our national energy mix.

As part of the G20, Indonesia has ratified international agreements in the field of environmental protection, especially in reducing CO2 emissions. Under the Paris Agreement, Indonesia has committed to reduce GHG emissions by 29 per cent in 2030 from "business as usual". Therefore, a reduction in the use of fossil fuel energy by increasing and promoting the use of new and renewable energy is critical.

Until 2017, the total installed capacity of national power plants reached around 60.8 GW. PLN, the Indonesian state-owned electricity company, generated around 41.7 GW (68.6 per cent), and independent power producers and other providers generated around 19.1 GW (31.4 per cent). Based on the type of energy source, hydropower plants (including mini hydro and micro hydro) produced around 5.45 GW (8.8 per cent). The biggest hydropower potential is located in Papua Island (22.4 GW), Kalimantan Island (21.6 GW), Sumatera Island (15.6 GW) and Sulawesi Island (10.2 GW), while Java-Bali is 4.2 GW and Nusa Tenggara-Maluku is 1.1 GW.

If we consider the requirements of our industrial zones or specific economic zones, electricity demand will be drastically increased. For example, domestic demand in Kayan-North Kalimantan is only 60 MW but when the industrial zone is developed, demand will increase to 1,000 MW. This demand could be covered by the hydropower plant on the Kayan River which has potential to deliver up to 6,000 MW.

In the Draft of the National Mid-Term Development Plan 2020-2024, the strategy for hydropower development is to be changed to not just follow demand, but to create demand. Timika in Papua, Konawe in Sulawesi and Kayan in North Kalimantan regions are examples of potential locations for increasing demand. In these areas mining activities and industrial smelting could be supported by hydropower projects with a large capacity. The goal is to increase the competitiveness of industry by creating low cost electricity.

It is expected that the private sector can participate in projects as independent power producers through Public Private Partnership (PPP) schemes. PPP schemes themselves continue to undergo transformation in their implementation in Indonesia, marked by the issuance of Presidential Regulation No. 38 regarding cooperation between government with business entities in providing infrastructure.

The Government of Indonesia has formulated several policies for incentivising the private sector in the development of renewable energy. Namely: developers can obtain a 5 per cent reduction in the income tax rate for their investment each year for a period of six years; accelerated depreciation of fixed assets can be completed within ten years; the income tax on dividends for foreign investors is at 10 per cent; and import duty exemptions for equipment and machinery that cannot be produced in Indonesia.

It is expected that these various policies could accelerate the development of hydropower sustainably and create a big impact in our economic development. The critical point in developing hydropower is making sure that the project is ready and attractive for investment. Thus, the comprehensive assessment of social, technical, economic and environmental aspects should be promoted.

We look forward to cooperating more productively with the International Hydropower Association (IHA) to accelerate the development of hydropower in Indonesia.

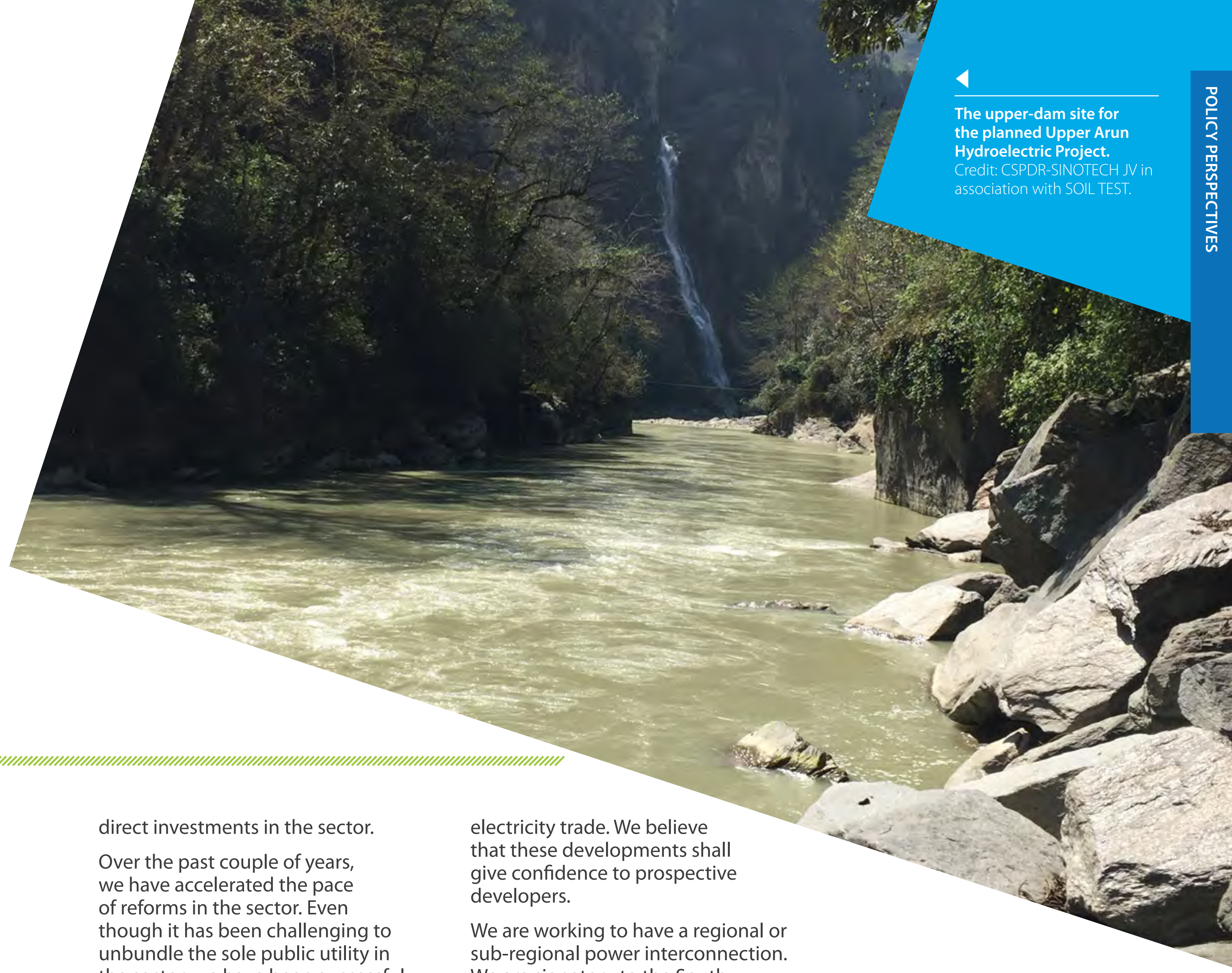
> The critical point in developing hydropower is making sure that the project is ready and attractive for investment

▲ **The weir of the 56 MW run-of-river Semangka hydropower plant in Sumatra, Indonesia.** Credit: Voith Hydro.

View from Nepal

Ensuring access to affordable, reliable and sustainable energy

Nepal's government is seeking to attract investment in the country's vast hydropower resources, while exploring regional energy interconnections, as a way of reducing reliance on fossil fuels, increasing off-grid access, and reaching middle-income status, writes H.E. Barsha Man Pun, Minister of Energy, Water Resources and Irrigation.



The upper-dam site for the planned Upper Arun Hydroelectric Project. Credit: CSPDR-SINOTECH JV in association with SOIL TEST.

In Nepal, after having enabled a political environment with a new constitution and the formation of government at federal, provincial and local levels, overall economic development is now the foremost priority. The present government's campaign for a 'prosperous Nepal and happy Nepali' cannot be realised without the complete economic transformation of the country. Energy, being the key driver for economic development, has become the main area of focus for the government. We are committed to adequate energy production and supply of electricity to achieve the accelerated double-digit growth of the Nepalese economy.

Nature has bestowed enormous hydropower potential, of about 83 GW, on us. Of this about 42 GW is deemed technically and economically feasible. We have been able to develop about 1.1 GW of installed capacity with a few pondage run-of-river projects and numerous run-of-river projects. The storage facility of Nepal's power system accounts only for 92 MW. On the brighter side, with the encouraging involvement of the private sector, around 2.5 GW of installed capacity is actively undergoing construction by prospective independent power producers. Out of these, around 2.4 GW is expected to be online within the next four years.

In the energy mix for the year 2016, the total energy produced was around 13 million tonnes of oil equivalent (MTOE), out of which the majority, around 66 per cent, came from fuel wood. The contribution of energy from renewables and electricity accounted for little over 6 per cent. For our energy requirement for the year 2050, estimated at around 17 MTOE, we intend to source 33 per cent of it from electricity and renewables next to 34 per cent from fuel wood and biomass. Thus, we foresee a substantial dominance of electricity and renewables in the projected energy mix for the target year 2050.

The Government of Nepal has set targets in the power sector for the next ten years. In five years, we intend to provide access to 100 per cent of the population through a mix of grid and off-grid systems. In the meantime, we are implementing several transmission and distribution system reinforcement projects to provide reliable electricity services to the people. The government is considering distributed electricity generation through micro-hydro, solar, and wind as complementary to the strengthening and expansion of the grid electricity distribution system.

The optimum exploitation of hydropower resources with seasonal and daily storage capacities along with the use of locally available renewable energy sources like solar and wind will be the key factor for a stronger and stable energy mix. This will greatly reduce our heavy dependence on imported fossil fuels through substitution with clean and renewable energy sources. By the next ten years, we are planning to develop 10,000 MW of generation for domestic consumption alone, with another 5,000 MW for cross-border trading.

We have initiated a programme, 'Nepal's Water - Citizen's Investment', through which we aim to mobilise financial resources from the public as an equity share for hydropower development, creating opportunities for people's participation, and to develop a sense of ownership in hydropower development. Investment that can be generated within Nepal is limited, so is the case for debt as domestic lending is inadequate for the development of larger projects. This clearly points to the need for foreign direct investments in the sector.

Over the past couple of years, we have accelerated the pace of reforms in the sector. Even though it has been challenging to unbundle the sole public utility in the sector, we have been successful in creating a generation company and a transmission grid company. Seven distribution companies are now being planned to function in different provinces. Legal instruments are already in place for the formation of a regulatory mechanism in the electricity sector through which the Electricity Regulation Commission will become functional very soon.

One of the basic policies of the government is to promote private investments in the power sector. To that end, we have investor-friendly regulations which treat national and foreign parties on par. We have been successful in opening up opportunities for accessing neighbouring power markets beyond our political borders. The Power Trade and Transmission Interconnection Agreement with India and understandings reached with China as well as with Bangladesh for cooperation in the power sector have laid the foundation for cross-border electricity trade. We believe that these developments shall give confidence to prospective developers.

We are working to have a regional or sub-regional power interconnection. We are signatory to the South Asian Association for Regional Cooperation (SAARC) Framework Agreement on Energy Cooperation, and also party to the understanding reached for the establishment of the Bay of Bengal Initiative for Multi-Sector Technical and Economic Cooperation (BIMSTEC) Grid Interconnection. Eventually, such sub-regional or regional interconnections should help us to optimise our power systems and lower operating costs.

We envision Nepal to be an enterprise-friendly middle-income country by 2030. We are populated by a vibrant and youthful middle-class with absolute poverty in the low single digits and decreasing. Under this overarching vision, Nepal is continuously pursuing to meet, among others, the target of Sustainable Development Goal 7 which deals with ensuring access to affordable, reliable, sustainable and modern energy for all.

> In five years, we intend to provide access to 100 per cent of the population

View from Uganda

Access to electricity is inextricably linked to socio-economic transformation

The Government of Uganda is committed to the sustainable development of its hydropower resources. Like many countries in Africa however, Uganda faces challenges in raising investment capital and enhancing local technical and management capacity, writes Honourable Minister of Energy and Mineral Development Irene Nafuna Muloni.

Uganda's President Yoweri Museveni plants a tree during an inauguration ceremony for the Isimba Hydropower Plant in March 2019. Credit: PA Images.

Access to clean energy in general and electricity in particular is an essential input in the growth and economic, social and political development of a country. Electricity is inextricably linked to socio-economic transformation at individual household and business levels, as well as at aggregate national level.

As a critical input in the development process, electricity consumption has multiplier effects on the economy. For a country to have adequate and reliable electricity supply that matches demand, it calls for deliberate policies and efforts to plan and develop electricity generation capacity based primarily on national natural energy resources.

According to the International Energy Agency's World Energy Outlook report of 2018, hydropower is the largest renewable electricity generation resource, meeting about 16 per cent of global electricity demand, followed by wind, solar PV and bio-energy. This trend is expected to continue in the medium term which therefore calls for sustainable development and utilisation of the hydropower resource.

For Uganda, the development of hydropower dates back to 1947 with the first two hydropower plants being commissioned in 1954 – the Owen Falls plant, now Nalubaale, with a capacity of 150 MW, and Mobuku I with a capacity of 5 MW which was to supply electricity to the copper mines of Kilembe in western Uganda. Over the last three decades, there has been significant growth of power demand in Uganda, averaging 8 per cent per annum. The majority of this demand has been met by the construction of additional hydropower generating plants which included: the refurbishment of Owen Falls dam and increasing its capacity to 180 MW, and the development of Kiira (200 MW), which was commissioned in 2000, Bujagali hydropower plant (250 MW), commissioned in 2012, and a number of small hydropower projects totalling 107 MW.

The key challenges for hydropower development in Uganda, and most countries in Africa, include the need for substantial up-front investment capital which cannot easily be raised by the sector, as well as environmental and social concerns such as the resettlement and compensations of persons affected by the projects, and inadequate local implementation experience and technical capacity.

Additionally, hydropower is sensitive to the climate driven hydrological cycle thus necessitating proper management of the river catchment areas. The prolonged drought experienced in Uganda between 2003 and 2007 led to a decline in hydropower generation of over 60 per cent, thus necessitating the deployment of expensive thermal power to reduce load shedding which had negatively impacted our economic growth.

To address the challenge of financing, the Government of Uganda put in place an Energy Investment Fund which enabled us to commence the construction of Bujagali hydropower plant as we awaited financial closure. The 250 MW Bujagali hydropower plant was developed under a public-private—partnership arrangement with Bujagali Energy Limited (BEL). The plant tremendously reduced our reliance on expensive thermal power. Additional investment capital has been attracted through bilateral financing with our development partners. The challenge of inadequate technical capacity has been addressed by putting in place a local content policy to ensure the participation of Ugandans during construction of the projects. The National Environment Management Authority (NEMA) is in place to ensure that resettlement and environmental issues are well addressed during the development of these projects.

To ensure that we develop our hydropower resources in a sustainable manner, in 2010 the government undertook a hydropower development master plan study. The study targeted sites above 50 MW mainly along the River Nile. The objective of the study was to prepare a master plan that is in line with the long-term power and transmission development plan. The hydropower master plan prioritised potential hydropower sites based on technical, environmental, economic and financial aspects, to prepare preliminary designs thereof, and to build government capacity in this field.

In line with the hydropower master plan, the government is fast-tracking the development of the identified hydropower sites. We are currently implementing two key flagship hydropower projects namely, Isimba (183.2 MW) and Karuma (600 MW). Other large hydropower plants being packaged for development include Ayago (840 MW), Orianga (392 MW), Uhuru (350 MW) and Kiba (290 MW). Regarding small hydropower projects, the current policy is that their development is undertaken by the private sector. The Renewable Energy Feed-in Tariffs (REFiT) are in place to promote investment in small hydropower and other renewable power projects.

The current contribution of hydropower in Uganda's electricity generation mix is 87 per cent. This figure will go up to 92 per cent once Karuma is commissioned. Hydropower is a key component in electricity generation expansion plan in line with our Vision 2040 strategy.

There is still over 2,000 MW of hydropower that is yet to be developed. Hydropower will therefore continue to play a critical role in providing electricity in Uganda in the medium term because of a number of benefits, such as its proven technology, high efficiency, low operation and maintenance costs, high flexibility, ability to be designed with a large storage capacity to cater for peak time demand, and due to its high reliability. For example, the Nalubaale hydropower project has been providing electricity to Uganda for the past 65 years and has the lowest tariff in the energy mix.

Therefore, for Uganda to achieve sustainable development, the hydropower resources that remain untapped will have to be developed so as to bring to fruition plans aimed at increasing access to electricity and per capita electricity consumption, and to contribute to the achievement of the Sustainable Development Goals.

Hydropower will continue to play a critical role in providing electricity in Uganda

View from Uruguay

The role of hydropower in the commitment to sustainable development

Almost 100 per cent of Uruguay's electricity is generated from hydropower and other renewable resources. Hydropower's role is not just historic, writes Honourable Minister of Industry, Energy and Mining Dr Guillermo Moncecchi, it will continue to provide a platform to develop non-conventional renewables and achieve sustainable development.

The Salto Grande Hydroelectric Complex on the Uruguay River between Argentina and Uruguay.

Although the discussion between historians and linguists over whether the country´s name in guaraní, Uruguay, refers to the 'river of snails' or the 'river of birds' is not settled, there is no doubt that etymologically, the name of this country shows a close link to the natural resource water. This link has a technical correlation, the first hydroelectric plant in South America, Cuñapirú Dam, was inaugurated in 1882 in association with a mining enterprise in Uruguay, and kept in operation until 1918.

At the beginning of the twentieth century, Uruguay reinforced this commitment, commissioning studies that concluded with the construction, around the middle of the century, of three hydroelectric plants. Those generation plants, together with the implementation of a binational dam with Argentina, have allowed Uruguay to be among a group of countries with both the largest installed capacity and hydroelectric generation per capita in the region.

Recent studies carried out by the Latin American Energy Organization, OLADE, show that, while at a Latin American level 25 per cent of potential generation capacity is effectively operative, this indicator exceeds 85 per cent in the case of Uruguay. All of the above shows that Uruguay has developed its hydroelectric resource at an early stage, practically reaching its large-scale operation capacity. As a consequence, its historical electric mix presents sustainability indicators that are more than satisfactory in international terms.

However, the impact of hydroelectric generation on the sustainability of the Uruguayan electricity mix does not end there, but presents two additional dimensions. On one hand it is the base on which, more recently, Uruguay has carried out a very dynamic incorporation of sources of non-conventional renewable energies. On the other hand, the construction of the binational power plant has been the driver for the development of regional interconnection infrastructure, a very valuable component to progress in the integration of other non-manageable sources of renewable generation.

Thus today, Uruguay, based on the execution of its energy policy, presents a ratio of approximately 1:1 between hydroelectric and wind power generation capacity (in fact internationally, Denmark, Uruguay, Portugal and Ireland, in that order, have the largest share of wind resource in the electricity mix). In addition, generation capacities from biomass and photovoltaic solar are developed.

As a result of this process, today our country shows with satisfaction that, in average terms in the last years, 98 per cent of electric energy has come from renewable sources and 99.8 per cent of the population has access to electric power. The share of hydroelectric energy in the electric mix is approximately 50 per cent in an average year, which complements 27 per cent of electricity generated from wind, 18 per cent from biomass, 3 per cent from solar power and approximately 2 per cent from thermal power plants using fossil fuels.

Simultaneously, Uruguay has changed the role that it traditionally occupied in the region as an energy sink, and since 2013 it has continued without interruption to be a net exporter of electricity to Argentina and Brazil. Additionally, in the short term, the possibility of advancing the electrification of other uses by orienting a surplus of renewable generation opens additional opportunities to the decarbonisation of other sectors of the economy in which it is more challenging to achieve transformation.

Between 2014 and 2017, a study was conducted on the complementarity of renewable sources and the demand for electrical energy, which evidenced, on one hand, a strong complementarity between hydroelectric and solar resources. On the other hand, it identified that by managing energy storage or demand it is possible to eliminate or significantly reduce the inclusion of new thermal generation plants in the next 30 years. Among other technological alternatives that could contribute to reach this objective, are pumped storage power plants. Uruguay is currently working actively in the assessment of alternatives aimed at the accumulation and management of demand. It advanced in the identification of potentially useable sites in the medium term for the location of plants that allow for the daily variability of energy demand.

In this context, our commitment to the future of the development of small-scale hydroelectric plants is not only compliant with the United Nations' Sustainable Development Goal (SDG) 7, but also responds to the water-food-energy nexus initiative through the promotion of new multi-purpose power plants destined for irrigation crops and drinking water for consumption by the population, which also include the possibility of electricity generation. The implementation of these new ventures does not only improve the sustainability of the energy sector, but also responds to the need for adaptation of a key sector of our economy in a country that, with 3.5 million inhabitants, produces food for more than 30 million people in the world.

In short, hydroelectric power in Uruguay has not only had a relevant role in the past, ensuring the sustainability of the electricity mix, but also in the present, acting as a platform to develop non-conventional renewable energies, redoubling the commitment to comply with the SDGs.

Hydroelectric power in Uruguay has not only had a relevant role in the past, but also in the present

- Gain international recognition
- Join a global network of leaders
- Help steer hydropower's future

iha
international hydropower association

Recognising your experience

Become a Fellow Member

If you are a highly experienced hydropower professional, you can apply to become a Fellow of the International Hydropower Association (IHA).

Fellow members join a network of hydropower leaders whose expertise is internationally recognised. As a Fellow, you will receive special invitations to IHA events and help to steer the sector's future development.

Fellow members are entitled to use the letters 'F.IHA' in their professional title. To qualify, you must have at least five years' experience in a senior management position in the hydropower sector or have 10 years' experience in a specialist field relating to hydropower. Applicants must be endorsed by two professional referees.

To learn more, please visit:

hydropower.org/fellow-iha

The Kruonis Pumped Storage Plant in Lithuania.
Credit: Lietuvos Energija.

Hydropower trends in focus

Analysing the multiple services provided by hydropower projects

A new research study by IHA shows the multiple power and non-power services provided by hydropower projects are often under-reported. Greater research is needed to identify and quantify these benefits and factor them into decision-making processes.

Overview

Single-purpose and multi-purpose hydropower projects deliver a range of power and non-power benefits to society and the environment. Over and above electricity generation, power-related benefits include flexible generation and storage, as well as reduced dependence on fossil fuels and avoidance of pollutants.

In addition, hydropower projects support local businesses, create employment and improve livelihoods. Projects deliver investment in transportation, education and health services, tourism and recreation, while boosting national macroeconomic growth and opportunities for trade. Communities also benefit from safely managed water for homes, industry and agriculture, and flood and drought mitigation.

A hydropower project designed and built for a single purpose will often find multiple other uses over its long lifetime. In order to analyse and quantify some of the often underreported benefits of hydropower, the International Hydropower Association (IHA) has undertaken a global study to analyse available databases that account for these additional services.

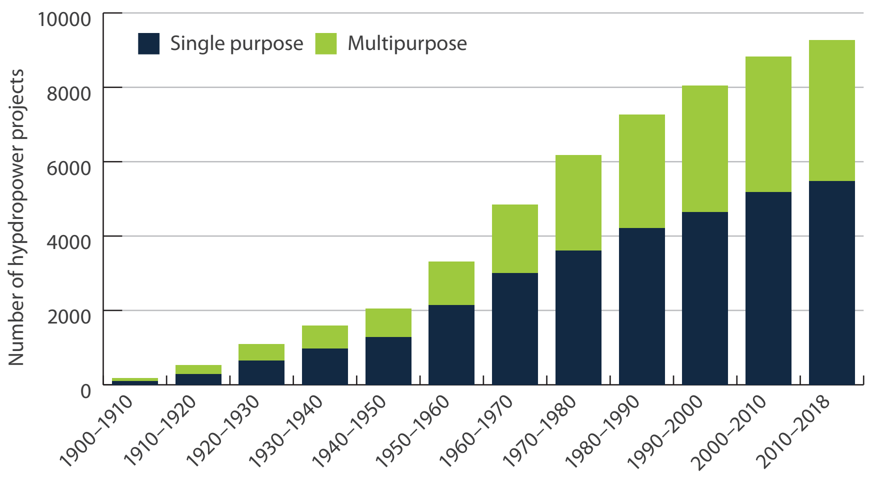


Figure 1. Cumulative number of hydropower projects (data from IHA / ICOLD)

Multi-purpose analysis

The majority (81 per cent) of the world's 51,512 existing large dams are single purpose according to the International Commission on Large Dams (ICOLD). ICOLD defines a large dam as having a height of 15 metres or greater from the lowest foundation to crest or between five metres and 15 metres impounding more than three million cubic metres.

Irrigation accounts for the most common single-purpose dam type (29 per cent), followed by hydropower (10 per cent) and flood control (5 per cent), excluding the 38 per cent of dams recorded as having an undefined purpose.

This study by IHA analyses 9,266 hydropower stations worldwide, of which, according to ICOLD, 40 per cent are multi-purpose and 60 per cent single purpose. Figure 1 shows the evolution of single and multi-purpose hydropower projects from 1900 to 2018.

Trends and evolution

Between 1950 and 1980, the number of newly commissioned multi-purpose hydropower projects doubled, with the highest rate of development of single-purpose hydropower dams occurring between 1950 and 1980. Between 1970 and 1980, 55 per cent of commissioned hydropower projects were multi-purpose.

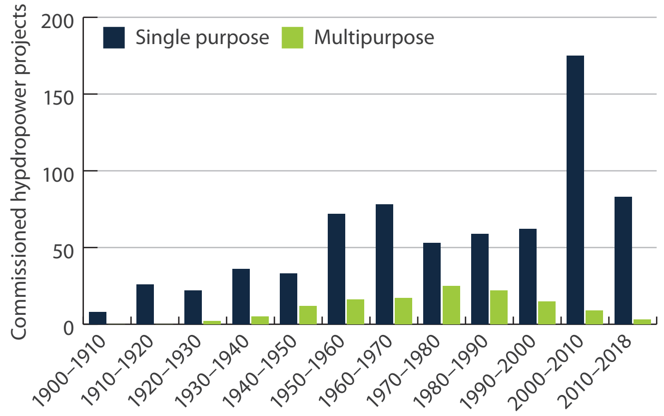


Figure 2. Growth of single and multi-purpose hydropower projects in South America (data from IHA / ICOLD)

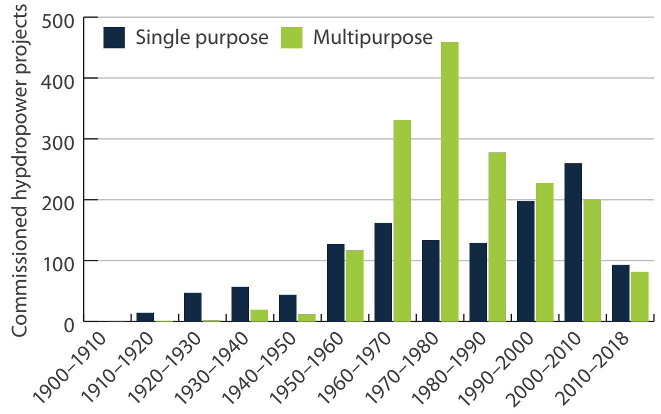


Figure 3. Growth of single and multi-purpose hydropower projects in South & Central Asia (data from IHA / ICOLD)

The global trend varies across geographical regions. Multi-purpose hydropower projects predominate in South and Central Asia, whereas South America has the lowest percentage of multi-purpose dams. Figure 2 and Figure 3 show decadal evolution growth by region for single and multi-purpose hydropower projects in South America and South and Central Asia.

Benefits provided by hydropower projects

From a macroeconomic perspective, multi-purpose hydropower projects provide many investment benefits over single-purpose projects. However, the complexity in planning, funding and implementing multi-purpose dams is a major challenge. This is due to the inherent complexity of dealing with multiple stakeholders, the need for a sustainable business model for financing, operations and maintenance, as well as the management of unforeseen risks and negative externalities.

In particular, diverging interests among different users can result in complex and potentially vulnerable contract structures. Conflicts can emerge in relation to the operation of the reservoir (i.e. if divided for water storage for divergent objectives or if water use patterns vary depending on the purpose) and project financing, as attracting private investors for a multi-purpose project is more challenging.

Nonetheless, a dam designed for a single purpose often becomes multi-purpose by practice. In many cases, this evolution does not allow the optimum realisation of project benefits. For example, the Kariba Dam, in the Zambezi river basin between Zambia and Zimbabwe, was commissioned in 1962 as a single purpose hydropower project, but the dam is now also used to irrigate over 2,700 ha of land, and provides fisheries, transportation, recreation and tourism with 17 hotels in the surrounding area. None of the databases IHA examined in this study reflect these additional services, provided at Kariba, nor for many other dams around the world.

Both single and multi-purpose hydropower projects provide a wide range of services and benefits to promote the sustainable development of the communities they serve. In many cases, these benefits were not taken into account in the design phase and later on are difficult to account for.

IHA hydropower database

Due to the need to better understand the range of services provided by hydropower projects, whether or not these services were anticipated in the design phase or emerged later after construction, this study undertook an in-depth analysis of the IHA Hydropower Database. This is the world's most comprehensive and up-to-date hydropower database, holding information on more than 12,000 operational stations globally.

This study looked at Ecuador, in South America, and considered 37 hydropower projects that account for 99 per cent of the country's hydropower installed capacity. Only 12.5 per cent of these projects were designed as multi-purpose. Information on additional benefits was gathered from 16 stations that account for 88 per cent of Ecuador's total hydropower installed capacity. The majority of these stations were commissioned in the last two decades, where only two out of the 16 were designed as multi-purpose.

The environmental and social investment programmes developed for these projects support close to one million people. These programmes include improved water quality, water supply and treatment, environmental conservation and irrigation, improved sewage systems, education, employment, and health opportunities, and increased electricity, capacity building, and tourism. Ecuador's Daule Peripa hydropower project, for example, has been essential in supporting population growth, especially in Guayaquil, where it is the main water supply source for its two million habitants.

Future research

More in-depth research is needed to identify and quantify hydropower project services, both power-related and non-power related, and factor these into decision-making processes, particularly at the project design phase.

IHA will continue working to raise awareness and share good practices about the additional services and benefits of well designed and responsibly managed hydropower projects. IHA will also continue to expand our Hydropower Database to quantify hydropower's contributions to energy and food security, as well as to the livelihoods of people in affected communities.

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Building climate resilience in the hydropower sector

IHA's new Hydropower Sector Climate Resilience Guide will provide a practical way forward to manage climate risks and incorporate resilience into proposed and existing hydropower projects.

Background

As a low carbon technology, hydropower produces almost two-thirds of the world's renewable electricity and will make a significant contribution to achieving the targets of the Paris Agreement and the Sustainable Development Goals. While offering countries protection against impacts exacerbated by climate change such as floods and drought, hydropower projects can also be susceptible to climate risks due to their dependency on precipitation and runoff.

Failure to adequately consider climate risks may lead to shortcomings in technical and financial performance, safety and environmental protection. In addition, investment decisions may not adequately recognise the role of hydropower infrastructure in providing climate adaptation services.

To facilitate the development of hydropower infrastructure that can withstand variable climatic risks, the International Hydropower Association (IHA), together with a range of partners, prepared a Hydropower Sector Climate Resilience Guide with the objective of providing practical and systematic guidance for hydropower engineers and project owners to develop climate resilient projects.

A pathway to informed decisions

To be launched at the World Hydropower Congress on 15 May 2019, the Hydropower Sector Climate Resilience Guide aims to address a need to provide international good practice on assessing climate change risks and to incorporate climate resilience into hydropower project planning, design and operations.

The guide seeks to evolve from defaulting to the use of only historical data and the assumption that hydrological variability will remain the same over the lifetime of the project,

> "The World Bank is pleased to support an industry guide for climate change resilience."
> - Pravin Karki, Global Lead for Hydropower and Dams, WBG

as well as the limited knowledge of how best to access, use and interpret climate change modelling and observed climate data. This approach neglects consideration of short- and long-term impacts that climate change may have on investments, due to the high uncertainty inherent in climate change projections.

The guide is designed to take users through a six-phased approach to incorporate climate resilience into hydropower project appraisal, design, construction and operation, resulting in more resilient hydropower project development and operation.

It is intended as a resource for project owners, financial institutions, governments and private developers, who will utilise the guide to make informed decisions in the development, rehabilitation and operation of hydropower projects. These stakeholders and decision-makers include:

- Project owners, developers and operators – managers responsible for the planning, development, design, construction and operation of hydropower projects to consider climate risks in new and existing hydropower projects.
- Policy-makers – officials in governments and national agencies looking at water and energy planning and regulatory aspects who may use the guide as a framework to evaluate systems risks.
- Financial institutions – project leads involved in the financing of new projects or major rehabilitation and upgrade of existing hydropower projects that request a climate risk assessment as a requirement for financing.

Development and consultation

The development of the Hydropower Sector Climate Resilience Guide was coordinated by IHA and developed with technical and financial support from the European Bank for Reconstruction and Development (EBRD) and the World Bank Group with funding from the Korea Green Growth Trust Fund.

The process began in 2015 with a workshop co-organised by the World Bank and IHA on the resilience of hydropower and dams to climate change and natural disasters. After consultation with multiple stakeholders a beta version was developed by the Mott McDonald consultancy, under contract with the World Bank, and released in September 2017.

During 2018 and early 2019, EBRD and the World Bank supported IHA members and hydropower developers and operators involved with new and existing hydropower projects around the world in piloting the beta version of the guide to check its applicability and practicality.

Testing and piloting the guide

Testing experiences from the pilot projects – representing reservoir and run-of-river projects of different scales including greenfield, rehabilitation and operating assets – were shared in a technical workshop in London in January 2019.

At the workshop, seven pilot projects from around the world presented their practical experiences of testing the beta version of the guide. The consensus view was that a single guide should provide a standardised approach for hydropower projects at any stage of their lifecycle, with the participants exploring challenges relating to performance metrics, risk thresholds evaluation, and reporting of results.

The technical workshop was a significant milestone towards developing the Hydropower Sector

> "We see financing hydropower as being indispensable to the clean energy transition, but we really must think about a project's resilience to the impacts of a changing climate when investing in the sector" - Dr Craig Davies, Head of Climate Resilience Investments, EBRD

Climate Resilience Guide, following which IHA worked with an advisory expert panel to integrate the feedback into the final version.

A tool for financial disclosures

Climate related financial disclosure is rapidly becoming a legal requirement for companies in many parts of the world. Increasingly, hydropower companies will be expected to disclose to regulators, investors and shareholders how such risks are being managed including measures to build resilience.

The guide will become highly relevant for hydropower operators and investors seeking robust ways of demonstrating the climate resilience of hydropower projects. In addition, it will facilitate assessments of climate risks and resilience measures required by financial institutions' emerging rating systems.

Aligned with sustainability tools

The Hydropower Sector Climate Resilience Guide complements the Hydropower Sustainability Guidelines on Good International Industry Practice (HGIIP), which define expected performance for the hydropower sector across a range of environmental, social, technical and governance topics, including climate change mitigation and resilience.

The guide also supports assessment tools used to measure project performance, such as the Hydropower Sustainability Assessment Protocol (HSAP) and the Hydropower ESG Gap Analysis Tool (HESG). These tools are used to examine whether a project is climate resilient and so, by following the guide, hydropower projects are more likely to achieve good assessment scores.

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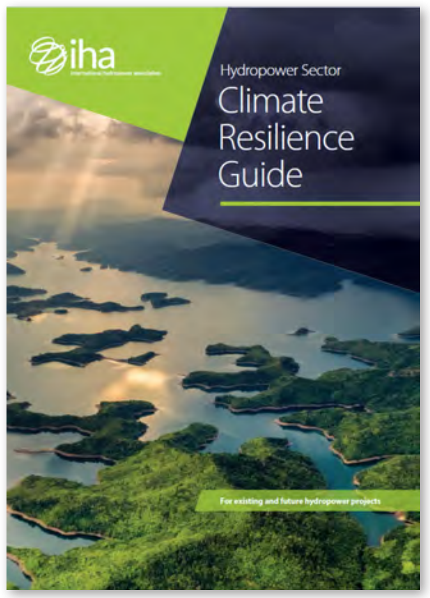

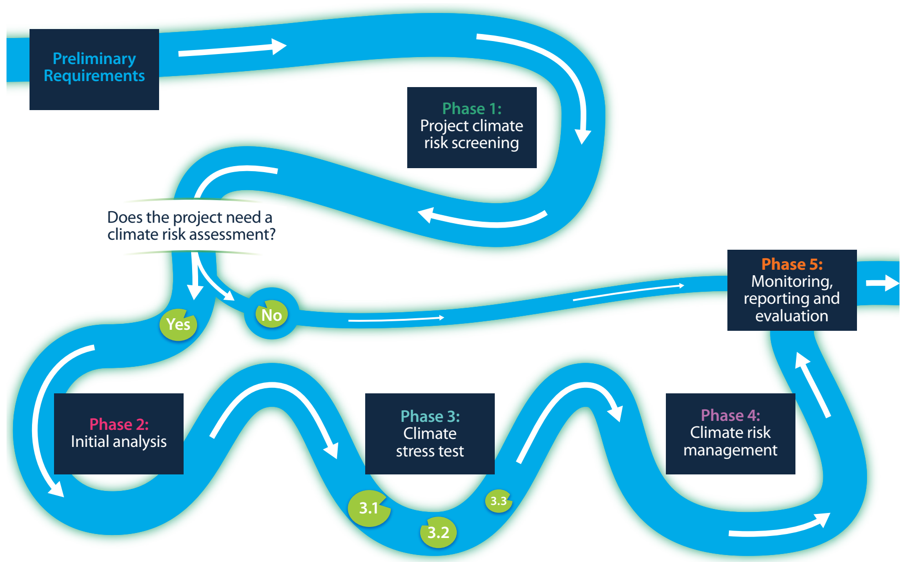

Adapting to the new era of digital hydropower design and operation

A growing proportion of the global fleet of hydropower assets is transitioning to digitalised systems and processes. This revolution in the way hydropower projects are designed, operated and maintained will ensure hydropower is well positioned to meet its role in the clean energy future.

The Salto Grande hydropower complex on the Uruguay River between Argentina and Uruguay is undergoing a modernisation programme.

Digitalisation has been part of the hydropower sector for decades with some of the earlier hydropower utilities pioneering the use of computers to manage and operate the electricity grid. Today, digitalisation covers a spectrum of systems and processes from design and construction to operation and maintenance (O&M), as demonstrated in Figure 1.

The early stages of planning and designing modern hydropower developments are now digitised by converting drawings and plans into data to create a computer model, known as a 'digital twin' of the plant, allowing multiple use scenarios and configurations to be simulated.

Enhanced digital control systems can improve the performance of turbines and generators, helping to extend the lifetime of a hydropower facility. Operations and maintenance can be optimised and costs reduced using advanced performance monitoring analytics, while maintenance processes can be improved through automatic key performance indicator (KPI) tracking and benchmarking.

Condition monitoring is becoming increasingly sophisticated with the advent of digital sensing technologies coupled with artificial intelligence. Smart condition monitoring and diagnostics can detect component failures or deterioration of equipment before they happen, by remotely collecting data and analysing it to improve diagnostics on faults. Innovative solutions such as the use of drones for asset and environmental inspections add another element to advanced condition monitoring.

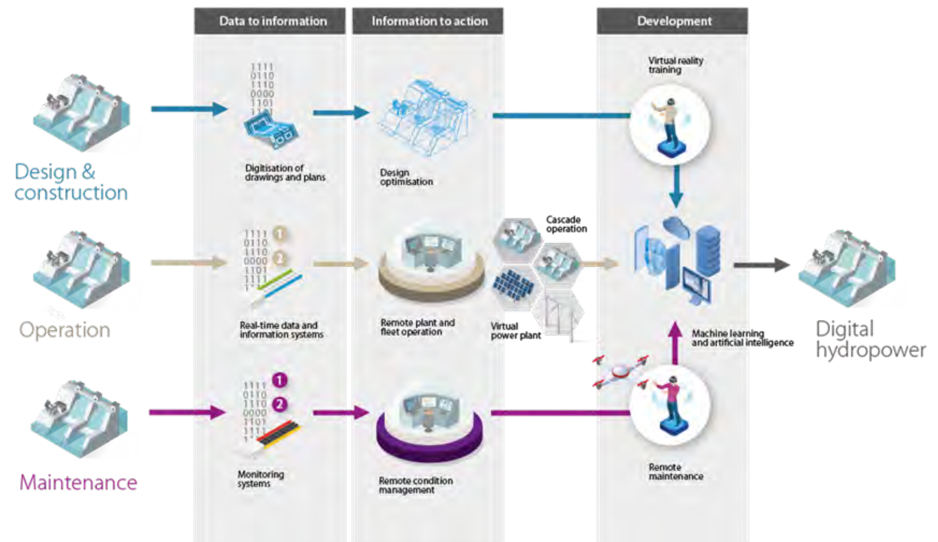

Figure 1. A schematic of hydropower digitalisation

Enabling other renewables

Around the world, digitalisation is being integrated into modernisation programmes for existing hydropower assets to ensure that increased flexibility and added cyber-security protections are replacing outdated analogue systems, and to improve overall workforce allocation with the use of remotely operated stations and centralised O&M for cascade systems.

The digitalisation of hydropower systems will also allow traditional hydropower systems – both pumped hydropower storage (PHS) and conventional hydropower – to work together with other renewable resources, by providing increased flexibility and enhanced control for ancillary services.

At the Salto Grande hydropower complex on the Uruguay River, a binational project operated by the governments of Argentina and Uruguay, an ongoing modernisation programme is rolling out digital control systems to adapt to new conditions such as an increasing share of variable renewable generation from wind and solar power. The multi-year digitalisation programme seeks to optimise performance through greater integration between operation and maintenance, with the initial phase focused on improving communications, protection systems and monitoring of the infrastructure, while the latter phases will include increased cyber-security, and further performance optimisation through integration of dispatch, generation and integrated water management.

In the Iberian peninsula, EDP Portugal is providing a new asset management platform at 56 hydropower units, which will extend the turbine operating range and support predictive analytics and advanced performance modelling. EDP is working closely with GE to implement new intelligent monitoring systems in 12 hydropower plants to enhance real time signal processing with high resolution data. In addition, EDP's digitalisation programme will include an asset optimisation pilot programme.

Emerging challenges

The process of digitalisation for hydropower assets will need to go beyond digital controls and digital systems for planning and operating at the station level. At the power system level, operators and markets will need to adapt to faster-reacting, more flexible operating regimes with digital technologies.

To some extent, the advent and application of new digital technologies throughout the entire energy sector, while improving production and efficiencies and facilitating flexible operation of utility-scale power systems, has also created increased 'entry points' for security breaches. To that end, the industry is responding with improved and much more secure IT/OT interconnections to provide additional protection, as well as cyber-security monitoring and rapid response systems to detect malicious attackers and restore systems.

Consultation with stakeholders in the industry has identified other challenges for utilities undergoing the digital transformation. Digitalisation can in some cases result in staff re-deployment, through remote operations and automated processes. In addition, developing local skills and expertise on new digital systems will often require training and knowledge transfer from experienced operators.

As the most mature and reliable source of renewable electricity, both existing and new hydropower projects are being prepared to meet even greater challenges on the road towards a clean energy future, and digitalisation is the means by which it will get there.

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Lake Cethana was recently named as one of the most promising sites for pumped hydropower storage in Tasmania, Australia.
Credit: Hydro Tasmania.

Securing the future for pumped hydropower storage projects

While we are witnessing renewed interest in pumped hydropower storage as a technology to ensure grid stability, many markets around the world have been slow to recognise its value to the clean energy transition.

As one of the central pillars of power grid flexibility, energy storage is a vital component of the energy transition. The significant increase in variable renewable energy (VRE) sources like wind and solar coupled with their displacement of conventional generators is putting increasing pressure on power grids. Energy storage technologies offer great potential to support renewable energies and power grids by absorbing and releasing energy when required and providing ancillary services that help maintain grid security and stability.

Pumped hydropower storage (PHS), the world's 'water battery', has provided storage and flexible power services to grids since the beginning of the twentieth century. Accounting for over 94 per cent of installed global energy storage capacity, and over 99 per cent in terms of energy stored, PHS also retains several advantages over other forms of storage including lifetime cost, levels of sustainability and scale.

Pumped storage technologies and operations have demonstrated their ability to respond to the new grid requirements incurred by the increasing deployment of VRE. PHS projects are reacting quicker, more often and at wider ranges to the higher magnitude and frequency of the fluctuations in supply and demand. But while technology and operations have kept pace, regulatory and policy frameworks have resisted change, putting the financial viability of some PHS projects at risk.

Much like the development of conventional hydropower, securing favourable financing arrangements for PHS is a challenging task, which needs to be tailored for each project. While a mature and trusted technology, PHS projects face a long gestation and payback period with high upfront capital costs. However, unlike conventional projects, with PHS it can be difficult to accurately forecast revenues derived from energy arbitrage, and many of the ancillary services provided are still not adequately remunerated, if at all, in many markets.

The vast majority of PHS projects in operation today were commissioned and financed under public ownership, often by vertically integrated utilities that enjoyed a monopoly status due to owning and operating all the generation, transmission and distribution assets.

Many of the projects under development today are still delivered under similar market structures, which points to deficiencies in how some liberalised markets are incentivising development and rewarding their services. The failure to provide the required certainty and clarity in policies and regulations in markets can deter investment in new projects and upgrading existing facilities. There are considered to be three broad classes of revenue models for PHS projects: 'cost-of-service', 'direct participation' and 'behind-the-meter'. In some circumstances, a mixture of models can be employed to optimise revenue streams:

Cost of service

Cost-of-service is a model where a facility is compensated via a regulated arrangement, whereby it is able to recoup its operating cost plus an agreed rate of return on its capital costs. This is commonly used by monopoly operators overseen by a state regulator. Variations of the model are used in China as payment or tariff mechanisms for PHS facilities (the majority owned by transmission and distribution companies) which reflect their value across the power system. In unbundled liberalised markets, regulators have tended to restrict bulk energy storage facilities, such as PHS, from benefiting from this model for fear that they would also seek revenue from the competitive part of the market and therefore gain an unfair advantage.

Direct participation

Direct-participation is the competitive part of a liberalised market in which PHS operators compete with other market participants. Revenue can be generated in several ways, specific to each market and they often need to be combined, known as 'revenue stacking,' to make a project financially viable. However, this can be challenging due to the differing operating demands required for each stream.

Energy arbitrage

Arbitrage is the main source of revenue for many PHS projects and involves using electricity to pump water during periods of low demand and off-peak prices, and generating when there is high demand into the spot market reflected by higher peak prices (i.e. shortage in supply to meet demand). The spread or difference in price between pumping and generating also needs to take into consideration the project's round-trip efficiency and other costs such as grid charges.

Forecasting revenue for arbitrage can be extremely difficult given the lifespan of projects. It requires detailed modelling which needs to account for potential changes in market dynamics and the regulatory environment, all of which impact market prices. For example, Germany's renewable energy policies have brought online large amounts of subsidised solar and wind which has significantly reduced-price differentials. In turn, this has negatively affected the profitability of existing PHS plants, and reportedly diminished the prospects of new investments. PHS developers must also take into account to what extent their own project will smooth prices and therefore impact their revenue derived from arbitrage. In today's markets, energy arbitrage alone is generally considered to be insufficient to warrant investment.

Long-term contracted revenue

Developers enter into Power Purchase Agreements (PPAs) or similar contracted arrangements with credit worthy off-takers (i.e. energy retailers, industrial customers or governments) and the nature of such agreements can determine the operating model of the facility.

For example, a project could act as an insurance product (known as 'cap contracts') for off-takers to guard against high price events. An extension of this is the capacity market mechanism which is designed to ensure sufficient and reliable supply is available across an entire market by providing payments (whether or not they are dispatched) to encourage investment in new capacity or for existing capacity to remain operational. Several governments around the world, including the United Kingdom, have established this mechanism resulting in mixed success for PHS due to the policy's preference for less-capital intensive projects and their inability to provide sufficiently long contracts. Capacity markets can also minimise energy price volatility which further reduces the ability of PHS to profit from arbitrage. Finally, innovative new products in some markets are seeing flexible technologies generate revenue for their firming function. These 'firming products' could involve wind or solar generators purchasing the dispatch rights to a PHS facility to firm up their supply in order to always meet their contracted obligations such as through PPAs. There are many variations on this that are also possible.

Ancillary services

These non-energy services such as frequency control and system restart can be provided and contracted to system operators, commonly via a tendering process. While some electricity markets around the world are offering opportunities for these services due to the need to integrate increasing VRE, for certain services such as inertia their true monetary value and contribution to the system is not yet fully understood and rewarded. Inertia will be vital for grid stability into the future as the share of coal and gas-fired generation decreases in a number of markets as they have traditionally provided this service for free. It should be noted though that as greater PHS and other forms of flexibility enter the grid, all offering similar ancillary services, it is expected that competition in this market will drive down prices.

Behind-the-meter generation

Behind-the-meter generation is when a project is located on the generator, consumer or end user side of the electricity meter and is undertaken for a variety of reasons, such as to improve supply reliability and to avoid peak electricity prices and grid charges. A hybrid model can involve the PHS facility being used for internal purposes while also offering services into the competitive electricity market to improve its viability.

Summary

Pumped hydropower storage has proven to be an essential component for modern and future clean energy systems. However, if PHS is to continue to deliver its vital services, either through existing projects or new greenfield projects, the market framework and regulatory treatment of this technology will need to evolve accordingly, particularly in liberalised markets.

Pumped storage should be seen not as just a back-up generator or a provider of ancillary grid services, but as a resource that provides benefits across a whole spectrum of roles within local and regional water and energy systems.

Further reading:

IHA working paper: The world's water battery: Pumped hydropower storage and the clean energy transition (2018).

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Regional interconnections

Energy cooperation in the Nordic power market

Integrating electricity markets through regional interconnection helps countries use hydropower and other renewable energy resources more efficiently. The Nordic Power Market offers a blueprint for other world regions to follow.

The Nordic countries host one of the world's most advanced cross-border electricity systems, integrating Norway, Sweden, Finland, Denmark and the Baltic states into a common regional market, and also reaching into mainland Europe. Nord Pool, which runs the Nordic Power Market, provides an overview of the benefits of interconnection and the role of hydropower in the region.

Nordic interconnection

For the last 30 years, investments in the Nordic regional system have generally focused on transmission infrastructure rather than new generating capacity. This has resulted in a high level of regional interconnection between Nordic states under a synchronised transmission grid, and high voltage interconnectors to the European and Baltic transmission systems.

In Norway, in particular, investments in interconnectors have almost quadrupled over the last 20 years, thanks to coordinated planning across the Nordic and European markets. Only until recently has there been renewed focus on adding new generating facilities, with the advent of green certificates for renewable energy.

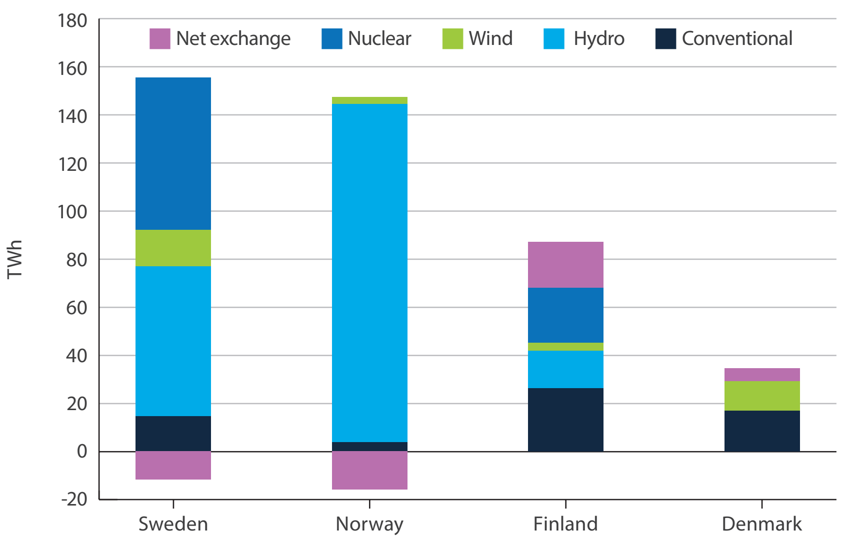

Figure 1. Nordic annual electricity generation in 2016 by source (source: Eurostat)

Key facts: Nordic regional power market

Location: Northern Europe, including Norway, Sweden, Finland, Denmark, Baltics and others
Project stage: Operational
Start date: 1996 first regional power exchange (started as Norwegian national market in 1993)
Energy volume traded: 524 TWh total volume traded in 2018
Summary: Regional cooperation in the Nordics has resulted in a well interconnected electricity system. Today, the Nordic Power Market supports regional trading of hydropower and other energy sources, improving system costs, efficiencies and security of supply for participating countries. Nord Pool is often referred to as the 'blueprint' model for Europe.

Several major interconnection projects are also currently under construction to further strengthen the country's regional links. This includes the NordLink between Norway and the Netherlands, two interconnections to Great Britain (North Sea Link and NorthConnect), the VIKING cable from Denmark to Great Britain and the COBRA cable project from Denmark to the Netherlands.

Generation mix

Generation in the Nordics is dominated by hydropower, along with contributions coming from nuclear, conventional thermal and wind. Figure 1 charts out the annual generation balance for Sweden, Norway, Finland and Denmark in 2016, and gives the breakdown of each energy source. The graph also shows the net electricity exchanges (in red) highlighting that the main hydro producers, Norway and Sweden, were also net exporters to the neighbouring countries.

Nordic Power Market

After power sector reforms in the 1990s, the Nord Pool market started operating in Norway in 1993 and with the inclusion of Sweden in 1996 became the first regional power exchange globally. Nord Pool has since supported competitive power exchange among Nordic states, and has extended this service to the Baltic states and Great Britain. Today, Nord Pool's day-ahead market acts as the cornerstone for the Nordic Power Market, where power is auctioned daily together with transmission capacities on an implicit basis. In general the market aims to maximise socio-economic benefits across the region, by reducing daily power prices and also enabling capital investments in the energy system to be planned at the regional scale.

Mutual benefits of hydropower and interconnection

Regional interconnections give countries the capability to access diverse energy resources and use hydropower more efficiently. For example, at times, low-price hydropower from Norway can leverage out wholesale prices across the market, while also providing flexibility to other power systems in the region – especially towards Denmark with its high penetration of wind power.

Figure 2 illustrates how regional interconnections in the Nordic region support greater use of hydropower under seasonal conditions (wet and

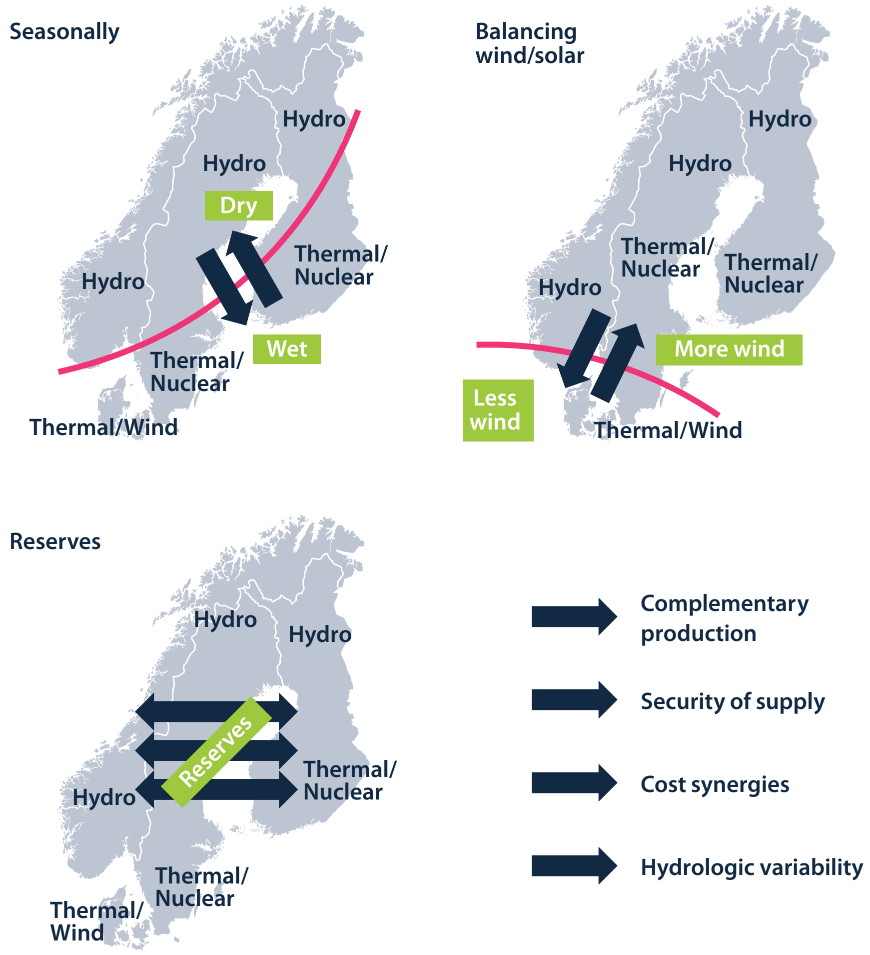

Figure 2. Examples of the benefits of regional interconnections. Credit: Nord Pool Consulting.

dry) or situations under low and high wind power conditions in Denmark, and as a complementary energy reserve to thermal power assets. In this way, the system improves energy security through regional cooperation, and develops greater resilience in the face of challenges from variable renewable resources and climate variability.

Summary

As shown in the Nordic experience, a regional market has the potential to provide significant benefits such as:

- Allowing a region to operate on a multilateral basis maximising their overall social welfare.
- More efficient utilisation of a region's energy resources, for example connecting countries with surplus generation to neighbouring countries with deficits.
- Helping utilities in the region to balance their excess supply and demand, improving access to energy services, and reducing the overall cost of infrastructure.
- Reducing the need for investment in power reserves to meet peak demand, therefore lowering operational costs while achieving a more reliable supply.
- Attracting additional investment into the region's interconnection by providing a price signal for investors.
- Accelerating the development and integration of renewable power capacity into a region.

This Nordic regional power market case study was provided by Nord Pool Consulting and is from a forthcoming compendium of case studies to be published by IHA on the benefits of and lessons learned from regional interconnections involving hydropower.

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Building national capacity to advance sustainable hydropower

Capacity-building among local stakeholders and institutions supports the regional development of water and energy services, guided by international good practices in sustainability.

The Cahora Bassa hydroelectric scheme in Mozambique was assessed under the Hydropower Sustainability Assessment Protocol as part of IHA's capacity-building programme.

In the context of hydropower, capacity-building is viewed as the development of local resources, physical and intangible, to improve the understanding of good practice in hydropower policy-making, development and operations.

In this light, an effective capacity-building programme looks to increase the impact and long-term sustainability of a hydropower project by strengthening normative and institutional capacity, particularly in developing countries which face major resource constraints. This requires engagement with a range of stakeholders including regulators, developers, project owners, as well as project-affected communities.

Capacity-building programmes delivered by the International Hydropower Association (IHA) in the Zambezi river basin, in Myanmar and in Indonesia during 2018 provide three examples of successful multi-stakeholder capacity-building programmes aimed at supporting the adoption of good practices in sustainable hydropower.

Basin-level development to address regional energy demands

Africa's fourth largest river basin, the Zambezi, offers vast hydropower resources that hold the potential to support social and economic development and improved livelihoods across southern Africa.

The river basin's technical potential of nearly 15,000 MW in installed hydropower capacity could prove sufficient to meet the estimated combined electricity demand of Angola, Botswana, Malawi, Mozambique, Namibia, Tanzania, Zambia and Zimbabwe – known collectively as the Riparian States.

Using the Hydropower Sustainability Assessment Protocol (HSAP) as a guiding reference, IHA and the World Bank partnered with government agencies and local organisations to assist the Riparian States in developing and utilising the basin's hydropower resource in a sustainable and responsible way.

The 2018 assistance programme consisted of a series of assisted self-assessments using the HSAP across the river basin, followed by an official assessment of the existing Cahora Bassa hydroelectric scheme in Mozambique using the protocol's 'operation stage' assessment criteria, and involved consultations with local community members.

Participants from a range of operators and water resource managers, including Hidroeléctrica de Cahora Bassa, the Zambezi River Authority and ZESCO, learned how to apply the methodology and principles enshrined within the HSAP to their hydropower projects.

Early stage decision-making to enhance performance

The Indonesia capacity-building programme, funded by the Swiss State Secretariat for Economic Affairs, was geared towards strengthening local institutional resources through assisted self-assessments and trainings.

The approach included an official early stage assessment of the Pelosika hydropower project and extensive capacity-building through pre-assessment training of relevant government and local government officials. The project incorporated local prospective assessors into the assessment team at Pelosika under the supervision of international accredited assessors, and also involved engagement with nearby communities.

A core group composed of selected staff from the Indonesian Ministry of National Development Planning, the Ministry of Energy and Mineral Resources, the Ministry of Public Works and Public Housing, and the State Electricity Company PLN attended training sessions on using the HSAP for sustainability assessment, which strengthened the internal capacity of national institutions. The core group participated in the HSAP 'early stage' assessment, which provided key members of staff with first-hand experience of assessment activities covering preparation, auditing, reporting and presentation of results.

High-level workshops were used to share assessment results with government stakeholders, allowing them to judge the value of the HSAP as an evidence-based decision-making tool. The events were a vehicle to raise awareness of international good practices, and to address specific interests, such as climate-aligned financing, and social and environmental safeguards.

Strengthened capacity to guide practitioners and policy-makers

The Myanmar capacity-building project was funded by the Norwegian Agency for Development Cooperation (Norad) and focused on building institutional capacity through a series of workshops, trainings and self-assessments. It began with a workshop for government representatives, which analysed how the assessment protocol could be used by the relevant departments to judge compliance with national laws and international standards.

A second IHA workshop introduced the HSAP to broader hydropower stakeholders at the national level. IHA assisted staff from the Ministry of Electricity and Energy to assess the Tha Htay hydropower project. The assessment was intended to identify areas for improvement, resulting in an action plan drafted to address identified issues at the project, portfolio and policy level.

The work in Myanmar concluded with a workshop to share the findings of the project. These activities contributed to Norad's overarching goal to increase the development impact and sustainability of hydropower.

> "Indonesia is on the path to installing an additional 15 GW of hydropower capacity and 65 multipurpose dams by 2025. The implementation of the Hydropower Sustainability Assessment Protocol during the Pelosika dam project's early stage was an important milestone, which has led to more effective multi-stakeholder participation and better project preparation." - Pak Abdul Malik, Director for Irrigation and Water Resources at Bappenas

Lessons learned and recommendations

The three capacity-building programmes were judged to have made an important contribution to the responsible management of water resources in the target areas. Through a structured process of training, assisted assessments, and tailored workshops, hydropower practitioners and government representatives developed the skills to understand and implement international good practice in sustainable hydropower and efficient water and energy resource management.

All three programmes provided evidence that using the 'early stage' and 'preparation stage' of the HSAP as self-assessments early in project development is beneficial. These self-assessments help operators prevent potential impacts and improve the overall performance of hydropower assets.

Overall, the programmes underlined a broader need for improving awareness internationally of what constitutes good practice in hydropower development, with stakeholders expressing support for tools that enhance capacity building and increase sustainability performance at all stages of a hydropower project's life cycle.

Further reading:

Application of the Hydropower Sustainability Assessment Protocol in the Zambezi River Basin, World Bank (2019).

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Sustainability

Hydropower Sustainability Tools

Hydropower plays a vital role in reducing the world's dependence on fossil fuels. As a renewable energy, it is essential that hydropower is developed sustainably.

IHA has played a leading role in the development of recognised sustainability guidelines and tools, working together with a range of partner organisations.

We serve as the management body for the Hydropower Sustainability Assessment Council, whose 100 members include representatives of social and environmental NGOs, intergovernmental organisations, development banks, governments and hydropower companies and contractors

As part of this role, we serve as a custodian of the Hydropower Sustainability Tools, which provide a framework for understanding and measuring hydropower project performance.

We also oversee the training and accreditation of independent project assessors, and deliver capacity-building programmes in developing countries.

Sustainability Guidelines

The Hydropower Sustainability Guidelines on Good International Industry Practice (HGIIP) define expected sustainability performance for the hydropower sector across a range of environmental, social, technical and governance topics.

The 26 guidelines present definitions of the processes and outcomes relating to good practice in project planning, operation and implementation. As a compendium, the guidelines are a reference document for meeting the expectations of lenders, regulators and consumers.

Developed for a range of stages in the lifecycle of a hydropower project, compliance with each guideline can be specified in commercial contracts between financiers and developers, and developers and contractors.

Launched in December 2018, the guidelines are aligned with standards developed by the World Bank, International Finance Corporation (IFC) and the Equator Principles group of banks.

Each guideline is hydropower-specific and designed to support assessments of project performance using either the Hydropower Sustainability Assessment Protocol or HESG Tool.

Assessment Protocol

The Hydropower Sustainability Assessment Protocol (HSAP) was developed through 30 months of cross-sector engagement between 2007 and 2010, and a review of IHA's previous sustainability tools, the World Commission on Dams Recommendations, the Equator Principles, the World Bank Safeguard Policies and IFC Performance Standards.

As a tool, it provides a common language for understanding how the criteria outlined in the Hydropower Sustainability Guidelines can be addressed at all stages of a project's lifecycle. Assessments use objective evidence to create a sustainability profile, which can be used to identify gaps and drive improvement. These assessments are delivered by independent accredited assessors.

The Hydropower Sustainability Assessment Protocol was updated in July 2018, following an 18 month consultation process, to examine hydropower's carbon footprint and resilience to climate change. A project that scores well under the new criteria will have a low carbon footprint and be resilient to the impacts of climate change.

Gap Analysis Tool

The Hydropower Sustainability ESG Gap Analysis (HESG) Tool was developed by IHA between February 2017 and June 2018 under the mandate of the Hydropower Sustainability Assessment Council, with the support of the Swiss State Secretariat for Economic Affairs (SECO).

The HESG Tool is based on the framework of the Hydropower Sustainability Assessment Protocol. It assesses projects against the requirements of the Hydropower Sustainability Assessment Protocol's environmental, social and governance topics.

The tool provides an action plan to help a project team address any gaps against good practice. It is divided into 12 sections which are compatible with IFC Environmental and Social Performance Standards and the World Bank's new Environmental and Social Framework.

Online

hydropower.org/sustainability

Hydropower Pro

Introducing Hydropower Pro, IHA's new online community

In early 2019, IHA launched Hydropower Pro, an exclusive new online community and mobile app for individual and corporate members.

Hydropower Pro brings together hydropower professionals to connect, exchange experiences and collaborate.

Online:

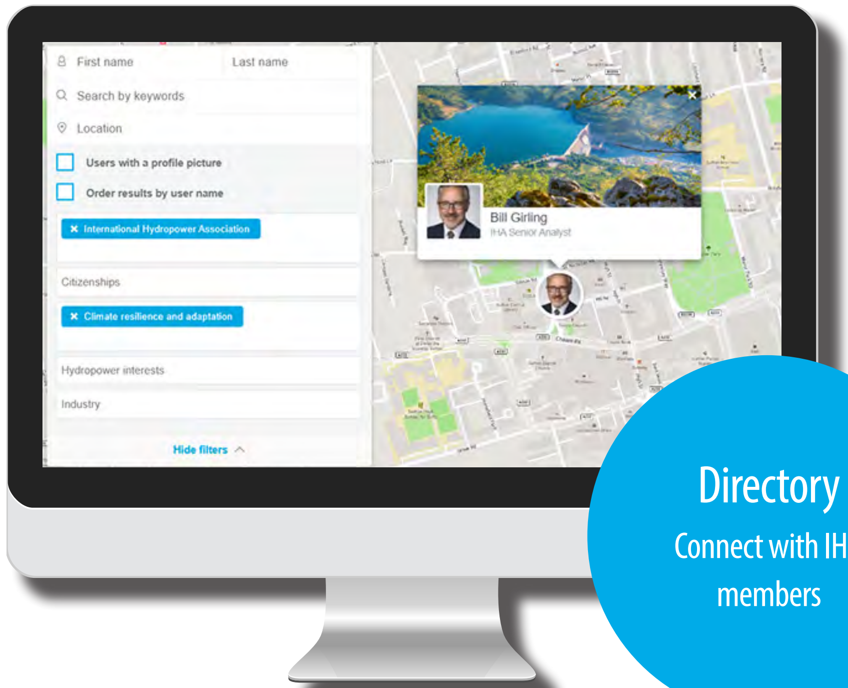
hydropower.org/pro

The platform offers:

- **Online groups** - forums for IHA knowledge networks and regions of interest
- **Resource libraries** - essential reports, publications, briefings and case studies
- **Member directory and messaging** - allowing members to network
- **News and blogging** - announcements and articles by IHA staff and members
- **Multi-platform access** - via desktop and mobile apps (iOS and Android)
- **Email alerts** - instant alerts and a weekly digest

"Hydropower Pro is a rich source of knowledge for the international hydropower community. It provides up-to-date, authoritative coverage of a broad range of news, events, issues and facts for the sector."

Colin Clark, Chief Technical Officer for Brookfield Renewable and IHA Vice President



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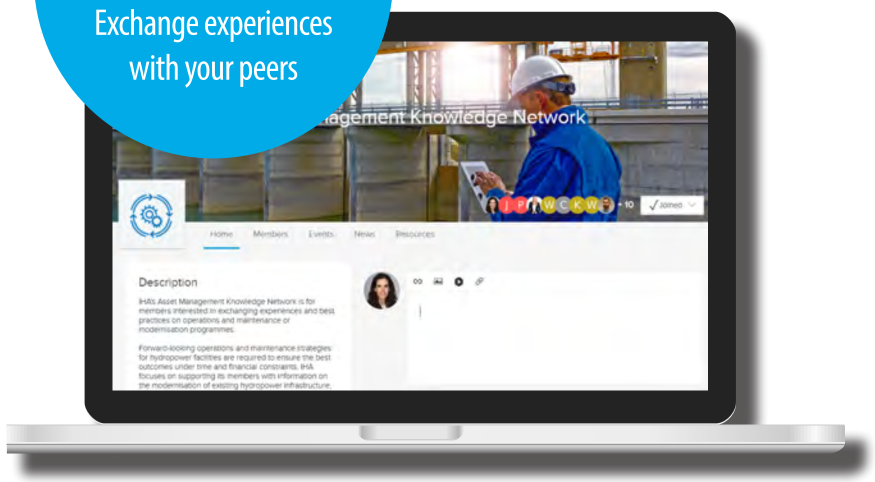


"Hydropower Pro offers a new link into the extensive world of hydropower. It helps me stay updated with the latest issues and events and network in my areas of interest."

Roger Gill, consultant and IHA Vice President

Reports
Access briefings and archive publications

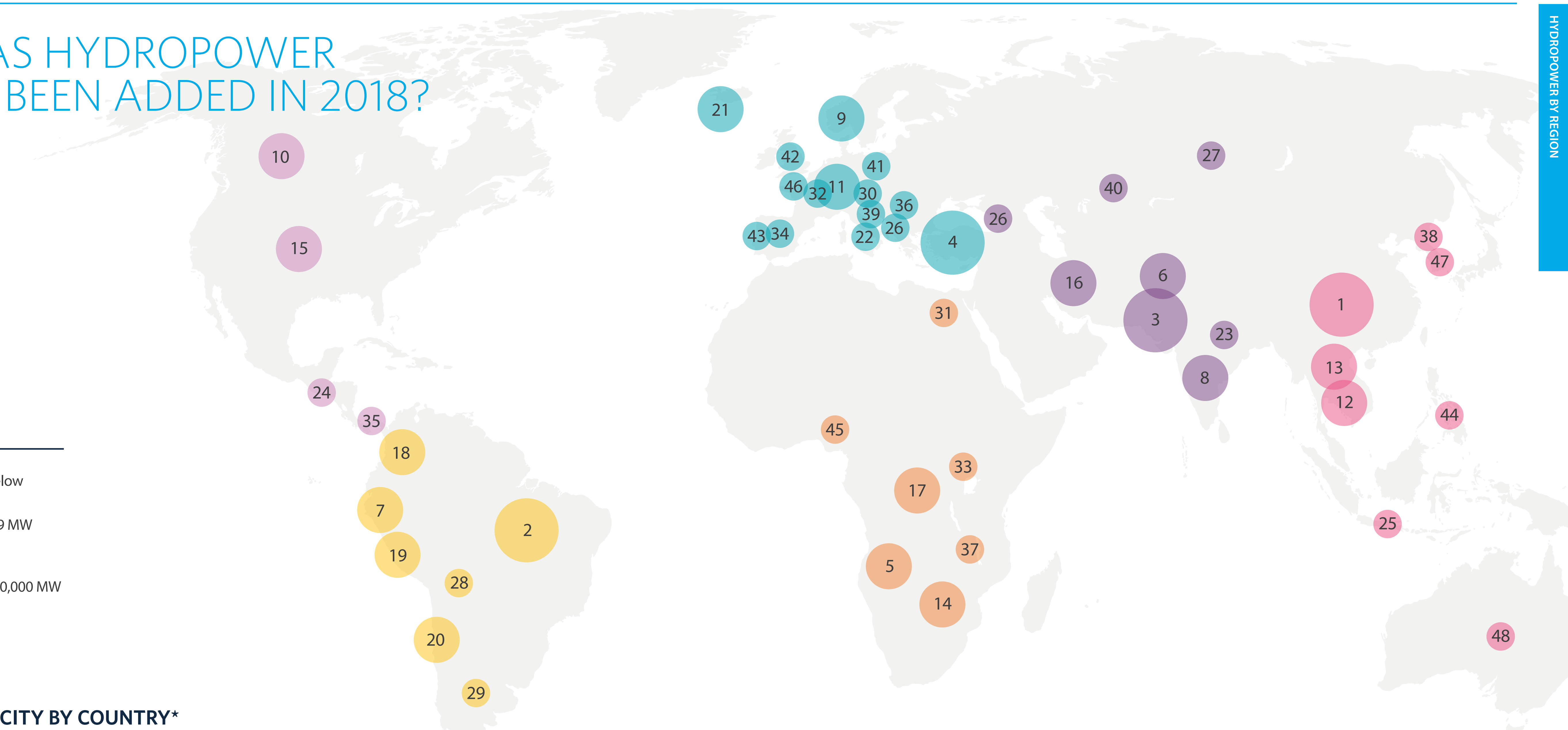
The Sogamoso hydroelectric power plant in Colombia.
Credit: Isagen S.A. E.S.P.

HYDROPOWER BY REGION

Maps

Analysis

WHERE HAS HYDROPOWER CAPACITY BEEN ADDED IN 2018?



Key

- 99 MW and below
- 100 MW to 999 MW
- 1,000 MW to 10,000 MW

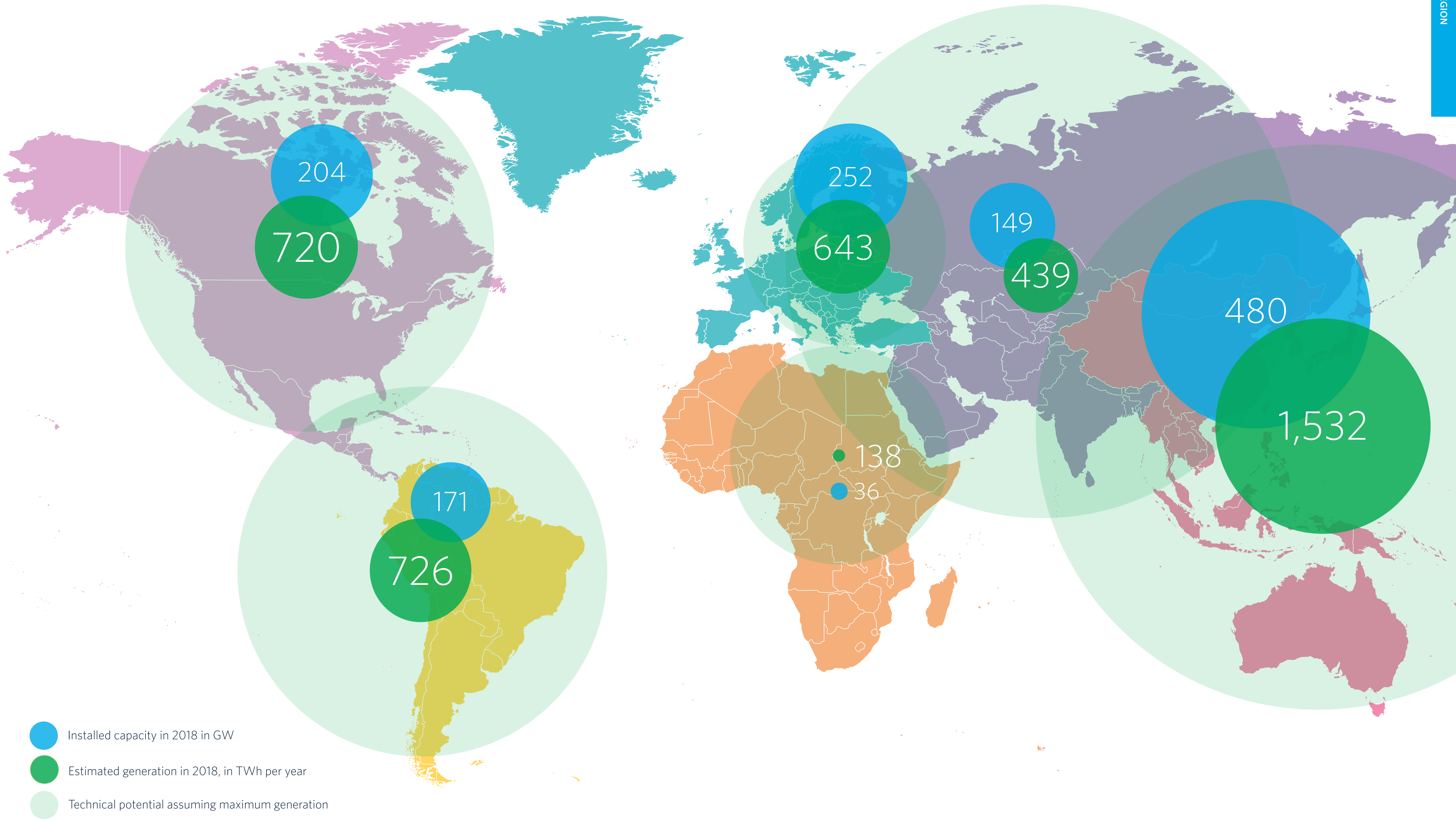
NEW INSTALLED CAPACITY BY COUNTRY*

Rank	Country	Capacity added (MW)	Rank	Country	Capacity added (MW)
1	China	8,540	13	Laos	254
2	Brazil	3,866	14	Zimbabwe	150
3	Pakistan	2,487	15	United States	141
4	Turkey	1,085	16	Iran	140
5	Angola	668	17	Democratic Republic of the Congo	121
6	Tajikistan	605	18	Colombia	111
7	Ecuador	556	19	Peru	111
8	India	535	20	Chile	110
9	Norway	419	21	Iceland	100
10	Canada	401	22	Italy	88
11	Austria	385	23	Nepal	71
12	Cambodia	300	24	Guatemala	61

Rank	Country	Capacity added (MW)	Rank	Country	Capacity added (MW)
25	Indonesia	61	37	Malawi	12
26	Georgia	60	38	North Korea	10
27	Russia	57	39	Bosnia and Herzegovina	9
28	Bolivia	55	40	Kazakhstan	7
29	Argentina	46	41	Czech Republic	4
30	Slovenia	45	42	United Kingdom	4
31	Egypt	32	43	Portugal	4
32	Switzerland	26	44	Philippines	2
33	Uganda	24	45	Nigeria	2
34	Spain	17	46	France	2
35	Panama	17	47	South Korea	1
36	Serbia	15	48	Australia	0.1

* including pumped storage

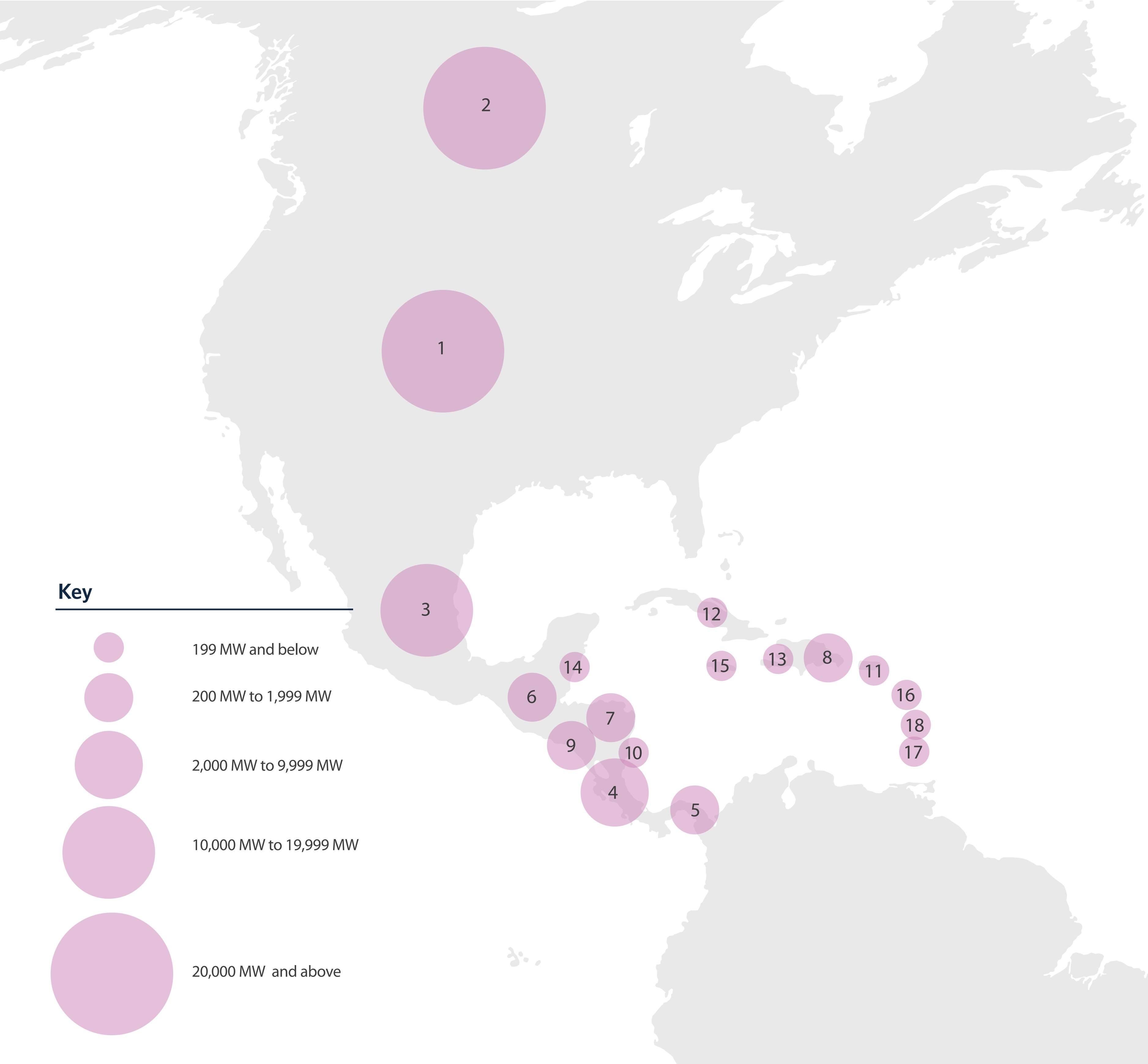
HYDROPOWER CAPACITY AND GENERATION BY REGION



NORTH AND CENTRAL AMERICA

The Romaine Complex on the Quebec north shore of the Saint Lawrence River in Canada. Photo Hydro-Québec.

NORTH AND CENTRAL AMERICA INSTALLED CAPACITY



COUNTRIES BY ADDED CAPACITY IN 2018 (MW*)

1st	2nd	3rd	4th
Canada	United States	Guatemala	Panama
401	141	61	17

NORTH AND CENTRAL AMERICA CAPACITY BY COUNTRY*

Rank	Country	Total installed capacity (MW)
1	United States	102,745
2	Canada	81,386
3	Mexico	12,117
4	Costa Rica	2,375
5	Panama	1,818
6	Guatemala	1,499
7	Honduras	656
8	Dominican Republic	543
9	El Salvador	472
10	Nicaragua	123
11	Puerto Rico	98
12	Cuba	64
13	Haiti	61
14	Belize	53
15	Jamaica	23
16	Guadeloupe	10
17	Saint Vincent And The Grenadines	7
18	Dominica	6

* including pumped storage

OVERVIEW

Despite limited growth in capacity over recent years, hydropower continues to dominate all sources of renewable energy across North and Central America. In 2018 a further 575 MW of conventional hydropower installed capacity was added.

In the United States, 311 TWh of hydropower was generated over 2018, making up around 8 per cent of total electricity generation and about 42 per cent of all renewable energy supply. Shifts in the national policy landscape for hydropower continue to evolve with new bills introduced in the US Congress that include hydropower in the definition of renewable energy and facilitate a timelier process for both new project approvals and existing projects in relicensing. During 2018, Congress approved a Water Infrastructure Act which included several provisions promoting hydropower deployment. With the rapid growth of solar PV, the US Department of Energy is focusing on the essential role that hydropower plays in the current and future energy profile of the US, with emphasis on the value of grid reliability and flexibility provided by pumped hydropower, the nations' largest source of grid-scale energy storage.

In Canada, 381 TWh of hydropower was generated over 2018, making up around 67 per cent of total electricity generation and over 85 per cent of all renewable energy supply in Canada. During 2018, 417 MW of new hydropower was added comprised of: the 395 MW Romaine 3 project in Québec; the 16 MW Yellow Falls project on the Mattagami River in Ontario; as well as two projects in British Columbia (BC) – the John Hart redevelopment project which increased the original plant capacity by 6 MW, and the 350 KW Nicknaqueet hydro-diesel hybrid in BC's Central Coast region.

Mexico continues to pursue its ambitious goals for increasing the country's share of renewable energy sources within its overall generation portfolio. Under the new leadership of President Andrés Manuel López Obrador, the government plans on increasing Mexico's hydropower generation significantly by the end of his six-year term by building hydro plants as well as rehabilitating existing facilities. Hydropower is a key pillar in the government's new national electricity programme, with an additional MXN 20 billion (USD 985 million) in investments announced to modernise and upgrade sixty existing hydroelectric plants. Mexico's state-owned power utility, Comisión Federal de Electricidad (CFE), has estimated that renovation of hydroelectric plants could add another 3,300 MW of capacity and increase the country's generation by 26 per cent.

Central America added a further 80 MW in 2018 and several projects are under active development in a region in which several countries produce the majority of their electricity from renewable sources, largely due to hydropower.

Currently, Guatemala has nearly 1,500 MW of installed hydropower capacity, making up 34 per cent of the country's overall energy supply. Over the past ten years, energy consumption from renewable sources doubled in the country, with renewables supplying up to 70 per cent of national consumption. Construction of the fourth phase of the 301 MW Renace hydroelectric complex was completed, and will add another 55 MW of hydropower capacity to the national system, when it is finally commissioned in 2019.

In Panama, work is progressing on the 63 MW Burica project and the 33 MW Pando project on the upper basin of the Chiriquí Viejo River. Two small hydropower projects went into service during 2018 – La Cuchilla at 8.7 MW and Macano 3 at 1.75 MW – bringing the total installed capacity of hydropower to 1,818 MW in Panama. Over the calendar year, 78 per cent of electricity was generated by hydropower, 11 per cent from thermal, 8 per cent from wind, 2 per cent from solar and 1 per cent from self-generation.

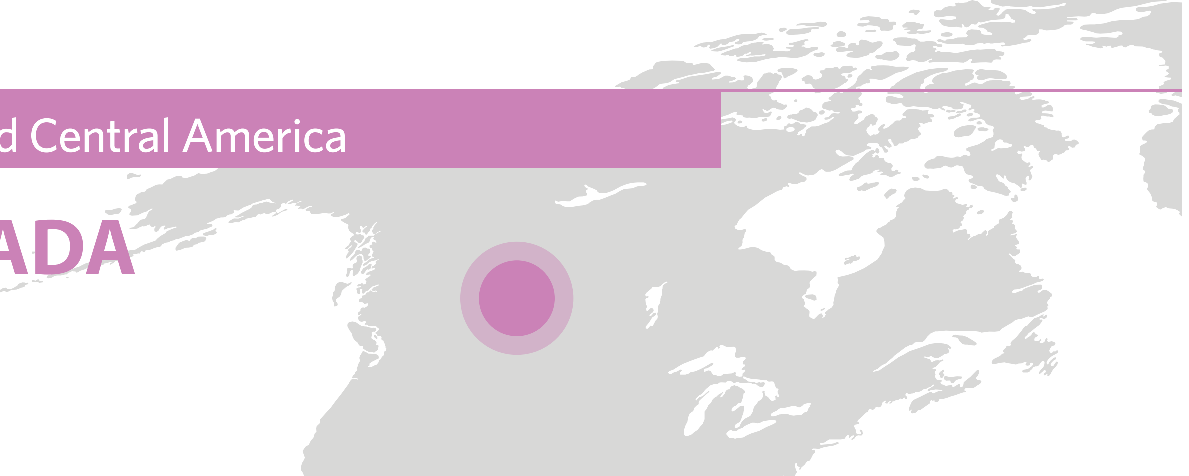
For the fourth consecutive year, Costa Rica generated more than 98 per cent of its power from renewable sources, with over 60 per cent provided by hydropower. While several hydropower projects are under development in Costa Rica, it was announced that the state power company, Instituto Costarricense de Electricidad terminated Hidrotárcoles' contract for the 50 MW Capulín-San Pablo hydroelectric project, after the contractor failed to meet the proposed commercial start-up date of August 2015.

In Honduras, authorities plan to advance a number of planned hydroelectric plants as part of the country's target to achieve 95 per cent of energy supplied from renewable sources by 2027. Despite significant delays, Sinohydro concluded construction of Patuca III, the largest dam after El Cajón, in late 2018. The project is located in the eastern region of Honduras and, when completed in late 2019, will contribute 6 per cent of the country's energy.

In El Salvador, the final phase of construction and commissioning of the El Chaparral is underway. The plant will have an installed capacity of 73 MW and is located in the department of San Miguel in the eastern part of the country.

The Keeyask project is under construction in Manitoba in Canada. Credit: Keeyask Hydropower Limited Partnership.

CANADA



Renewable energy accounts for two-thirds of Canada's power generation largely due to its significant hydropower resources, which make it the third largest producer of hydropower in the world in 2018.

During 2018, work progressed on four major hydropower projects under construction across four provinces. In British Columbia, BC Hydro's 1,100 MW Site C project on the Peace River, commenced construction in July 2015 and is anticipated to be completed by 2024. The project will generate about 5,300 GWh per year.

In Labrador, the 824 MW Muskrat Falls project on the Lower Churchill River was expected to go into service in 2019, generating about 4,900 GWh.

In Manitoba, the Keeyask Hydropower Limited Partnership, a partnership between Manitoba Hydro and four Manitoba First Nations, is developing the 695 MW Keeyask project on the Nelson River within the ancestral homeland of all four partner First Nations; construction commenced in July 2014, with completion scheduled for 2021, generating about 4,400 GWh.

Work continues on Hydro-Québec's La Romaine 4 hydropower project, scheduled to go into service in 2021 at a capacity of 245 MW. La Romaine 4 is the final stage of the 1,550 MW La Romaine complex, which will generate 8,000 GWh. Romaine 3 was commissioned in late 2017, adding 395 MW.

Other hydropower projects completed or under construction in 2018 include BC Hydro's John Hart redevelopment project, uprated from its original installed capacity of 126 MW to 132 MW at a cost of approximately CAD 1.1 billion. The project featured several unique improvements including a new underground powerhouse.

The Nicknaqueet 350 KW hydro-diesel hybrid went into service in early 2018 in BC's Central Coast region, and is expected to replace 92 per cent of existing diesel generation for the community. Elsewhere in the province, work continues on the Narrows Inlet 33 MW project, developed in a partnership between the Shíshálh Nation and BluEarth Renewables, which is expected to be fully commissioned in 2019.

The 16 MW Yellow Falls project developed by Boralex on the Mattagami River in Ontario will be commissioned in mid-2019. Ontario Power Generation (OPG) also announced its issue of CAD 450 million of green bonds, used to partially fund the development of a 28 MW hydropower project and the expansion of an existing project.

Alberta's legislature approved the construction of the proposed Canyon Creek Pumped Hydro Energy Storage Project. The project will have a storage capacity of 75 MW for 37 hours of full-capacity operation.

Work continues to advance major new interconnections between Canada and the United States. Bipole III, Manitoba Hydro's new 500 kV HVDC transmission project was commissioned in July 2018 after five years of construction.

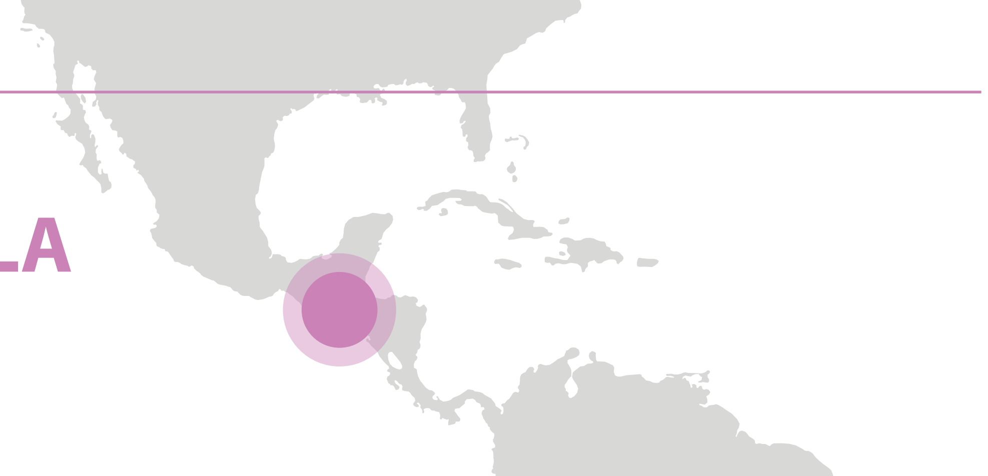
In addition, the National Energy Board issued its decision approving the Manitoba Hydro – Manitoba-Minnesota Transmission Project subject to a number of conditions.

In Quebec and New England (USA), work is underway to advance the proposed des Appalaches-Maine interconnection with the New England Clean Energy Connect (NECEC) transmission project through Maine.

In January 2019, Canada joined other countries in becoming a member of the International Renewable Energy Agency (IRENA).

37.2 MILLION POPULATION	**81,386 MW** INSTALLED HYDROPOWER CAPACITY	**381,179 GWh** HYDROPOWER GENERATION	**60%** HYDROPOWER SHARE OF ELECTRIC POWER INSTALLED CAPACITY

GUATEMALA



Guatemala has almost 1,500 MW of installed hydropower capacity, making up 41 per cent of the country's overall energy production. Hydropower plays an important role in meeting ambitious targets for renewable energy generation. Over the past 10 years, energy consumption from renewable sources has doubled with generation representing between 65 per cent and 70 per cent of national consumption.

Guatemala's hydraulic resources have the potential to add roughly 11 GW of hydropower capacity, of which roughly 6 GW is technically exploitable according to the Energy Ministry. However, the country continues to face a challenging environment for new hydropower development due to legal obstacles and high crime rates. In recent years 16 hydroelectric projects have reportedly been halted, amounting to USD1.5 billion in investment. Work continues to pass legislation that will improve the consultative process with indigenous peoples.

Despite many challenges, construction of the fourth phase of the 301 MW Renace hydroelectric complex in Alta Verapaz was completed in 2018, with Renace IV becoming operational in January 2019, adding 55 MW more hydropower capacity to the national system. The Renace complex is now the largest hydropower plant in the country.

Other hydropower facilities commissioned in 2018 include the 60 MW OXEC II project, the second installation downstream of the 26 MW OXEC plant on the Cahabón River, in the Alta Verapaz Department of north central Guatemala. OXEC II began operation in September 2018, after the project had been suspended in 2017 due to opposition from indigenous groups.

The power market in Guatemala is unbundled with about 50 companies (private and state-owned) acting in generation, distribution, and transmission. Guatemala is connected via the Central American Electrical Integration System (SIEPAC) to Honduras and El Salvador. Northern Guatemala is also connected to Mexico's transmission system.

The Mexico-Guatemala interconnection project consists of a 103 kilometre 400 kV transmission line, with 32 kilometres in Mexico and 71 kilometres in Guatemala. Under an existing contractual arrangement, Guatemala's electric utility, the National Institute of Electrification (INDE), acquires 120 MW of power from the Mexican energy authority, CFE, increasing to 200 MW when CFE has surplus energy. The contract enables CFE to purchase energy on the Guatemalan electricity market in the event of a contingency. This interconnection between the Mexican transmission system and the Central American market has been important for facilitating energy transactions between both countries through medium- and long-term bilateral contracts.

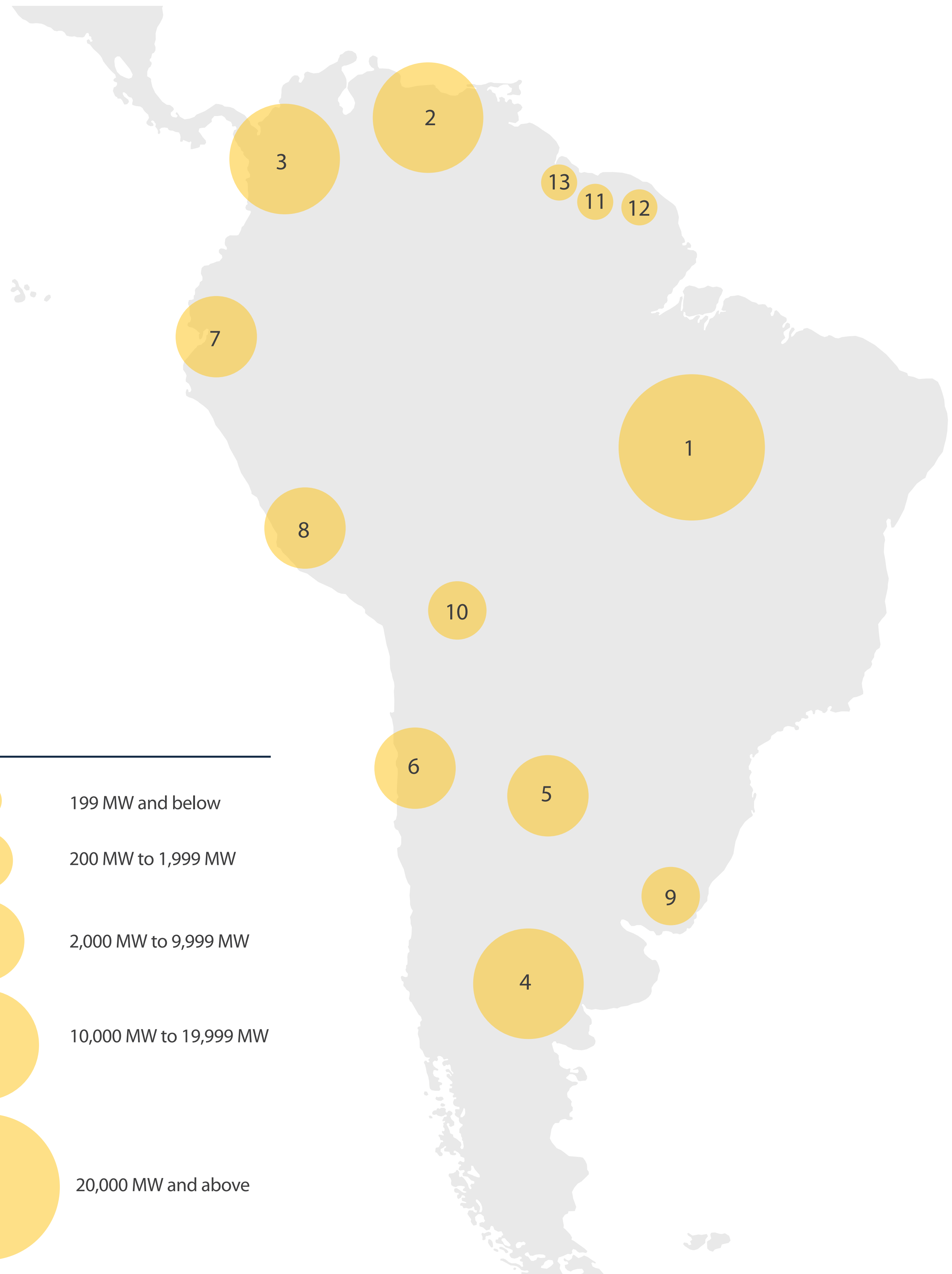
There is a strong push to reform the regional market in order to enable better opportunities to export energy to Mexico and Central America, specifically El Salvador where energy prices are not competitive. It was reported that in 2018, electricity exports to neighbouring countries, in particular to Mexico increased by 76 per cent compared to exports in 2017.

16.8 MILLION POPULATION	**1,499 MW** INSTALLED HYDROPOWER CAPACITY	**5,191 GWh** HYDROPOWER GENERATION	**34%** HYDROPOWER SHARE OF ELECTRIC POWER INSTALLED CAPACITY

SOUTH AMERICA

The Jaguas hydroelectric power plant, Colombia.
Credit: Isagen S.A. E.S.P.

SOUTH AMERICA INSTALLED CAPACITY



Key

- 199 MW and below
- 200 MW to 1,999 MW
- 2,000 MW to 9,999 MW
- 10,000 MW to 19,999 MW
- 20,000 MW and above

COUNTRIES BY ADDED CAPACITY IN 2018 (MW*)

1st	2nd	3rd	4th	5th
Brazil	Ecuador	Colombia	Peru	Chile
3,866	556	111	111	110

SOUTH AMERICA CAPACITY BY COUNTRY*

Rank	Country	Total installed capacity (MW)
1	Brazil	104,139
2	Venezuela	15,393
3	Colombia	11,837
4	Argentina	11,288
5	Paraguay	8,810
6	Chile	6,753
7	Ecuador	5,072
8	Peru	4,995
9	Uruguay	1,538
10	Bolivia	658
11	Suriname	189
12	French Guiana	119
13	Guyana	1

* including pumped storage

South America

OVERVIEW

South America saw the fastest hydropower growth rate after the East Asia and Pacific region in 2018 with close to 4,855 MW of capacity added. Brazil contributed the bulk – approximately 80 per cent – of this new capacity, which was mainly attributed to the addition of 3,055 MW to the 11,000 MW Belo Monte hydropower complex.

Hydropower generation in South America is increasingly challenged by climate variability. The region experienced weak La Niña events in the summer of 2017-2018, resulting in severe drought that affected Argentina, Uruguay, Venezuela and north-eastern parts of Brazil. The drought partially accounted for power rationing in Venezuela, and the fall in reservoir levels prompted Brazil's highest energy imports in 17 years, with 1,131 GWh coming from Argentina and Uruguay in 2018.

Variations in climate and installed capacity have strengthened the need for regional interconnections to meet growing demand in countries with an energy deficit. As such, Bolivia's state-owned power company, ENDE, is developing an interconnection line to Argentina, while similar plans for Brazil, Paraguay and Peru are in the pipeline. Plans have also been made for a 500 kV transmission line connecting Ecuador and Peru.

The region is moving towards diversifying its renewable energy mix to protect countries from the impacts of severe weather events like droughts and floods. Argentina aims to boost its renewable sources such as wind and solar from 2 per cent to 20 per cent by 2025 and Chile's new energy policy is moving away from coal generation to renewables diversification.

The region is also undergoing the rehabilitation and expansion of some major projects in Brazil, Paraguay and Argentina. Itaipú, the world's largest dam by electricity generation, owned jointly by the governments of Brazil and Paraguay, began a 10-year global modernisation project. The 14,000 MW Itaipú hydropower plant achieved its highest power generation for the first five months of 2018 since its inauguration in 1984, but saw this decrease from May to September, due to water scarcity.

Paraguay's state-power company, ANDE, is moving forward with plans for rehabilitation, upgrade and modernisation of its 200 MW Acaray hydropower plant with USD 125 million in financing from the Inter-American Development Bank (IDB). IDB also approved USD 80 million in financing the modernisation of the 1,890 MW Argentine-Uruguayan bi-national hydropower plant, Salto Grande. Yacyretá complex on the Argentina-Paraguay border is also undergoing rehabilitation and expansion to add 270 MW, which will become operational in 2023, boosting electricity production at Yacyretá by 10 per cent.

Brazil has now overtaken the United States as the world's second largest country by installed hydropower capacity. During 2018, a group of private companies consisting of hydropower developers and operators formed the Forum for the Development of Midsize Hydropower Plants in order to strengthen private sector investments in hydropower. This was prompted by the government's decision to end concession auctions for new hydropower projects larger than 30 MW.

Colombia's 2,400 MW Ituango project has been under construction for seven years and is set to be the country's largest power plant, supplying 17 per cent of its electricity, when it comes into operation at the end of 2021. On 28 April 2018, an obstruction was reported in the auxiliary diversion tunnel which had been safely diverting the waterway during construction. With water levels rapidly rising in the reservoir, HidroItuango took the decision to drain water from the reservoir through the powerhouse to avoid the risk of dam collapse. On 12 May, the pressure of the reservoir uncovered one of the two original diversion tunnels that had been permanently blocked and generated a sudden increase of outflows. This affected the nearby town of Puerto Valdivia, however no casualties were reported. The project has taken steps to mitigate the risks and the damage from the incident.

Ecuador added 556 MW of capacity, with the commissioning of two major projects; 180 MW Delsitanisagua and 275 MW Minas San Francisco. The country's electricity master plan envisions the installation of 4.7 GW between 2018 and 2025 with the bulk of it coming from hydropower from projects such as Cardenillo (596 MW) and Santiago G8 (3,600 MW). This will increase hydropower's electricity share to 92 per cent by 2035 from the current 58 per cent.

As part of the Peruvian government's commitment to become energy self-sufficient by 2040, six plants came into operation in 2018 adding 110.6 MW of installed capacity. The country has also approved the development of hydropower projects amounting to 250 MW.

In Chile, the Ministry of Energy announced plans to phase-out coal generation with a goal to procure 70 per cent of national electricity generation from renewables by 2050. This has positioned a number of hydropower projects in the development pipeline of up to 1.3 GW, the most notable one being the 531 MW Alto Maipo hydropower complex expected to start operations in 2020.

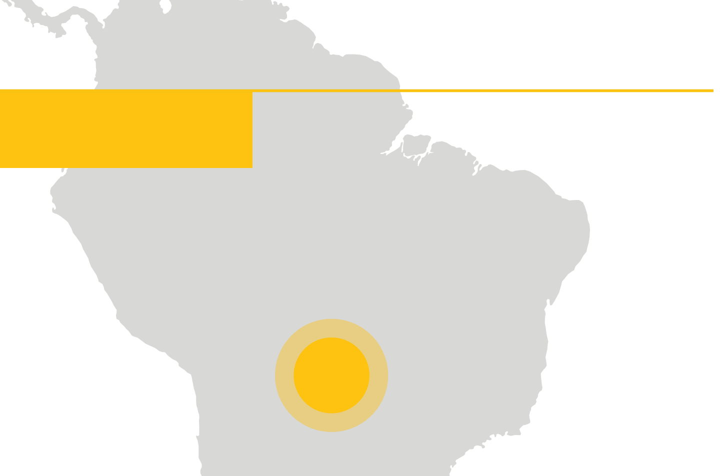
Bolivia added 55 MW of hydropower capacity in 2018 with the commissioning of the first phase of the San Jose hydropower project, with an additional capacity of 560 MW expected to come online between 2019-2023. Farther along the development pipeline are projects in their early stage amounting to 6,200 MW. These developments will aim at increasing the country's hydroelectricity share and market surplus energy to neighbouring countries. In this context, Bolivia and Brazil began inventory studies for a binational hydro project in March 2018.

In Guyana, two hydropower projects of a combined capacity of 4.15 MW are advancing development under Guyana's Low Carbon Development Strategy (LCDS), with financing received through the United Arab Emirates and the Guyana REDD-plus Investment Fund (GRIF).

Uruguay is one of six countries in the world to produce 100 per cent renewable energy with more than 80 per cent of its electricity production generated from hydropower. In January 2018, the government obtained climate insurance worth USD 450 million from the International Bank for Reconstruction and Development (IBRD) to protect its energy utility from additional costs induced by drought and the need to resort to high cost thermal generation.

The Itaipú hydropower plant, owned jointly by Brazil and Paraguay, marks its 35th anniversary in May 2019.
Credit: Itaipu Binacional.

PARAGUAY



Paraguay's electricity generation is produced by 100 per cent renewable energy sources with a power production capacity close to 60,000 GWh per year. The 14,000 MW Itaipú hydropower plant, together with the 3,200 MW Yacyretá and 210 MW Acaray plants, supply the National Interconnected System to satisfy electricity demand.

Acaray is owned by the state-owned generation and distribution company, ANDE, while Itaipú and Yacyretá are binational hydropower plants owned jointly with the governments of Brazil (Itaipú Binational), and Argentina (Yacyretá Binational Entity).

Itaipú alone accounted for 90.8 per cent of supply to Paraguay's total electricity demand in 2018. Itaipú is the largest hydropower plant in the world in electricity generation and the second in terms of installed capacity. The plant closed 2018 with its fourth best production in history at 96.6 TWh since beginning operations, and set a world record in 2016 with the production of 103.1 TWh.

In 2018, domestic demand was met using only 35 per cent of Paraguay's' overall power production from hydroelectric resources. The surplus of electricity generated from the binational hydropower plants Itaipú and Yacyretá is sold to Brazil and Argentina, making Paraguay the fourth largest exporter of electricity in the world. Electricity exports represent more than 70 per cent of total generation and constitute approximately 25 per cent of total exports. In 2017 Paraguay exported USD 2.1 billion worth of electricity, which represented 7.1 per cent of GDP.

All three of Paraguay's hydropower assets are undergoing developments as a means to increase power generation to meet the country's requirements by 2030.

Itaipú is undergoing a modernisation project to increase the power plant's asset life and boost electricity generation. The modernisation project will take at least 10 years with an investment of USD 500 million. The GE consortium was contracted for the early stages of the project to provide electrical equipment for the electrical modernisation of 24 overhead cranes.

In 2018, a call for bidding was made for the expansion of Yacyretá hydropower plant to add three turbine-generator units to the 3.2 GW plant's existing 20 units. The expansion project will add 276 MW and will increase production by 9 per cent, increasing annual generation from 20 TWh to 22 TWh. Paraguay and Argentina through the Yacyretá Binational Entity will fund the cost of the USD 500 million works. Meanwhile, the 20 existing units are undergoing rehabilitation to increase their useful life by 50 years.

The Inter-American Development Bank (IDB) approved a USD 125 million loan in 2018 to modernise Acaray hydropower plant to extend its working life and boost its reliability and generating capacity. The programme includes rehabilitation of the facility and improvements to its operation and management as well as the modernisation of the plant's electromechanical equipment.

ANDE is progressing with upgrading, strengthening and extension of the transmission and distribution infrastructure as part of Paraguay's new master plan 2016-2025. The masterplan aims to meet the sustained growth of energy demand that was estimated at an annual rate of 8.6 per cent. The reinforcement will also contribute to the efficient utilisation of the binational hydropower plants Itaipú and Yacyretá in 2030, when the country is expected to be consuming all of its generated electricity.

Paraguay also plans to continue developing its hydropower potential with projects such as Itá Corá-Itatí (1,600 MW) scheduled with Argentina at an estimated total cost of USD 4 billion. Itá Corá-Itatí project is in the pre-feasibility stage with tenders for environmental study having been announced in 2018.

Besides hydropower, biomass and fossil fuels make up Paraguay's energy mix, accounting for 44 and 40 per cent respectively, of which all the fossil fuels are imported. Paraguay's need to minimise importation of fossil fuels prompted the creation of the country's first sectoral policy, the 2040 national energy policy. The 2040 energy policy will guide energy development towards harnessing the country's resources, the efficient use of energy for the country's social and economic development and increasing awareness of energy benefits among the populations.

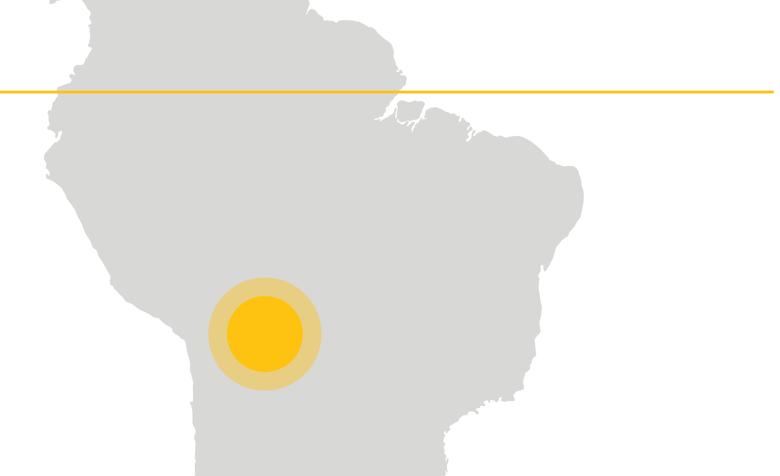
7 MILLION
POPULATION

8,810 MW
INSTALLED HYDROPOWER CAPACITY

59,110 GWh
HYDROPOWER GENERATION

100%
HYDROPOWER SHARE OF ELECTRIC POWER INSTALLED CAPACITY

BOLIVIA



Due to the country's topography and extensive river network, Bolivia has an estimated hydropower potential of more than 40,000 MW. As a result, hydropower is set to play a central role in fulfilling the government's aim of becoming a major exporter of renewable electricity.

Over the past decade, Bolivia has enjoyed significant progress in social and economic development largely thanks to its natural gas exports which have generated billions of dollars in revenue for the government. Per capita income has more than doubled, electricity access has increased to above 90 per cent for the first time and the poverty rate has fallen dramatically. Government subsidised natural gas also dominates the country's electricity sector, with gas-fired power plants accounting for up to 70 per cent of its total installed generating capacity.

As part of an ambitious National Electricity Plan 2025, the Bolivian government intends to drastically reduce its use of gas for power generation in favour of renewables, and free up additional gas supplies for exports. Integral to this strategy is a plan to increase the share of hydropower within the country's electricity mix from 29 per cent to 70 per cent in 2025. This will satisfy increasing demand and support up to 7,600 MW of potential large hydropower schemes for exports. This level of capacity would not only help displace domestic gas generation but would also enable Bolivia to export excess renewable electricity to neighbouring countries, and in the process position the country as a regional energy hub.

The plan will require some USD 17 billion in investment by 2025 and is heavily reliant on two large hydropower schemes: El Bala hydropower complex with a capacity of up to 3,700 MW under development and El Rio Grande hydropower complex with up to 2,900 MW.

Located north of the capital La Paz on the Beni River, El Bala complex has been considered a national priority for several decades. Despite the economic benefits through export revenue generation, the project continues to face considerable opposition from local community groups and international NGOs concerning potential environmental impacts in the Madidi National Park and a need for resettlement schemes.

In addition, the Bolivian government is assessing large-scale projects with Brazil along the Madeira River through a binational initiative which could add a further 3,000 MW of capacity to Bolivia. Studies are being undertaken with Brazilian authorities to determine the potential design and locations of future hydropower projects as part of the initiative.

In 2018, the 55 MW San Jose I project was commissioned, the first of a two-powerhouse complex located on the eastern slopes of the Andes in the Cochabamba region. Owned by the state-run company Empresa Nacional de Electricidad (ENDE) Corani, the USD 139 million project was built by PowerChina and is expected to save the country up to USD 6 million a year in electricity costs. Its sister station, the 69 MW San Jose II is expected to be commissioned in early 2019. Other large projects under construction are the 280 MW Ivirizu hydropower plant in Cochabamba and the 203 MW Miguillas hydropower complex in the La Paz region.

In order to support the government's export aspirations, several feasibility studies are being undertaken for the construction of transmission lines to Brazil and Argentina. Construction is underway on an interconnector between Yaguacua in southern Bolivia and Tartagal in northern Argentina, with a capacity of 500kV. The transmission line is 110 kilometres in length and is being developed by ENDE.

11.3 MILLION
POPULATION

658 MW
INSTALLED HYDROPOWER CAPACITY

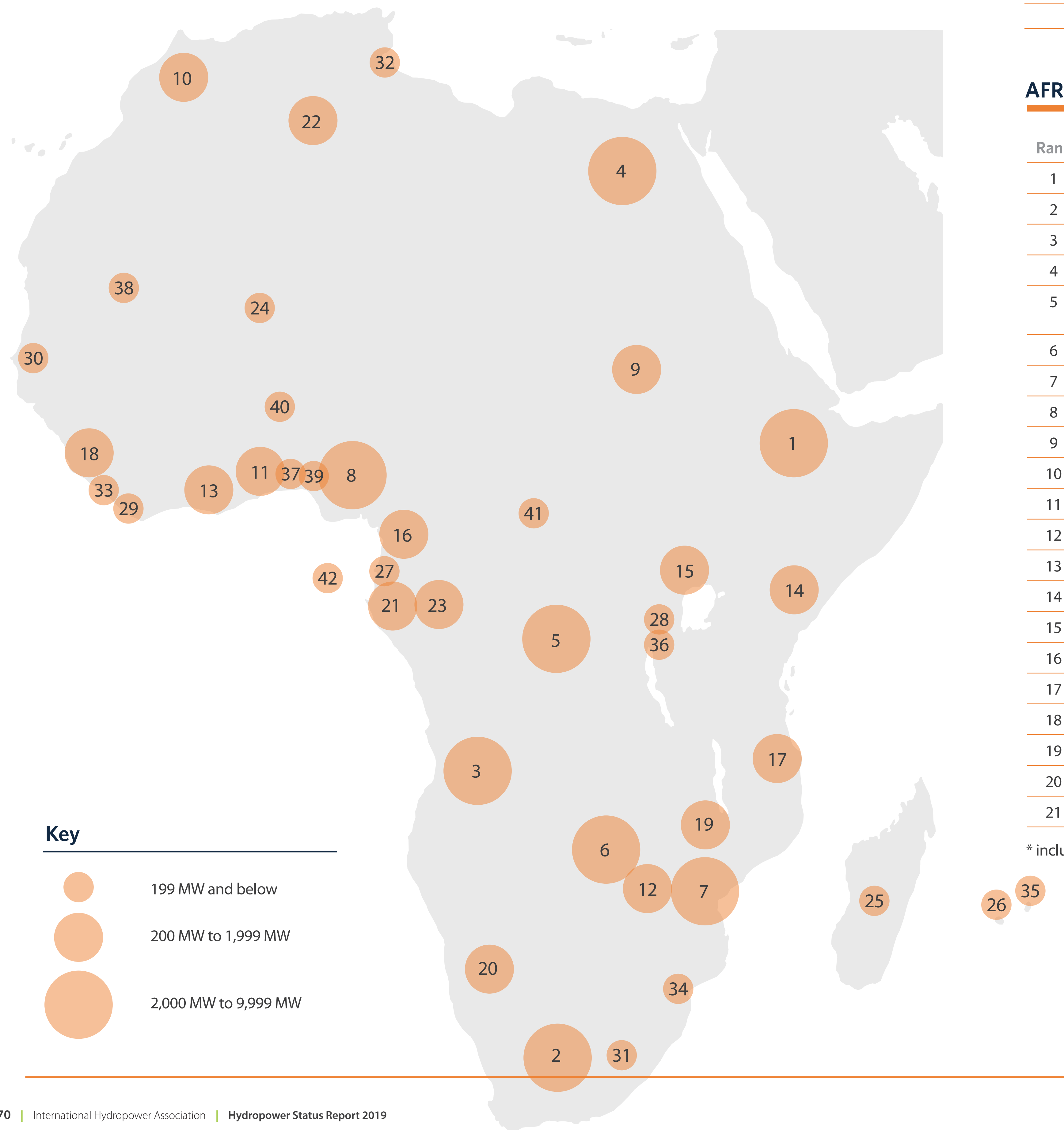
2,490 GWh
HYDROPOWER GENERATION

29%
HYDROPOWER SHARE OF ELECTRIC POWER INSTALLED CAPACITY

AFRICA

The Jebba Power Station on the Niger River in Nigeria.
Credit: Mainstream Energy Solutions.

AFRICA INSTALLED CAPACITY



COUNTRIES BY ADDED CAPACITY IN 2018 (MW*)

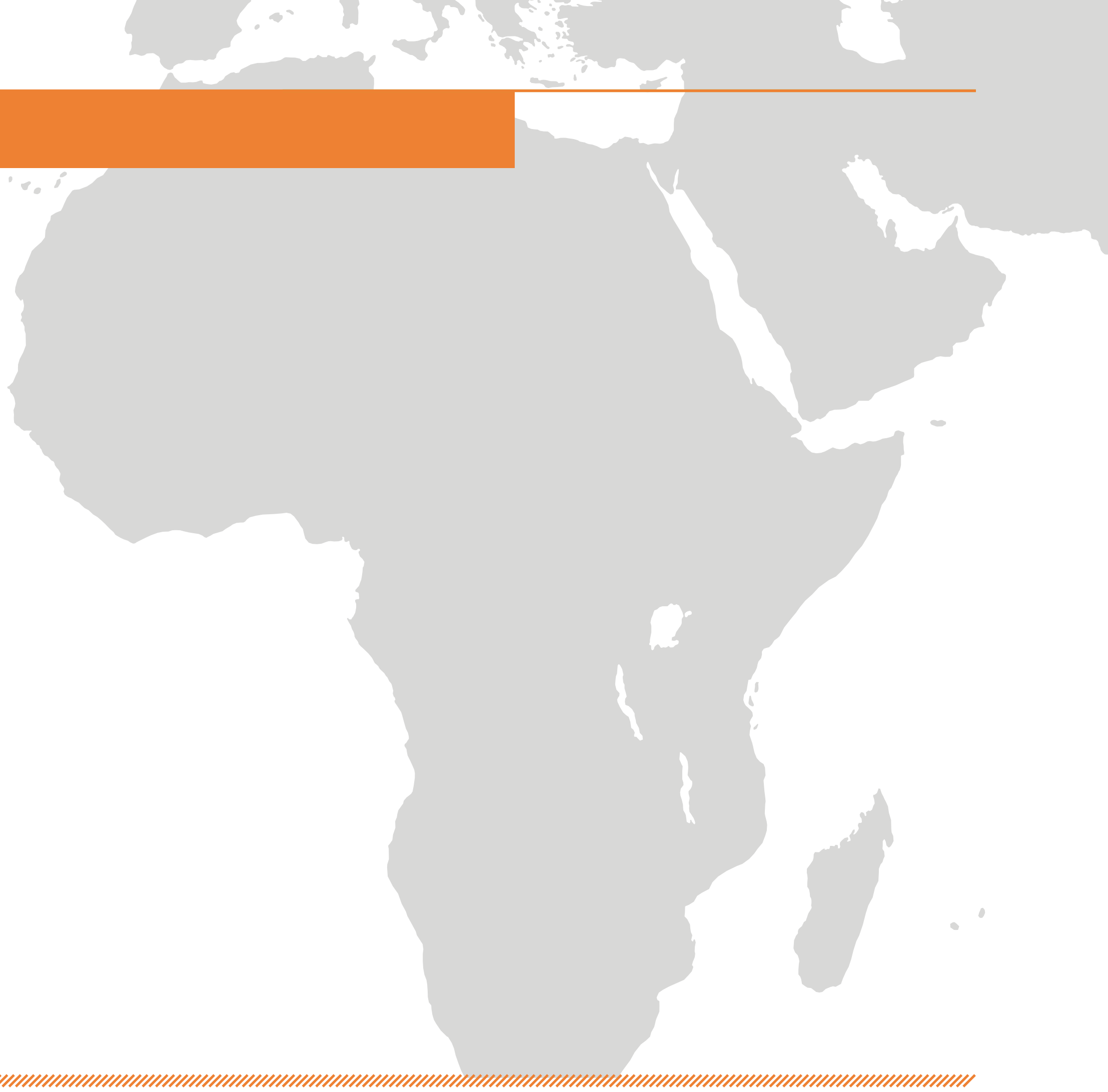
1st	2nd	3rd	4th	5th
Angola	Zimbabwe	Democratic Republic of the Congo	Egypt	Uganda
668	150	121	32	24

AFRICA CAPACITY BY COUNTRY*

Rank	Country	Total installed capacity (MW)	Rank	Country	Total installed capacity (MW)
1	Ethiopia	3,822	22	Algeria	269
2	South Africa	3,595	23	Congo	242
3	Angola	3,083	24	Mali	180
4	Egypt	2,876	25	Madagascar	164
5	Democratic Republic of the Congo	2,704	26	Reunion	134
6	Zambia	2,397	27	Equatorial Guinea	128
7	Mozambique	2,191	28	Rwanda	105
8	Nigeria	2,064	29	Liberia	93
9	Sudan	1,923	30	Senegal	81
10	Morocco	1,770	31	Lesotho	73
11	Ghana	1,584	32	Tunisia	66
12	Zimbabwe	1,076	33	Sierra Leone	64
13	Cote D'Ivoire	879	34	Eswatini	60
14	Kenya	826	35	Mauritius	60
15	Uganda	768	36	Burundi	57
16	Cameroon	747	37	Togo	49
17	Tanzania	572	38	Mauritania	48
18	Guinea	368	39	Benin	33
19	Malawi	364	40	Burkina Faso	32
20	Namibia	347	41	Central African Republic	19
21	Gabon	331	42	Sao Tome And Principe	2

* including pumped storage

OVERVIEW



A computer generated impression of the under development Nachtigal hydropower project in Cameroon. Credit: EDF.

Africa has the highest percentage of untapped technical hydropower potential in the world, with only 11 per cent utilised. In 2018, over 1 GW of hydropower capacity was put into operation across the continent, with total installed capacity now exceeding 36 GW.

Despite its vast renewable energy resources, Africa continues to rely on oil and gas along with traditional biomass combustion for energy consumption. Hydropower is responsible for 86 per cent of all non-fossil fuel energy use.

The African Union and African Development Bank supported Programme for Infrastructure Development in Africa (PIDA) regards hydropower development as a priority, alongside interconnections for regional power pools. The PIDA estimates that the region's total generating capacity needs to increase by 6 per cent per year to 2040 from the current total of 125 GW to keep pace with rising electricity demand.

Africa's hydropower installed capacity is expected to grow by about 4,700 MW over the next two to three years. Major projects include the 2,070 MW Lauca hydropower project in Angola (of which 1,336 MW is already operational), the 750 MW Kafue Gorge Lower Power Station in Zambia, the 700 MW Zungeru project in Nigeria, as well as the 183.2 MW Isimba project, commissioned in March 2019, and soon to be commissioned 600 MW Karuma project in Uganda.

Ethiopia has targeted energy access for all its citizens by 2025. Achieving this goal means the country will need to increase power from 4,566 MW to more than 17,300 MW by 2025, with the assistance of new hydropower, wind, geothermal and biomass projects. The Great Ethiopian Renaissance Dam (GERD), expected to reach 6,350 MW, was around two-thirds completed by the end of 2018. The government's Growth and Transformation Plan (GTP) outlines a 15-year strategy with three five-year phases to transform Ethiopia from a developing country to a middle income country by 2025.

In Angola, the Lauca project commissioned two more turbines in 2018, making it the largest hydropower plant in the country with 1,336 MW of installed capacity. The filling of the reservoir was completed in April 2018. Lauca (2,070 MW) and Caculo Cabaça (2,172 MW) are scheduled to be fully commissioned by 2019 and 2022 respectively. Together the two projects will contribute almost a third of a national target 9.9 GW of installed generation by 2025. The government has a target to achieve a 60 per cent electrification rate and has undertaken a strategic environmental assessment to evaluate its 18 GW hydropower potential as part of its 2025 strategy.

In the Democratic Republic of Congo, the 150 MW Zongo II hydropower project was formally inaugurated in June 2018, adding 100 MW of installed capacity to the 50 MW in operation since 2017. As part of the modernisation project, the Mwadingusha hydropower plant increased its installed capacity from 22 MW to 32 MW. It is expected that the modernisation of the three remaining turbines will be finished in 2019, augmenting installed capacity to 71 MW. The country's mining sector is also investing in hydropower to provide them with power supply security. In 2018, the 11 MW Azambi hydropower project was also commissioned.

In Malawi, the Nkula hydropower station was successfully rehabilitated. Originally commissioned in 1966, it had previously been running at less than nameplate capacity due to its poor condition. As a result, the rehabilitated and modernised hydropower station has extended its operational life by at least an additional 30 years and output capacity has increased from the original 24 MW to 36 MW.

In Egypt, the 32 MW New Assiut Barrage Project was inaugurated in August 2018. The barrage includes two navigation locks and provides irrigation water to 690,000 hectares of land, providing access to electricity for an estimated 130,000 families. It was designed to replace an existing dam built in the early twentieth century 400 metres downstream. During 2018, contracts were also signed for the 2,400 MW Ataqa project, the country's first ever pumped storage hydropower plant. An interconnection project between Egypt and Sudan forms part of Egypt´s plan to become a regional electricity hub for Arab, African and European countries.

In Uganda, the Isimba Hydroelectric Dam was set for technical commissioning tests in early 2019 while the Karuma project was expected to be commissioned by the end of 2019. These two hydropower stations will double Uganda's total hydropower installed capacity, moving from 764 MW today to 1552 MW.

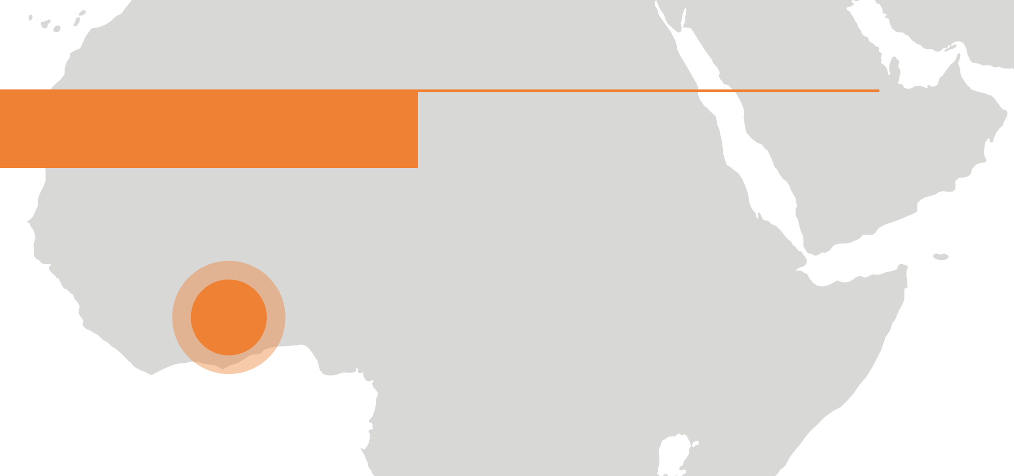
In Mozambique, the government issued an extension for the Cahora Bassa hydroelectric power station, providing for a new concession period of 15 years in favour of national company Hidroelectrica Cahora Bassa. The Mozambican government has also decided to create a cabinet coordinated by the Ministry of Mineral Resources and Energy, which integrates Hydroelectrica Cahora Bassa and national utility Electricidade de Moçambique to coordinate the development of the Mpanda Nkuwa Hydroelectric Power Plant. The Mpanda Nkuwa plant will be located about 60 km downstream of the Cahora Bassa Dam on the Zambezi River, and tenders have been launched for the selection of the transition adviser and project director.

In Zambia, the government in partnership with KfW has launched the GET FiT 100 MW Hydro Tender in 2018, to be awarded between 2019 and 2020.

In Zimbabwe, the Kariba South Bank expansion project was commissioned in March 2018, adding 150 MW of installed capacity to the grid. The newly commissioned unit, together the unit commissioned in 2017, will significantly reduce the country's power supply deficit.

In Cameroon, construction of the 200 MW Memve'ele project was completed and is nearly operational. The 420 MW Nachtigal project, the largest independent hydropower project in Sub Saharan Africa, reached financial close in 2018 (see country profile).

GHANA



Ghana has rich natural resources and significant hydropower potential. The energy sector today is a mixture of thermal, hydropower and small solar developments. Total grid electricity generation in 2018 was 14,069 GWh of which 4,991 GWh (39.2 per cent) was from hydropower. This is accounted for by three hydropower stations: Akosombo (1,020 MW), Kpong (160 MW) and Bui (404 MW). Hydropower makes up 40 per cent of total electric installed capacity.

The construction of Akosombo, commissioned in 1965, launched a revolution in the energy sector, expanding electricity access to the wider population and allowing exports of electricity to neighbouring countries. Hydropower generation has been since then an integral part of Ghana´s electricity mix, peaking in 2000 with 73 per cent of total installed electricity capacity. Over the last decade, electricity demand has grown rapidly, with a 52 per cent increase since 2008.

Ghana committed to universal access to electricity as far back as 1989 when only 15-20 per cent of the population had access to electricity. By 2016, this figure had risen to 82.5 per cent. Ghana is also participating in the United Nations Sustainable Energy for All (SE4ALL) initiative, which sets a universal access target for 2030.

The government is focusing on securing electricity supply by means of diversification, in order to deliver a more resilient and dynamic energy sector. The government's goal is to add 10 per cent of power supplied by non-hydro renewable energy sources by 2020. This renewable energy for electricity is expected to come mainly from solar, wind, biomass and municipal solid waste, but also smaller scale hydropower plants.

Despite the increase in generation capacity, which has outstripped demand, the country has experienced power supply shortages due to fuel supply challenges and high losses in the distribution system. In a 2018 World Energy Council survey, Ghana's energy leaders identified the energy-water nexus, along with corruption as critical uncertainties faced by the sector. Digitalisation and grid optimisation are now emerging as preferred solutions to address power shortages through improving efficiency.

Hydropower generation has declined in recent years because of low reservoir levels. In 2018, Akosombo had to operate three turbines out of the six units during off-peak periods and up to four turbines during peak periods in order to keep above its minimum operating level by the end of the dry season. Currently only about half the country's hydropower installed capacity is available.

From 2017 to mid 2018, Ghana was a net exporter of electricity. Improving interconnection lines is one of the country's policy priorities. Ghana Grid Company (GRIDCo) has agreed to build a new computerised maintenance management system to help optimise grid operations, which will help the country to continue supplying electricity to Burkina Faso.

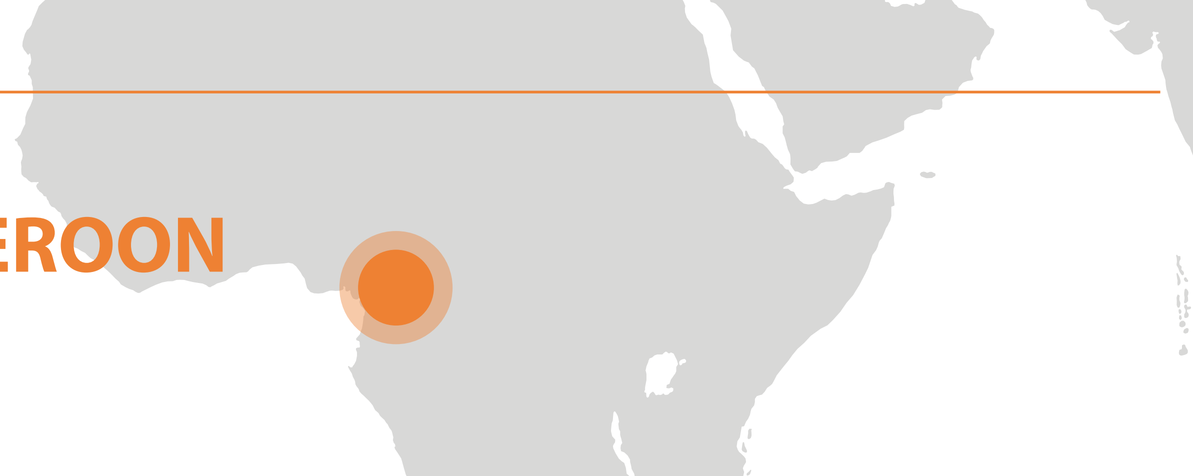
29.8 MILLION
POPULATION

1,584 MW
INSTALLED HYDROPOWER CAPACITY

4,991 GWh
HYDROPOWER GENERATION

40%
HYDROPOWER SHARE OF ELECTRIC POWER INSTALLED CAPACITY

CAMEROON



Cameroon has the third highest hydropower potential in Sub-Saharan Africa after the Democratic Republic of Congo and Ethiopia. Hydropower is currently the sole renewable energy source on the grid, accounting for 54 per cent of the country's total electricity installed capacity, while the remainder comes from thermal sources. The country also relies on off-grid diesel generation and small-scale hydropower for rural electrification.

With a rising population and the acceleration of industrial development, electricity demand is expected to triple to 5,000 MW by 2020, as compared to 1,455 MW in 2014.

Increasing energy access is central to Cameroon's goal to become a middle-income country and to reduce poverty levels below 10 per cent by 2035. In 2018, six out of 10 of Cameroonians had access to electricity, however access varies widely between urban and rural areas. To meet growing energy demand, the government has prioritised energy sector investment in the national budget and in its Vision 2035 development policy.

Domestic hydropower potential is estimated to be 23,000 MW, with 75 per cent of this capacity concentrated in the Sanaga River basin located in the north of the country. However only 3 per cent of Cameroon's hydropower potential has currently been exploited. Forecasts estimate that hydropower will represent about 75 per cent of the energy mix by 2023. In order to mitigate regular power shortages induced by water variations and insufficient energy supply, the government intends to maximise its renewable energy potential and generate 25 per cent of renewable energy from variable sources like solar and wind.

The 200 MW Memve'ele hydropower plant is nearly operational with construction work completed in 2017. The project will be connected to the national grid once transmission lines are completed. As of December 2018, the energy evacuation line was 55 per cent executed.

The Lom Pangar regulating dam, built in 2016, has enabled the regulation of seasonal flow fluctuations in the Sanaga River basin. This has boosted the annual generation of the Edéa and Songloulou hydropower plants by 700 GWh from 2015 to 2017and made possible construction of the 30 MW Lom Pangar project to improve rural electrification in the eastern region; the hydropower plant is expected to become operational in 2020.

The 420 MW Nachtigal hydropower project, the largest independent hydropower project in Sub Saharan Africa, has been developed by the Cameroonian government together with the International Finance Corporation and EDF Group. With construction already underway, the project will augment the country's electricity generation by 30 per cent (more than 2,900 GWh/year) when it begins operation in 2023. The combination of local and foreign currency financing is expected to minimise forex challenges and allow for low local tariffs, making the project economically sustainable.

Another major project under development is the 1,800 MW Grand Eweng project which will be the fourth largest hydropower plant in Africa following its completion in 2024. Other planned projects include Kpep (485 MW) and Makay (365 MW). With these projects, Cameroon will have added about 3,000 MW of hydropower capacity by 2025.

Cameroon's energy sector holds promising possibilities of development and diversification to explore alternative sources of renewables across the country and utilise its massive hydropower potential. The realisation of Cameroon's policy of economic emergence by 2035 will be greatly achieved from the ongoing hydropower development of the Sanaga River basin.

In April 2018, the National Electricity Transport Corporation (SONATREL) was granted sole charge of managing Cameroon's electricity transmission network which was previously managed by the private utility, Energy of Cameroon (ENEO). Its mission is to modernise and put in place new transmission lines and improve efficiency, given transmission losses are currently estimated at 40 per cent.

25.5 MILLION
POPULATION

747 MW
INSTALLED HYDROPOWER CAPACITY

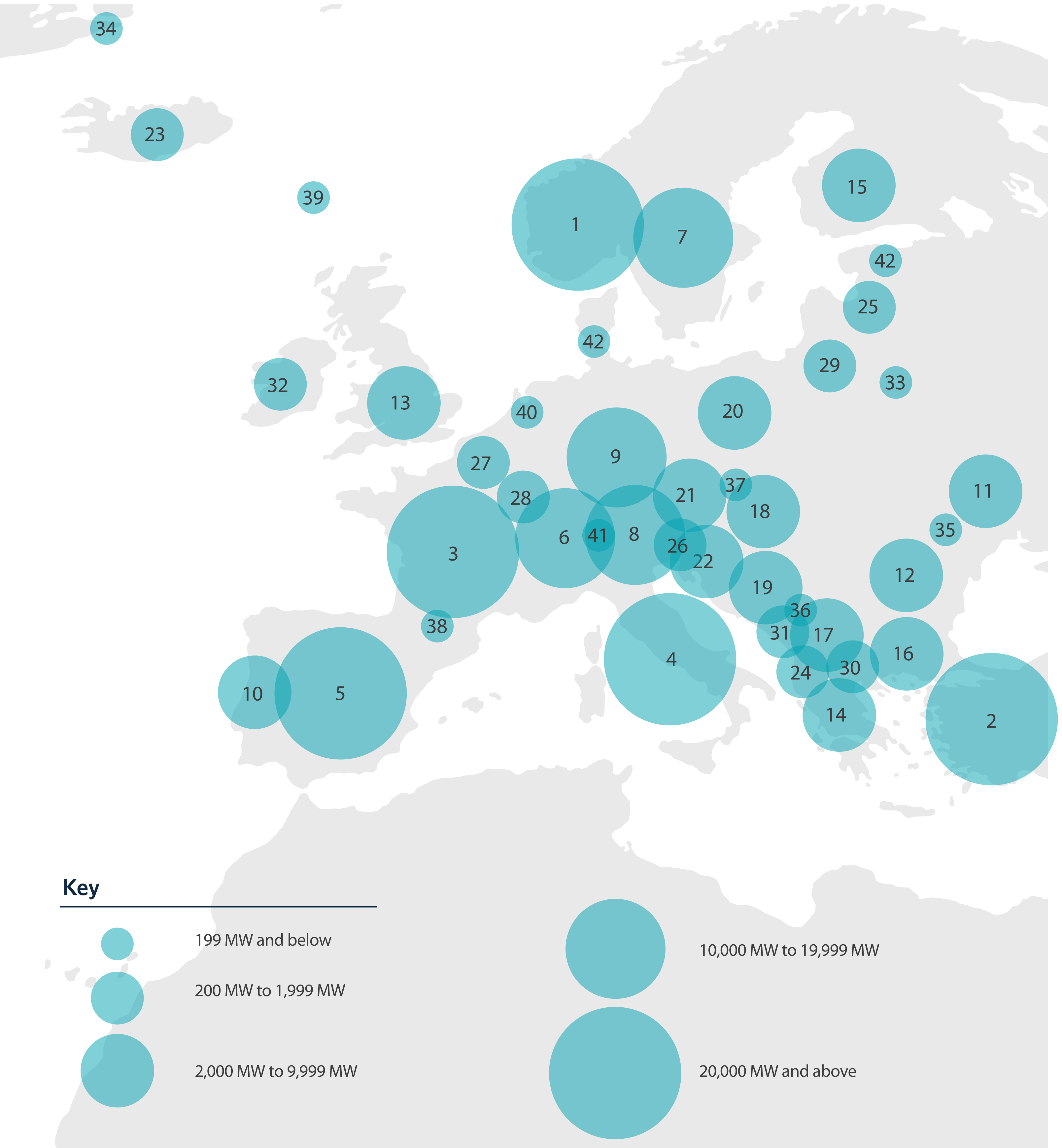
4,973 GWh
HYDROPOWER GENERATION

54%
HYDROPOWER SHARE OF ELECTRIC POWER INSTALLED CAPACITY

EUROPE

Kvilesteinsvatn dam, Vikafjellet, Norway.
Credit: Statkraft.

EUROPE INSTALLED CAPACITY



COUNTRIES BY ADDED CAPACITY IN 2018 (MW*)

1st	2nd	3rd	4th	5th
Turkey	Norway	Austria	Iceland	Italy
1,085	419	385	100	88

EUROPE CAPACITY BY COUNTRY*

Rank	Country	Total installed capacity (MW)	Rank	Country	Total installed capacity (MW)
1	Norway	32,256	22	Croatia	2,141
2	Turkey	28,358	23	Iceland	2,086
3	France	25,519	24	Albania	2,020
4	Italy	22,926	25	Latvia	1,576
5	Spain	20,378	26	Slovenia	1,524
6	Switzerland	16,948	27	Belgium	1,427
7	Sweden	16,466	28	Luxembourg	1,330
8	Austria	14,535	29	Lithuania	1,016
9	Germany	11,258	30	North Macedonia	674
10	Portugal	7,347	31	Montenegro	658
11	Ukraine	6,785	32	Ireland	529
12	Romania	6,328	33	Belarus	97
13	United Kingdom	4,712	34	Greenland	91
14	Greece	3,396	35	Moldova	76
15	Finland	3,236	36	Kosovo	68
16	Bulgaria	3,129	37	Hungary	56
17	Serbia	2,932	38	Andorra	45
18	Slovakia	2,522	39	Faroe Islands	39
19	Bosnia and Herzegovina	2,513	40	Netherlands	37
20	Poland	2,353	41	Liechtenstein	35
21	Czechia	2,268	42	Denmark	9

* including pumped storage

Europe

OVERVIEW

Hydropower in Europe continued to grow in 2018, with 2.2 GW added. The majority of new installed capacity occurred outside of the European Union, with 1,085 MW in Turkey and 419 MW in Norway. Within the EU, traditional hydropower mainstays Austria (385 MW) and Italy (88 MW) all increased their hydropower installed capacity, with remaining European countries adding a further 225 MW.

The bulk of Europe's renewable electricity is provided by hydropower. In 2018, hydropower generated an estimated 643 TWh (not including generation from pumped storage), which accounts for approximately 17 per cent of total generation. Wind and solar have grown considerably in the last 10 years, from nearly 64 GW and 16 GW in 2008 to 190 GW and 127 GW, respectively, in 2018, accounting for the vast majority of new installed generating capacity.

The substantial growth of renewables, coupled with the decommissioning of large-scale conventional synchronous generators, has put increased onus on hydropower's ability to provide flexibility in order to maintain secure, affordable and sustainable energy supply under the EU's Framework Strategy for the Energy Union. Launched in 2015, the Energy Union drives regional energy and climate policies.

In late 2018, the European Commission presented its strategy for a climate neutral Europe by 2050, and followed up three months later with a pledge to invest over EUR 10 billion in innovative clean technologies under its Innovation Fund for climate action, starting in 2020. The Innovation Fund seeks to enable innovative low-carbon technologies and processes, including renewable energy generation and energy storage.

The Innovation Fund complements the EU's ongoing Horizon 2020 programme which supports the Hydropower-Europe initiative, launched in early 2019 to develop a research and innovation agenda and strategic innovation roadmap for hydropower.

European electricity grids have increased their level of interconnection in recent years, and there are plans to further enhance cross-border power transmission capacities through the EU's Trans-European Networks for Energy (TEN-E) strategy. This builds upon the EU's 2014 objective that EU members should have international transmission interconnection capacity of at least 10 per cent of total domestic generation capacity by 2020. Germany's power system, already connected to 12 other power systems, is still seeking to expand (see country profile).

In 2018, Turkey added over 1 GW of new hydropower capacity in a bid to meet growing power demand, over 5.5 per cent annually on average since 2002, and to reduce reliance on energy imports. Turkey connected the 625 MW Upper Kaleköy project in 2018, making it the country's seventh largest hydropower project. Located in the east of the country, the project is one of a cascade of six projects along the Murat River, including the 580 MW Beyhan 1 project completed in 2015, and the 500 MW Lower Kaleköy project scheduled for completion in 2020. In the same region, Turkey also commissioned the 140 MW Kiğı project during 2018.

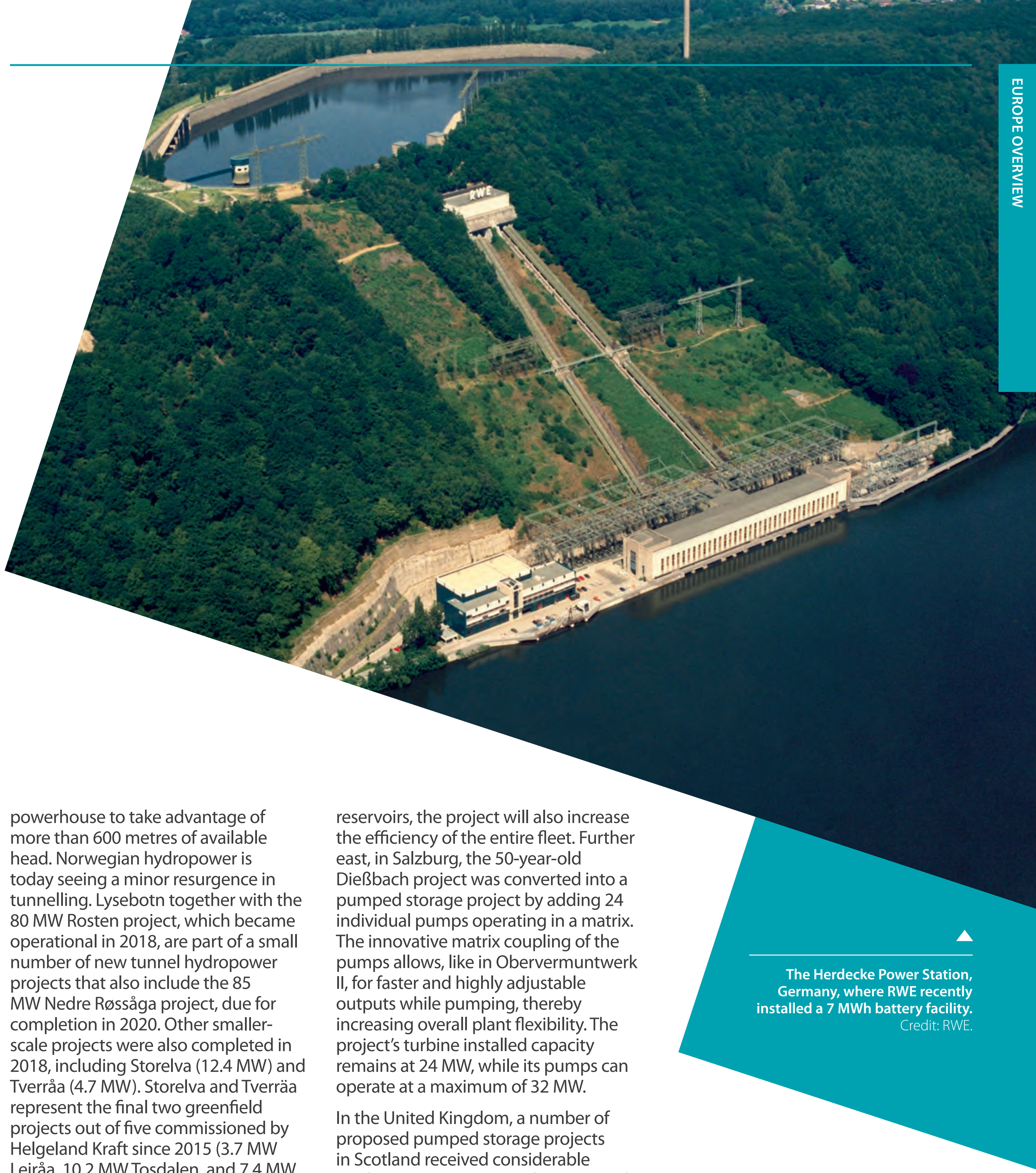
Norway completed the replacement of the 210 MW Lysebotn plant, first commissioned in 1953, with a new 370 MW project named Lysebotn II, making it one of the larger projects in the country. The project involved constructing a new underground powerhouse to take advantage of more than 600 metres of available head. Norwegian hydropower is today seeing a minor resurgence in tunnelling. Lysebotn together with the 80 MW Rosten project, which became operational in 2018, are part of a small number of new tunnel hydropower projects that also include the 85 MW Nedre Røssåga project, due for completion in 2020. Other smaller-scale projects were also completed in 2018, including Storelva (12.4 MW) and Tverråa (4.7 MW). Storelva and Tverräa represent the final two greenfield projects out of five commissioned by Helgeland Kraft since 2015 (3.7 MW Leiråa, 10.2 MW Tosdalen, and 7.4 MW Bjørnstokk).

Austrian pumped storage developers completed two expansion projects in 2018. In the west, the 360 MW Obermuntwerk II project employs a ternary configuration of individual pumps and turbines (each 180 MW), which are highly flexible and allow for faster-responding, operation over a broader range, allowing the project to better respond to modern grid requirements arising from variable wind and solar. Utilising waters in the already existing Silvretta and Vermunt reservoirs, the project will also increase the efficiency of the entire fleet. Further east, in Salzburg, the 50-year-old Dießbach project was converted into a pumped storage project by adding 24 individual pumps operating in a matrix. The innovative matrix coupling of the pumps allows, like in Obervermuntwerk II, for faster and highly adjustable outputs while pumping, thereby increasing overall plant flexibility. The project's turbine installed capacity remains at 24 MW, while its pumps can operate at a maximum of 32 MW.

In the United Kingdom, a number of proposed pumped storage projects in Scotland received considerable media attention in 2018. The proposed projects look to provide balancing services for Scottish off-shore windfarms, and many of these will use existing infrastructure. France is also pursuing increased energy storage deployment, targeting 10 GW of new storage by 2035 (see country profile).

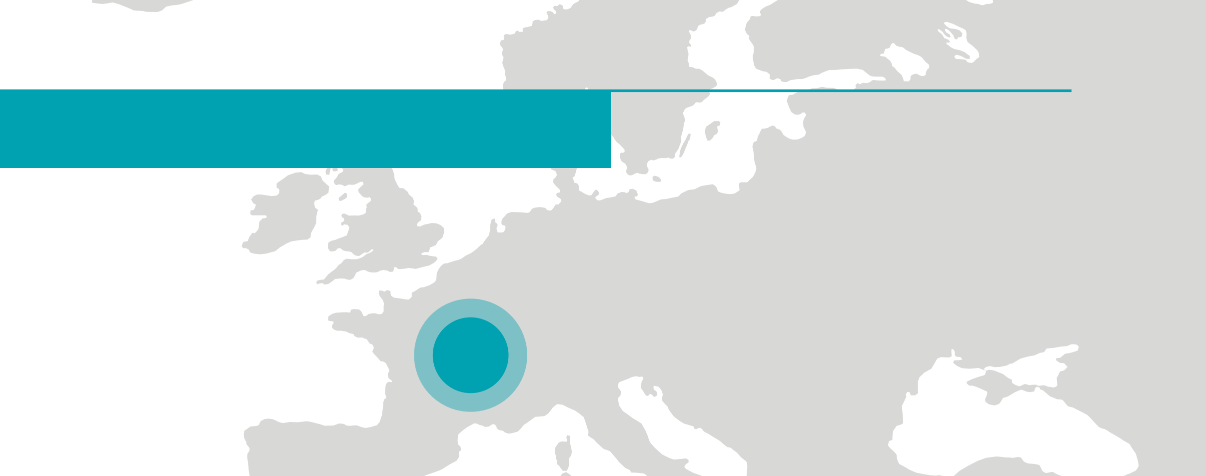
After two years of construction, Iceland completed the 100 MW Búrfell II project, which utilises water from the reservoir of the existing Burfell project in order to maximise exploitation of strong flows from the Þjórsá River. The station consists of a single 100 MW turbine, but future plans anticipate a 40 MW addition.

Slovenia commissioned the 45 MW Brežice project during 2018. It is the fourth of a five-project cascade along the Sava River, which include the already completed Boštanj, Blanca and Krško projects and the planned 28 MW Mokrice project, a further 10 kilometres downstream.



The Herdecke Power Station, Germany, where RWE recently installed a 7 MWh battery facility. Credit: RWE.

FRANCE



Thanks to its large share of hydropower and nuclear energy, France has achieved an absolute decoupling of its greenhouse gas emissions from GDP growth since 2005, as emissions have either held steady or reduced as the economy has grown. In 2018, nuclear energy made up 71 per cent of the country's power generation, while hydropower represented 10 per cent.

The country's 25.5 GW of installed hydropower capacity, including 5 GW of pumped storage, makes it the third largest European producer of hydroelectricity behind only Norway and Turkey. Despite recent rapid growth in solar and wind supply, hydropower continues to make up over half of renewable energy supply.

The 2015 Energy Transition for Green Growth Act (LTECV) set ambitious goals for France's energy transition, targeting 40 per cent of electricity generation to be sourced from renewables by 2030, up from 18.4 per cent in 2018. The ETL mandates a Multiannual Energy Programme (PPE) to assign compulsory installed capacity targets for each generation technology.

In 2018, the first revision to the PPE announced objectives for energy storage projects with the following: the closure of all coal plants by 2022; tripling wind generating capacity; increasing solar capacity fivefold by 2030; and decommissioning France's nuclear assets to reduce nuclear generation by 50 per cent by 2035. The PPE targeted an increase of hydropower installed capacity by roughly 500 MW to 26.05 GW by 2023.

As the new plan forecasts 35 per cent of variable renewable electricity supply in 2035, compared to only 5 per cent today, hydropower is poised to play a central role in meeting the flexibility needs of the evolving electricity system. Hydropower currently provides approximately 50 per cent of France's power system flexibility, and pumped storage still dominates the country's storage landscape.

In March 2018, EDF unveiled its EUR 8 billion new energy storage plan of more than 10 GW of new storage by 2035, which includes provisions for up to 2 GW of new pumped storage, in line with the previous PPE's target of adding 1 to 2 GW of pumped storage between 2025 and 2030.

In France, hydropower generation facilities greater than 4.5 MW in capacity are operated under concessions awarded by the French state, which allows companies to operate facilities for a set period of time. Among these plants, more than 80 per cent are operated by EDF and 15 per cent by Engie. Despite uncertainty in the renewal of hydropower concessions, EDF and other French operators continue to invest significantly in the maintenance and renovation of their hydropower assets. In 2015 the European Commission launched a legal proceeding against France to ensure "competitive bidding for hydroelectric concessions". The French authorities are still in discussion with the EU to close this case.

Despite the uncertain environment, major hydropower projects have been launched in recent years. As part of the PPE, 2018 saw the announcement of the winners of 37 MW out of the 105 MW of hydropower capacity tendered.

EDF is currently constructing the 92 MW Romanche-Gavet hydropower plant, which will replace the six powerhouses and five dams in the valley and increase production by 30 per cent. The first turbine commissioning is expected in 2019, and the project will be completely online in 2020. In addition, the 330 MW La Coche pumped storage plant is currently undergoing upgrades to add a 240 MW Pelton turbine, making it the most powerful of its type in France; the upgrading is expected to be completed in 2019, which will increase production by 20 per cent.

Major regional interconnection projects achieved significant milestones in 2018. In July, a EUR 578 million grant agreement was signed to strengthen the energy interconnection between France and Spain, which aims to increase interconnection capacity between both countries to 5,000 MW.

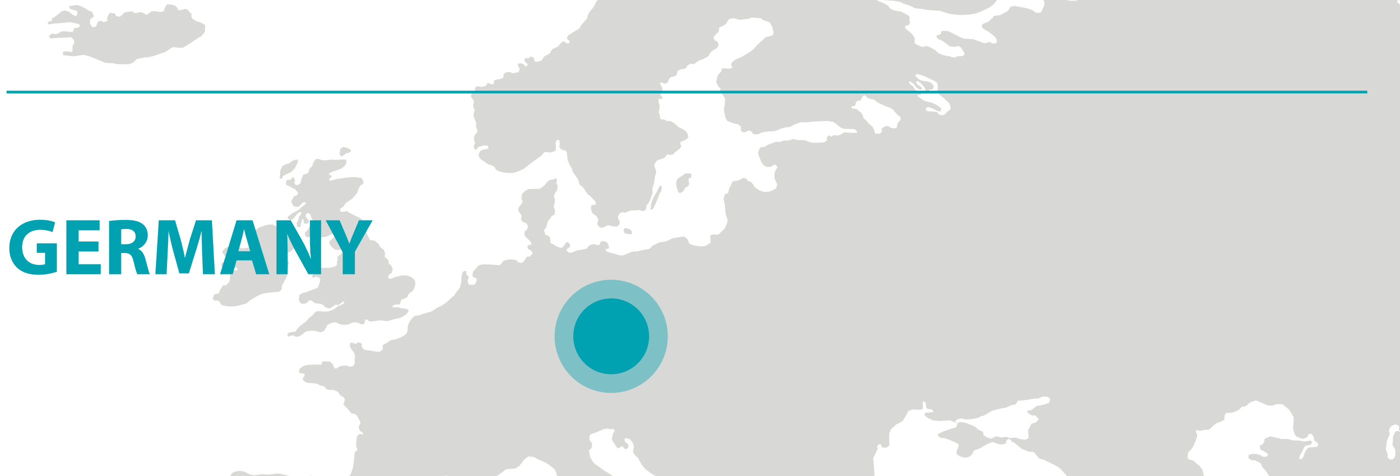
67.2 MILLION
POPULATION

25,519 MW
INSTALLED HYDROPOWER CAPACITY

63,100 GWh
HYDROPOWER GENERATION

19.5%
HYDROPOWER SHARE OF ELECTRIC POWER INSTALLED CAPACITY

GERMANY



Germany, Europe's largest economy, has a rich hydropower heritage and is at the vanguard of the transition to renewable power systems. Germany's Energiewende policies – targeting a shift towards renewable energy, greenhouse gas emissions reductions, and a phase-out of nuclear energy – resulted in renewables contributing 35.2 per cent of electricity generation in 2018, roughly the same as coal. Due to drought, hydropower generation dropped almost 15 per cent, and contributed 2.6 per cent of total power production, accounting for just over 7 per cent of total generation from renewables. The majority of the country's hydropower resources are located in the mountainous southern provinces, with 50 per cent of all projects located in Bavaria and 20 per cent in Baden-Württemberg. These two states account for over 80 per cent of annual German hydropower production. Of an estimated 7,300 hydropower stations, about 6,900 have less than 1 MW capacity, while nearly 6,000 have less than 100 kW.

As deployment of wind and solar continues to grow, flexibility will become a key criterion for the next phase of Germany's energy transition. Hydropower, despite occupying only a small proportion of the energy mix, will remain a system cornerstone due to its relative reliability and predictability. German flexibility services, whether coming from interconnections to neighbouring grids, energy storage, flexible generation or demand-side management all depend on hydropower resources in some fashion.

Germany has twelve 'electrical neighbours' with interconnectors totalling roughly 20 GW. To the north, Germany can tap into Nordic hydropower reservoirs. The 1,400 MW HVDC subsea cable with Norway, Nordlink, is expected to be completed in 2019 and will allow Norwegian hydropower reservoirs to absorb excess German wind and supply hydropower. To the south, hydropower-rich Austria and Switzerland contribute over 3.5 GW of hydropower to Germany's system.

Until October 2018, Germany, Austria and Luxembourg shared a common power price-bidding zone, allowing for unlimited commercial exchange of power between the grids. Bottlenecks in Germany's north-south transmission grid, however, were causing problems and knock-on effects to neighbouring countries.

In 2018, the EU split the common price-zone at the German – Austrian border, giving Germany time to build the necessary north-south connectors. Nevertheless, Austrian hydropower projects will continue to support the German grid, constrained only by the physical capacity of their interconnectors. Austrian pumped storage projects will still have access to the German grid, including the 360 MW Obervermuntwerk II pumped hydropower project in Vorarlberg, commissioned in 2018.

Germany itself has 6,806 MW of installed pumped storage capacity, but the German grid is serviced by a further 3 GW sourced from Luxembourg, Switzerland and Austria. These pumped storage projects still provide the lion's share of utility-scale power storage, storing 8 TWh of power in 2015. Policy makers are aware that reforms are needed to continue to support storage facilities. The influx of low-marginal cost wind and solar has altered electricity price dynamics with consequences on business models for PHS operators.

In spite of outdated regulatory frameworks, both Engie Germany and RWE deployed innovative batteries coupled with their pumped storage projects in 2018. In addition to upgrading the Pfreimd project, Engie installed onsite a 12.5 MW lithium-ion battery to provide additional rapid frequency balancing services. This augments the already significant balancing role of the project, which itself is responsible for 5 per cent of all balancing power delivered to Germany's grid network and 1 per cent of total balancing power in Western Europe. RWE installed a 7 MWh battery facility at their Herdecke Power Station.

82.7 MILLION
POPULATION

11,258 MW
INSTALLED HYDROPOWER CAPACITY

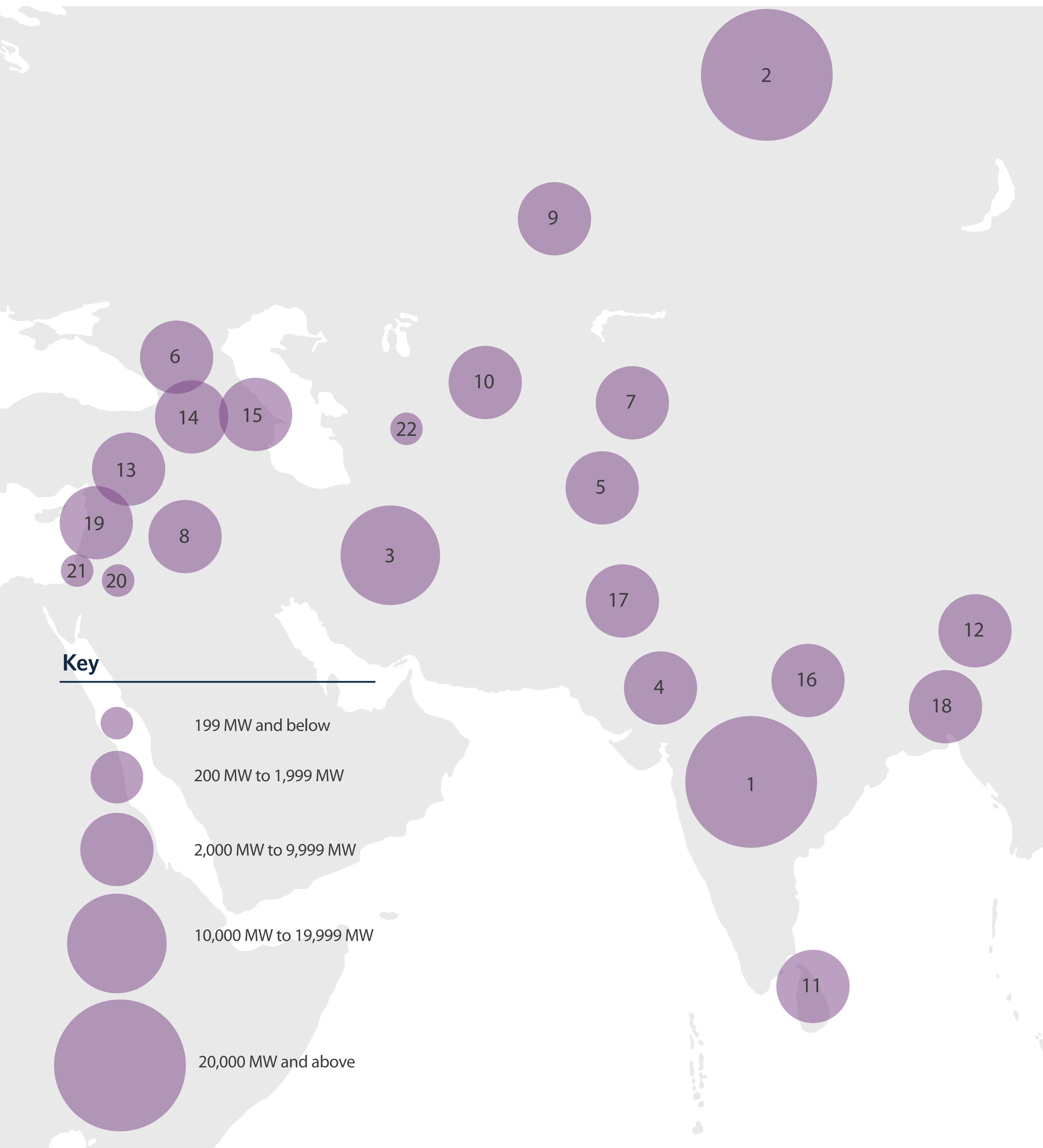
16,290 GWh
HYDROPOWER GENERATION

2.7%
HYDROPOWER SHARE OF ELECTRIC POWER INSTALLED CAPACITY

SOUTH AND CENTRAL ASIA

The Krasnoyarsk hydropower plant on the Yenisey River in Russia.
Credit: En+ Group.

SOUTH AND CENTRAL ASIA INSTALLED CAPACITY



COUNTRIES BY ADDED CAPACITY IN 2018 (MW*)

1st	2nd	3rd	4th	5th
Pakistan	Tajikistan	India	Iran	Nepal
2,487	605	535	140	71

SOUTH AND CENTRAL ASIA CAPACITY BY COUNTRY*

Rank	Country	Total installed capacity (MW)
1	India	49,917
2	Russia	48,506
3	Iran	11,951
4	Pakistan	9,827
5	Tajikistan	5,795
6	Georgia	3,221
7	Kyrgyzstan	3,091
8	Iraq	2,753
9	Kazakhstan	2,561
10	Uzbekistan	1,731
11	Sri Lanka	1,719
12	Bhutan	1,615
13	Syria	1,505
14	Armenia	1,249
15	Azerbaijan	1,122
16	Nepal	1,016
17	Afghanistan	461
18	Bangladesh	230
19	Lebanon	221
20	Jordan	12
21	Israel	7
22	Turkmenistan	1

* including pumped storage

South and Central Asia

OVERVIEW

Hydropower installed capacity grew by 3.96 GW across South and Central Asia in 2018, which continues a similar growth trend seen last year. Pakistan accounted for the majority of new capacity added, while Tajikistan passed a key milestone with the first unit of the Rogun hydropower project entering into operation. India also announced a major new energy policy, formally recognising large hydropower projects above 25 MW as renewable and setting hydropower purchase obligations for utilities.

Completion of the Tarbela Fourth Extension Hydropower Project in Pakistan was the largest addition in this region. Situated on the Indus river, the extension added 1,410 MW to the existing 3,478 MW Tarbela hydropower complex from three new units commissioned in 2018, bringing the site's installed capacity to 4,888 MW. The Water and Power Development Authority (WAPDA) also announced that the 969 MW Neelum Jhelum and 108 MW Golen Gol hydropower projects went into operation. Together these projects grew Pakistan's hydropower sector by over 25 per cent last year alone, underlining its vital contribution to meeting the country's electricity needs.

Neighbouring countries in South Asia are looking to advance opportunities from hydropower development. In Bhutan, the 720 MW Mangdechhu project is close to completion and, upon entering service, which is planned for 2019, will expand total grid supplies by almost 50 per cent. India, which led the region's hydropower growth in 2017, counted a net increase of 535 MW in 2018 due to the addition of several new hydropower units and existing asset upgrades. The Indian government has also given a welcome boost to hydropower after announcing that large hydropower projects would be recognised as part of the Renewable Purchase Obligations (RPO) scheme, together with small-scale hydropower which was already covered.

There has also been increasing attention on cross-border electricity trade in the subcontinent between several countries in South Asia's Association for Regional Cooperation (SAARC). For example, Nepal and Bhutan have each signed agreements with India to sell power generated from upcoming hydropower projects, and in 2018 Bangladesh agreed to a new power deal with Nepal. At the end of 2018, India issued new guidelines making provisions for neighbouring countries to transfer power via its national grid to a third country, representing a major breakthrough for regional power trade.

In Central Asia, further to significant progress on Tajikistan's Rogun project, modernisation programmes of large, existing hydropower stations are moving ahead as well as new capacity in the pipeline. A major contract was awarded at Kyrgyzstan's largest and oldest facility, Toktogul, which will increase plant capacity from 1,200 to 1,440 MW. In Kazakhstan 61.5 MW of new hydropower capacity was successfully auctioned in 2018, and state-owned Samruk-Energy put the first modernised unit at the Shardarinsk plant back into operation.

The 456 MW Upper Tamakoshi Hydropower Project is under construction in Nepal. Credit: Government of Nepal.

Across the border, UzbekHydroEnergo has plans to develop new stations and modernise Uzbekistan's existing fleet, most of which was built between 30 to 80 years ago. Additionally one of four turbines at the largest facility in Afghanistan, the 100 MW Naghlu plant, was brought back online in 2018 after six years out of service.

Regional interconnections continue to play an important role in Central Asia. For instance Tajik-Uzbek power flows were restored in 2018, with added financing plans to reconnect Tajikistan's grid to the once-unified Central Asian Power System (CAPS). Countries involved in the CASA 1000 project to interconnect Kyrgyzstan, Tajikistan, Afghanistan and Pakistan have also made progress in procuring construction contracts.

In Russia, hydropower made up approximately 17 per cent of overall electricity generated in 2018, where modernisation of the installed hydropower fleet is regarded to be a priority. In Siberia, turbine repairs and upgrades were completed at the 3,840 MW Ust-Ilimsk station, improving performance, and are now underway at the 662 MW Irkutsk and 6,000 MW Krasnoyarsk facilities. New capacity has been installed at the Ust-Srednekans plant in the far northeast of Russia totalling 310 MW in 2019, whereas in western Russia the 1,375 MW Saratov station is undergoing modernisation and the 346 MW Zaramagskaya-1 is under construction near the Georgian border.

Ageing hydropower stations in the South Caucasus are being modernised, with notable investments in the 1,300 MW Enguri dam in Georgia and the 424 MW Mingachevir modernisation completed in Azerbaijan in 2018.

In Georgia, hydropower generated almost 10 TWh in 2018, making up 82 per cent of the country's total generation mix. Added installations in 2018 included the 27 MW Kirnati and 21 MW Old Energy hydropower stations along with smaller-scale projects, while a portfolio of assets is at the planning stage. This includes the 433 MW Namakhvani project being developed by the privately-held Clean Energy Group Georgia, which when complete, promises to raise electricity generation in the country by 15 per cent.

In Iran, new hydropower units are coming online. The last two units at the 210 MW Daryan hydropower station were synchronised to the grid in 2018. The Daryan facility, located in Kermanshah province close to Iran's western border, includes a multi-purpose reservoir providing irrigation to areas of southwest Iran. The Sardasht project in West Azerbaijan province and the Bakhtiari project on the border of Lorestan and Khuzestan provinces are under construction and when complete will add 1,650 MW to the country's capacity. Droughts have however affected the Middle East in recent years impacting hydropower production, with lower reservoir levels reported in Iran in summer 2018 compared to previous years.

NEPAL

With approximately 1 GW of installed capacity, hydropower provides almost all of Nepal's domestic electricity generation on the grid. The economy is experiencing rising power demand, with forecasts that it will more than double by 2025 compared to 2018, making clear the need for new capacity.

According to its annual report, the public-owned Nepal Electricity Authority (NEA) owns 50 per cent of the country's hydropower assets and the other 50 per cent is owned by independent power producers (IPPs). Additions in 2018 included the 30 MW Chameliya hydropower plant. The run-of-river project was inaugurated by the former Prime Minister of Nepal, Sher Bahadur Deuba, in February 2018, marking the end of a 10-year long development period.

Recently commissioned IPPs include the 13.6 MW Thapa Khola hydropower plant, commissioned at the end of 2017, and the 13 MW Madkyu Khola project which came online in 2018, alongside smaller plants. The new Dhalkebar-Muzaffarpur transmission line from Nepal to India was also commissioned in 2018, giving a welcome boost to Nepal's power system.

Thanks to new capacity and greater imports from India at peak times, the NEA was able to end the power shortages and load shedding that had affected Nepal for a decade. Work to expand the existing electricity network however will be critical to provide 100 per cent of the population with access to grid electricity, compared to the 70 per cent reported last year, while also reducing use of off-grid diesel generation.

These steps are part of the government's ambitious plans to reach 5 GW total hydropower capacity over the next five years, as recently set out in a white paper by the Ministry of Energy, Water Resources and Irrigation. Nepal is also looking to improve the governance of its electricity sector, including establishing a new Electricity Regulatory Commission (ERC) which would help increase private sector investment.

There are several ongoing hydropower developments due to come online in the next couple of years. Construction of the 456 MW Upper Tamakoshi project near the border with Tibet is close to completion. The run-of-river plant will be the country's largest hydropower station expanding national capacity significantly and has been fully funded by domestic sources including the NEA and other local organisations. The first unit aims to start production at the end of 2019. The 60 MW Upper Trishuli 3A hydropower and 14 MW Kulekhani III plants are also both expected to be completed in 2019, with a series of other public and private construction projects planned.

Most of Nepal's existing hydropower stations are run-of-river schemes, meaning power generation is impacted by seasonal rainfall patterns. With further large run-of-river projects in the pipeline, there is a need to manage surplus power produced during the monsoon months (typically from around May to October), while facing deficits in the dry seasons. To address this, the NEA is planning storage schemes including the 140 MW Tanahu project and other, larger reservoir projects. This infrastructure will play an important role in regulating the power system and managing water resources.

The Nepali government is also looking to greater regional interconnection to help balance supply and demand. As a member of the South Asian Association for Regional Cooperation (SAARC), Nepal has access to the region's electricity markets and is looking to expand its power trading agreements with India, as well as other countries such as Bangladesh and China.

Interconnections exist along the border with India at various locations. The cross-border Dhalkebar–Muzaffarpur line is currently operating at the 220kV level and will be charged at 400kW once the 400kV substation at Dhalkebar is completed. A second cross-border transmission project, the 400 kV Butwal-Gorakhpur line, is also at the advanced stage of preparation, which will expand flow capacity and support large-scale hydropower developments in Nepal with new export routes.

30 MILLION
POPULATION

1,016 MW
INSTALLED HYDROPOWER CAPACITY

3,900 GWh
HYDROPOWER GENERATION

95%
HYDROPOWER SHARE OF ELECTRIC POWER INSTALLED CAPACITY

TAJIKISTAN

With mountains covering 93 per cent of the country and vast natural water reserves, Tajikistan has significant hydropower potential. Investment in existing and new energy infrastructure has been a strategic priority for the government and significant progress was made in 2018.

President Emomali Rahmon inaugurated the first of six turbines at the 3,600 MW Rogun hydropower scheme, which began operations in 2018, adding a much needed 600 MW of capacity to the grid. The dam height was reported to reach 75 metres at the end of 2018 and will be the world's tallest at 335 metres upon completion in 2032.

Construction of the Rogun scheme originally began in 1976 but was stalled for decades due to political instability, civil war, floods and financial setbacks. Construction restarted in 2016 following a push from the Tajik government and support from neighbouring Uzbekistan after it dropped its objections. When fully commissioned Rogun will represent a landmark achievement and ensure hydropower continues to fulfil Tajikistan's electricity needs, alleviating shortages and raising export opportunities to surrounding countries.

Achieving energy independence by 2030 is one of Tajikistan's priority policy objectives, as reflected in the country's National Development Strategy. The Ministry of Energy and Water Resources is targeting an increase in total generating capacity to 10 GW, as well as reduced network losses and greater power exports. To achieve this, measures have been introduced to attract foreign funding, including tax exemptions, legal rights and guarantees in hydropower construction.

A World Bank study released in 2018 described the Rogun scheme as the 'centrepiece' of Tajikistan's development strategy and highlighted its role in spurring economic growth. However to ensure completion of the scheme and realise the country's development objectives, the study also called for structural reforms to ensure a more sustainable business environment.

Most of Tajikistan's main hydropower plants are installed along the Vakhsh River downstream of Rogun. This includes the 3,000 MW Nurek dam, currently the tallest in Central Asia, operated by national utility Barqi Tojik. Commissioned in the 1970s, a major contract was awarded in 2018 to replace all nine power units with new 380 MW Francis turbines and generators, expected to increase total output by 12 per cent. The first unit of the Golovnaya hydropower station was also put back into service in 2018, as part of an ongoing modernisation programme looking to raise plant capacity from 240 MW to 270 MW.

Further north in the Sughd region, the 127 MW Qairokkum hydropower plant on the Syr Darya, built even earlier in the 1950s, has secured investment for replacements and repairs. Financing from international funds will assist in raising plant capacity to 174 MW and include measures to improve climate resilience.

Adapting hydropower facilities to manage greater climate extremes is becoming a global issue, particularly for countries like Tajikistan that are vulnerable to climatic and hydrologic variability. The funding package will bolster the operator's capabilities and working practices in climate risk management based on international good practice.

Alongside hydropower, development of the grid network is a focus for the government. With diplomatic relations much improved in recent years, Tajik-Uzbek transmission lines were restored in April 2018 allowing annual export of up to 1.5 TWh to Uzbekistan. In addition, the CASA 1000 project is progressing and will bolster regional trading opportunities with Afghanistan and Pakistan once completed.

In the eastern region of Tajikistan, known as Gorno-Badakhshan Autonomous Oblast (GBAO), an international initiative has supported repairs and installations of small-scale hydropower. The Aga Khan Fund for Economic Development (AKFED) set up a public-private partnership to assume responsibility for existing units and build new local hydro. These efforts were recognised in 2017 for expanding energy access in the GBAO region, after a reported 96 per cent of households had achieved access to reliable and clean energy supplies.

9 MILLION
POPULATION

5,795 MW
INSTALLED HYDROPOWER CAPACITY

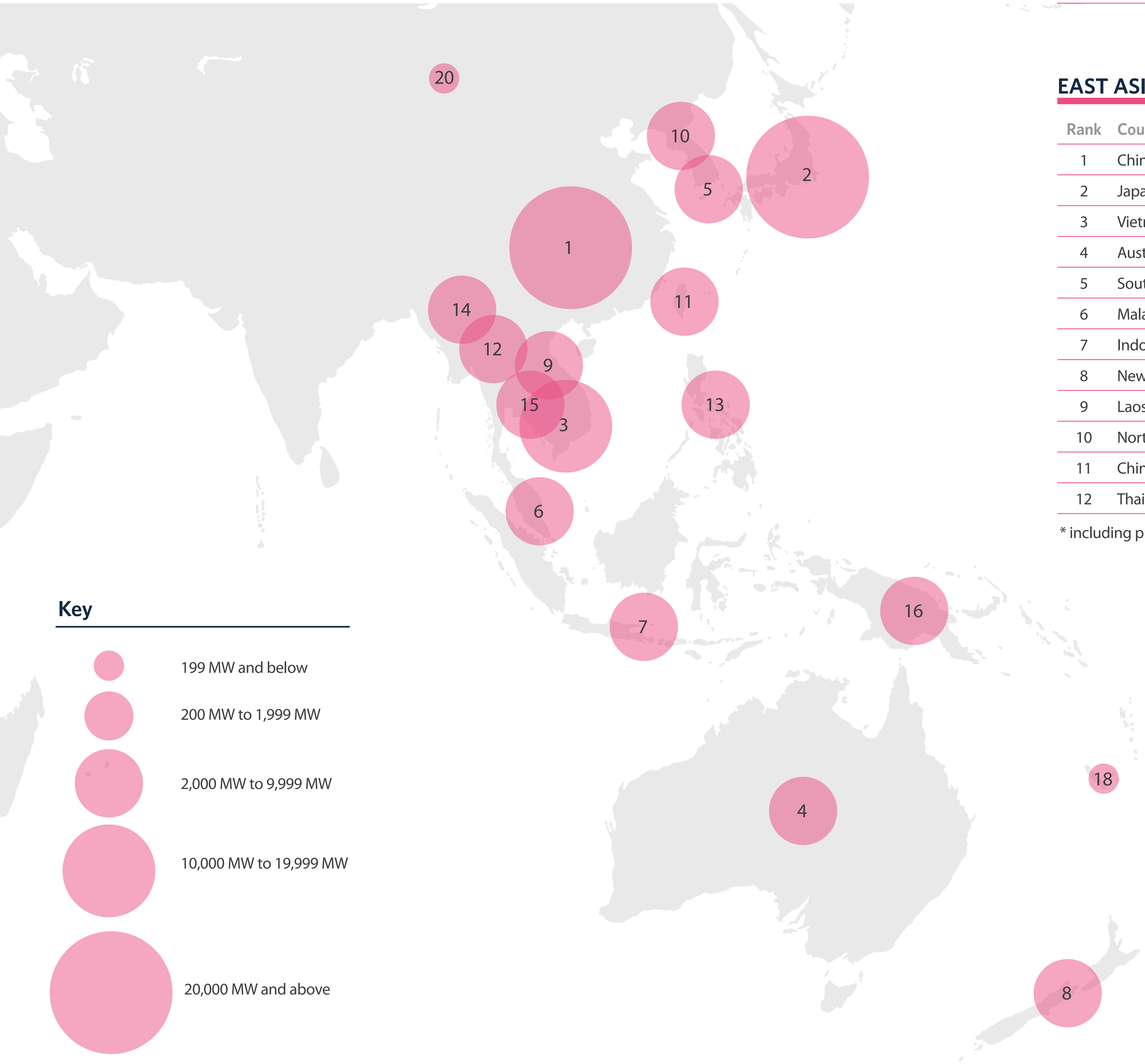
17,738 GWh
HYDROPOWER GENERATION

95%
HYDROPOWER SHARE OF ELECTRIC POWER INSTALLED CAPACITY

EAST ASIA AND PACIFIC

Baihetan hydropower project under construction.
Credit: China Three Gorges.

EAST ASIA AND PACIFIC INSTALLED CAPACITY



COUNTRIES BY ADDED CAPACITY IN 2018 (MW*)

1st	2nd	3rd	4th	5th
China	Cambodia	Laos	Indonesia	North Korea
8,540	300	254	61	10

EAST ASIA AND PACIFIC CAPACITY*

Rank	Country	Total installed capacity	Rank	Country	Total installed capacity
1	China	352,260	13	Philippines	4,314
2	Japan	49,905	14	Myanmar	3,331
3	Vietnam	16,679	15	Cambodia	1,667
4	Australia	8,790	16	Papua New Guinea	234
5	South Korea	6,490	17	Fiji	125
6	Malaysia	6,094	18	New Caledonia	78
7	Indonesia	5,511	19	French Polynesia	47
8	New Zealand	5,346	20	Mongolia	23
9	Laos	5,308	21	Samoa	12
10	North Korea	5,010			
11	Chinese Taipei	4,691			
12	Thailand	4,510			

* including pumped storage

OVERVIEW

The East Asia and Pacific region continued to be the engine room of the world's hydropower sector in 2018, having added 9.2 GW of installed capacity, more than any other region. China accounted for most of the capacity additions with 8.54 GW added, including 1.5 GW of pumped storage. Excluding China, over 650 MW was added in the region.

China's installed capacity passed 350 GW in 2018 with several projects, mainly located in the country's south-west entering into operation. The need to reduce renewables curtailment, including hydropower, remains high on the government's agenda having issued the Clean Energy Consumption Action Plan 2018-2020. The plan emphasised the importance of reforming China's electricity market, improving provincial interconnections, increasing energy storage (including pumped storage) and enhancing power system flexibility.

Outside of China, significant activity took place in the Greater Mekong region, notably in Myanmar where after some delay the government issued a notice to proceed for both the 1,050 MW Shweli 3 and the 60 MW Deeoke projects. Shweli 3 in Shan State is considered to be a priority project in order to meet the energy needs of the country over the medium term and will be developed by a consortium led by French utility EDF. The International Finance Corporation also released a Strategic Environmental Assessment (SEA) of Myanmar's hydropower sector, the culmination of a two-year process, which is seeking to help guide sustainable hydropower development with a strong focus on the need for basin-level planning.

Laos commissioned a further 254 MW in capacity, but the sector experienced a very difficult year due to the collapse of Xe-Pian Xe-Nam's saddle dam in July 2018. Following the collapse, the Laotian government announced an investigation into its causes, a review of all existing and under-construction dams and a halt to proposed projects. The government also established a centre for dam safety management in order to prevent such incidents occurring in the future.

In Indonesia on the island of Sumatra the 56 MW Semangka project was commissioned in December 2018. Developed by two South Korean companies, together with local partners the run-of-river project will help displace fossil fuel fired power plants which dominate Sumatra's electricity grid. With up to 6 GW of capacity either under construction or in the planning stages, hydropower is playing a key role in supporting the Indonesian government's aim to increase the share of renewables in the country's total energy use to 23 per cent by 2025 from 13 per cent in 2018.

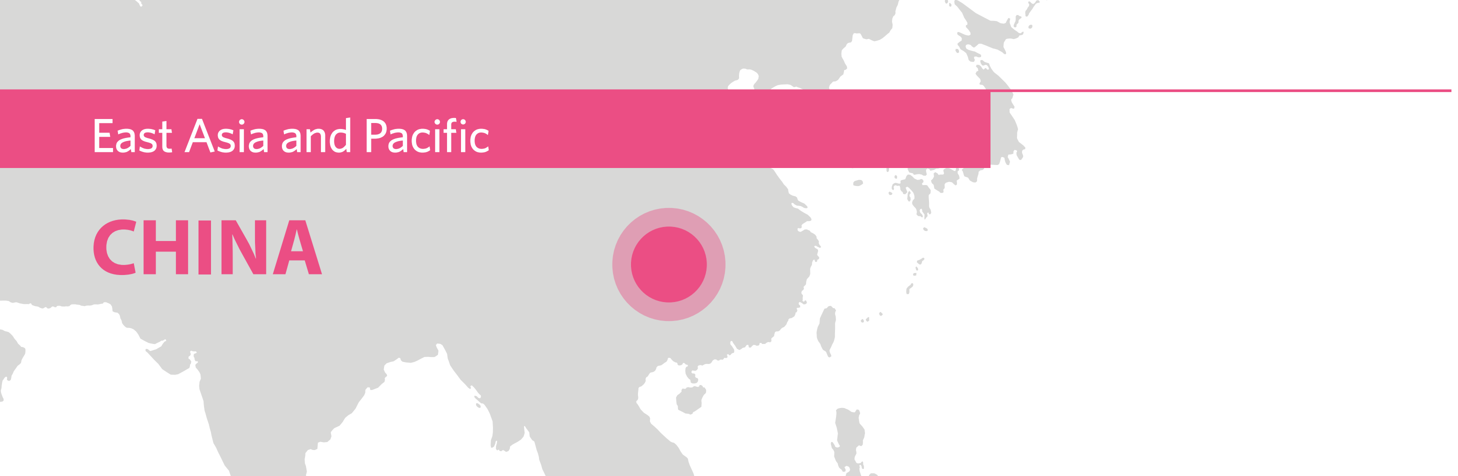
Australia continued to progress with the development of several pumped storage projects, most notably Snowy Hydro's 'Snowy 2.0' project and Tasmania's 'Battery of the Nation' initiative. In late 2018, the board of Snowy Hydro approved a final investment decision to proceed with the project and in early 2019 its sole shareholder, the Australian Government followed suit. To be completed by 2025, Snowy 2.0 will provide an additional 2,000 MW of capacity and up to 175 hours of storage. Tasmania's hydropower resources were identified by the state and federal government as an important future source of providing more flexible, reliable and dispatchable renewable energy to a transforming National Electricity Market with greater interconnection capacity to the mainland. In June 2018, Hydro Tasmania identified 14 options that represent 4,800 MW of cost-effective pumped storage potential and these options are now being investigated further to identify sites that could deliver an additional 2,500 MW of capacity.

In the Pacific, the Papua New Guinea Electrification Partnership was formed to support the aim of providing power to 70 per cent of the country's population by 2030, up from around 13 per cent in 2018. Backed by the government, as well as Australia, Japan, New Zealand and the United States, the USD 1.7 billion initiative will help fund new generation capacity as well as transmission and distribution lines throughout the country, which has significant untapped hydropower resources.

The 15 MW Tina River project in the Solomon Islands took a step closer to construction with the signing of several key agreements in 2018 including a power purchase agreement between the government and two Korean developers, K-water and Hyundai Engineering. In a country which is heavily reliant on expensive diesel power, the project has gained financial support from a number of development agencies and national governments with construction now expected to commence in 2019.

In Fiji, the European Investment Bank commissioned a feasibility study to identify the best hydropower scheme on the Qaliwana River which is able to meet the energy sector objectives of both the Fijian government and the Fiji Electricity Authority.

Lake Rowallan was recently named as one of the most promising sites for pumped hydropower storage in Tasmania, Australia.
Credit: Hydro Tasmania.



CHINA

The year 2018 marked the 40th anniversary of China's historic economic reform programme, which introduced market principles and opened up the economy to foreign investment. Since these important reforms, China's hydropower sector has grown twenty-fold to a total capacity of 352 GW, representing over a quarter of the world's installed capacity. A further 8.54 GW capacity was added last year, including 1.5 GW of pumped storage.

In recent years, annual capacity growth has slowed in line with weaker economic conditions and reduced power demand growth, resulting in overcapacity and renewables curtailment. In 2018, 33,200 GWh of wind and solar and 69,100 GWh of hydropower generation was curtailed. To tackle this problem, the Chinese government issued the 'Clean Energy Consumption Action Plan 2018–2020' which aims to virtually eliminate curtailment by 2020. The Sichuan provincial government also announced plans to establish a 'hydropower consumption demonstration zone' with direct power purchase and dedicated power lines for local industrial users.

Inter-provincial power transmission channels have been constructed to export excess hydropower generation and in 2018, two further transmission lines from Yunnan province achieved significant progress. The 800 kV Northwestern Yunnan-Guangdong UHVDC power transmission project with a transmission capacity of 5,000 MW was commissioned, and the world's first UHV multi-terminal DC project, the 800 kV Wudongde–Guangdong and Guangxi transmission began construction.

Pumped storage is essential to provide flexibility to the power system and continues to be a priority in China's energy transition. The 1,200 MW Shenzhen station was commissioned last year and is the country's first large scale pumped storage built in a city, in addition the 600 MW Qiongzhong station entered into operation. Furthermore, the main civil works of three pumped storage projects (1,200 MW Fu Kang, 1,800 MW Jurong and 1,200 MW Yongtai) began construction in 2018. A number of conventional projects were also commissioned, including 1,900 MW Huangdeng, 348 MW Sha Ping II, 920 MW Dahuaqiao and 420 MW Li Di stations. Meanwhile, substantial progress has been made with the world's largest hydropower project currently under construction, China Three Gorges Corporation's (CTG) 16,000 MW Baihetan project, with the completion of intake towers for spillway tunnels.

Apart from advancing infrastructure development, the Chinese government also implemented a series of reforms and policies to speed up their clean energy transformation. In 2018, China began reforming its electricity market to transition from a planned dispatch to an electricity spot market that will allow renewables to be dispatched first, and hydropower is expected to benefit from increased generation. Pilot spot markets, which is the buying and selling of electricity for immediate delivery, are being developed in eight provinces and regions; however, seven of them failed to meet the 2018 deadline and have been postponed and in 2019, the central government will intervene to accelerate their development. Furthermore, ancillary services markets that will better reward the services of pumped storage were successfully implemented in five regional power markets including Northeast China.

In November 2018, the government released its third public consultation on their renewable portfolio standard, which sets provincial wide minimum consumption levels of renewable electricity. The new standard will require designated electricity users to purchase an obligated amount of renewable energy certificates from renewable energy generators, which will further help to increase hydropower consumption and reduce curtailment.

Finally, China continues to promote green finance for its massive clean energy investment needs. Internationally-aligned green bond issuance reached USD 31.2 billion (CNY 210.3 billion) in 2018, and China's green bond market is the world's second largest, accounting for 18 per cent of global issuance. The country's green bond standards were developed to support the financing of clean energy projects including large-scale hydropower. Between 2017 and 2018, CTG raised USD 2.25 billion to finance its Jinsha River cascade projects, including the Baihetan and Wudongde hydropower projects.

1.4 BILLION
POPULATION

352.26 GW
INSTALLED HYDROPOWER CAPACITY

1,232,900 GWh
HYDROPOWER GENERATION

18.5%
HYDROPOWER SHARE OF ELECTRIC POWER INSTALLED CAPACITY

CAMBODIA

As one of the fastest growing economies in Asia, Cambodia is seeking to rapidly expand its power sector to keep up with increasing demand, having experienced double digit annual growth in recent years. Blessed with vast water resources including the Mekong River, hydropower is Cambodia's main source of electricity. With less than 20 per cent of its estimated technical potential developed, this source of renewable energy is set to play an even greater role in the future.

Cambodia's electricity sector is undergoing a major transformation, and high on the government's agenda is increasing access (72 per cent of households currently have access), improving grid reliability, and reducing imports and costs for consumers.

Electricity imports, largely from heavy fuel oil, represent around 15 per cent of consumption and the government is aiming to become self-sufficient in the medium term to help address high tariffs which are deterring greater foreign investment. Cambodia's electricity prices are some of the highest in the region and range from USD 0.09 - 0.25 per kilowatt hour in urban areas connected to the central grid to USD 0.40 - 0.80 per kilowatt hour in rural areas.

In 2018 Cambodia took an important step forward in achieving its energy goals with the commissioning of the 400 MW Lower Sesan II project. Located in the northeast of the country on a major tributary of the Mekong River, it was built at a cost of USD 780 million and is a joint-venture between China's Hydrolancang International Energy (holding a 51 per cent stake), Cambodia's Royal Group (39 per cent) and Vietnam's EVN International Joint Stock Company (10 per cent).

As the country's largest hydropower project, Lower Sesan II will boost electricity production by 20 per cent with the electricity being sold to the state-owned utility Electricité du Cambodge at a base price of USD 0.0695 cents/kWh. Its development was underpinned by a 45 year Build-Operate-Transfer (BOT) contract with the government which will also benefit from annual tax revenues in the order of USD 30 million.

With Lower Sesan II entering into operation, Chinese built hydropower projects in Cambodia have an installed capacity of over 1,300 MW and account for half of the country's total installed capacity from all energy sources. All based on BOT contracts, hydropower development has been a key pillar of Sino-Cambodia relations over the past decade and is set to continue as part of China's Belt and Road Initiative.

Several more hydropower projects have been proposed in recent years including the 2,600 MW Sambor project located on the mainstream of the Mekong River. Given its significant generating potential, the government views the project as an opportunity to generate revenue through exporting its electricity to neighbouring countries including Vietnam and Thailand where regional interconnectors are already in operation. However, the project has raised environmental and social concerns, particularly over the impact on fish migrations and a final decision on its future is still to be made.

As a founding member of the Mekong River Commission in 1995, an inter-governmental organisation formed to jointly manage the shared water resource Cambodia is committed to regional cooperation in order to sustainably develop the Mekong River basin. Yet as outlined in the country's National Strategic Development Plan 2014-2018, challenges remain including insufficient financial resources and institutional capacity which needs to be addressed.

16.4 MILLION
POPULATION

1,667 MW
INSTALLED HYDROPOWER CAPACITY

2,581 GWh
HYDROPOWER GENERATION

63%
HYDROPOWER SHARE OF ELECTRIC POWER INSTALLED CAPACITY

INSTALLED CAPACITY AND GENERATION 2018

AFRICA

Country	Total installed capacity including pumped storage (MW)	Pumped storage (MW)	Generation (TWh)
Algeria	269	-	0.09
Angola	3,083	-	13.50
Benin	33	-	0.07
Botswana	-	-	-
Burkina Faso	32	-	0.10
Burundi	57	-	0.15
Cote dIvoire	879	-	2.31
Cameroon	747	-	4.97
Cape Verde	-	-	-
Central African Republic	19	-	0.15
Chad	-	-	-
Comoros	-	-	-
Congo	242	-	1.06
Democratic Republic of the Congo	2,704	-	9.24
Djibouti	-	-	-
Egypt	2,876	-	13.10
Equatorial Guinea	128	-	0.12
Eritrea	-	-	-
Eswatini	60	-	0.26
Ethiopia	3,822	-	9.68
Gabon	331	-	1.74
Gambia	-	-	-
Ghana	1,584	-	4.99
Guinea	368	-	1.36
Guinea-bissau	-	-	-
Kenya	826	-	2.89
Lesotho	73	-	0.50
Liberia	93	-	0.49
Libya	-	-	-
Madagascar	164	-	0.72
Malawi	376	-	1.12
Maldives	-	-	-
Mali	180	-	0.95
Mauritania	48	-	0.19
Mauritius	60	-	0.09
Morocco	1,770	464	2.17
Mozambique	2,191	-	14.40
Namibia	347	-	1.33
Niger	-	-	-
Nigeria	2,064	-	5.97
Reunion	134	-	0.50
Rwanda	105	-	0.37
Sao Tome And Principe	2	-	0.01
Senegal	81	-	0.33
Seychelles	-	-	-
Sierra Leone	64	-	0.17
Somalia	-	-	-
South Africa	3,595	2,912	6.93
South Sudan	-	-	-
Sudan	1,923	-	8.42
Tanzania	572	-	2.21
Togo	49	-	0.10
Tunisia	66	-	0.07
Uganda	773	-	3.78
Western Sahara	-	-	-
Yemen	-	-	-
Zambia	2,397	-	13.65
Zimbabwe	1,076	-	7.54
TOTAL	36,264	3,376	138

SOUTH AND CENTRAL ASIA

Country	Total installed capacity including pumped storage (MW)	Pumped storage (MW)	Generation (TWh)
Afghanistan	461	-	1.10
Armenia	1,249	-	2.31
Azerbaijan	1,122	-	1.90
Bahrain	-	-	-
Bangladesh	230	-	0.87
Bhutan	1,615	-	7.50
Georgia	3,221	-	9.95
India	49,917	4,786	129.96
Iran	11,951	1,040	10.03
Iraq	2,753	240	4.40
Israel	7	-	0.02
Jordan	12	-	0.05
Kazakhstan	2,561	-	10.50
Kuwait	-	-	-
Kyrgyzstan	3,091	-	12.20
Lebanon	221	-	0.60
Nepal	1,016	-	3.90
Oman	-	-	-
Pakistan	9,827	-	25.63
Qatar	-	-	-
Russia	48,506	1,385	183.76
Saudi Arabia	-	-	-
Sri Lanka	1,719	-	3.15
Syria	1,505	-	3.10
Tajikistan	5,795	-	17.70
Turkmenistan	1	-	0.00
United Arab Emirates	-	-	-
Uzbekistan	1,731	-	10.50
TOTAL	148,511	7,451	439

EAST ASIA AND PACIFIC

Country	Total installed capacity including pumped storage (MW)	Pumped storage (MW)	Generation (TWh)
American Samoa	-	-	-
Australia	8,790	1,340	17.91
Brunei	-	-	-
Cambodia	1,667	-	2.58
China	352,260	29,990	1,232.90
Chinese Taipei	4,691	2,602	7.84
Cook Islands	-	-	-
Fiji	125	-	0.36
French Polynesia	47	-	0.27
Guam	-	-	-
Hong Kong	-	-	-
Indonesia	5,511	-	17.91
Japan	49,905	27,637	88.47
Kiribati	-	-	-
Laos	5,308	-	22.75
Macau	-	-	-
Malaysia	6,094	-	15.66
Marshall Islands	-	-	-
Micronesia, Federated States Of	-	-	-
Mongolia	23	-	0.05
Myanmar	3,331	-	8.37
Nauru	-	-	-
New Caledonia	78	-	0.33
New Zealand	5,346	-	25.89
Niue	-	-	-
North Korea	5,010	-	12.94
Papua New Guinea	234	-	0.78
Philippines	4,314	685	11.09
Samoa	12	-	0.04
Singapore	-	-	-
Solomon Islands	-	-	-
South Korea	6,490	4,700	7.27
Thailand	4,510	1,000	7.60
Timor-Leste	-	-	-
Tonga	-	-	-
Tuvalu	-	-	-
Vanuatu	-	-	-
Vietnam	16,679	-	52.60
TOTAL	480,426	67,954	1,534

EUROPE

Country	Total installed capacity including pumped storage (MW)	Pumped storage (MW)	Generation (TWh)
Albania	2,020	-	8.55
Andorra	45	-	0.12
Austria	14,535	5,596	37.70
Belarus	97	-	0.41
Belgium	1,427	1,307	0.22
Bosnia and Herzegovina	2,513	420	6.15
Bulgaria	3,129	1,404	5.00
Croatia	2,141	293	7.71
Cyprus	-	-	-
Czechia	2,268	1,172	2.75
Denmark	9	-	0.01
Estonia	8	-	0.02
Faroe Islands	39	-	0.11
Finland	3,236	-	13.15
France	25,519	6,985	63.10
Germany	11,258	6,806	16.29
Gibraltar	-	-	-
Greece	3,396	699	5.84
Greenland	91	-	0.42
Hungary	56	-	0.21
Iceland	2,086	-	13.69
Ireland	529	292	0.91
Italy	22,926	7,555	49.28
Kosovo	68	-	0.31
Latvia	1,576	-	2.81
Liechtenstein	35	-	0.13
Lithuania	1,016	900	0.43
Luxembourg	1,330	1,296	0.07
Malta	-	-	-
Moldova	76	-	0.35
Monaco	-	-	-
Montenegro	658	-	2.04
Netherlands	37	-	0.07
North Macedonia	674	-	1.58
Norway	32,256	1,392	139.51
Poland	2,353	1,782	2.64
Portugal	7,347	3,919	12.27
Romania	6,328	92	17.68
San Marino	-	-	-
Serbia	2,932	628	10.39
Slovakia	2,522	1,017	3.78
Slovenia	1,524	180	5.11
Spain	20,378	6,177	34.12
Sweden	16,466	99	60.94
Switzerland	16,948	3,057	37.78
Turkey	28,358	-	59.75
Ukraine	6,785	1,563	11.78
United Kingdom	4,712	2,833	7.83
TOTAL	251,707	57,464	643

SOUTH AMERICA

Country	Total installed capacity including pumped storage (MW)	Pumped storage (MW)	Generation (TWh)
Argentina	11,288	974	36.85
Bolivia	658	-	2.49
Brazil	104,139	30	417.91
Chile	6,753	-	23.26
Colombia	11,837	-	56.65
Ecuador	5,072	-	20.76
French Guiana	119	-	0.58
Guyana	1	-	-
Paraguay	8,810	-	59.11
Peru	4,995	-	29.36
Suriname	189	-	1.10
Uruguay	1,538	-	6.14
Venezuela	15,393	-	72.09
TOTAL	170,792	1,004	726

NORTH AND CENTRAL AMERICA

Country	Total installed capacity including pumped storage (MW)	Pumped storage (MW)	Generation (TWh)
Anguilla	-	-	-
Antigua and Barbuda	-	-	-
Aruba	-	-	-
Bahamas	-	-	-
Barbados	-	-	-
Belize	53	-	0.24
Bermuda	-	-	-
Canada	81,386	177	381.18
Cayman Islands	-	-	-
Costa Rica	2,375	-	8.74
Cuba	64	-	0.10
Dominica	6	-	0.03
Dominican Republic	543	-	1.33
El Salvador	472	-	1.54
Grenada	-	-	-
Guadeloupe	10	-	0.02
Guatemala	1,499	-	5.19
Haiti	61	-	0.15
Honduras	656	-	2.59
Jamaica	23	-	0.12
Martinique	-	-	-
Mexico	12,117	-	15.90
Montserrat	-	-	-
Nicaragua	123	-	0.43
Panama	1,818	-	10.78
Puerto Rico	98	-	0.11
Saint Bartholemy	-	-	-
Saint Kitts And Nevis	-	-	-
Saint Lucia	-	-	-
Saint Pierre And Miquelon	-	-	-
Saint Vincent And The Grenadines	7	-	0.03
Trinidad And Tobago	-	-	-
Turks And Caicos Islands	-	-	-
United States	102,745	22,855	291.72
Virgin Islands, British	-	-	-
Virgin Islands, U.S.	-	-	-
TOTAL	204,056	23,032	720

WORLD

	Total installed capacity including pumped storage (MW)	Pumped storage (MW)	Generation (TWh)
TOTAL	1,291,757	160,281	4,200

Membership

Join us

IHA membership is open to organisations and professionals with an interest in sustainable hydropower.

Our members are part of the world's most extensive hydropower network and enjoy better access to information, new connections and strong representation on issues that affect them.

IHA members receive reduced registration rates to participate in special events such as the World Hydropower Congress.

Shape your future

We provide a strong, credible voice for the sector and the role of hydropower in the future at national, regional and international forums. As a member, you can help to shape our strategy and activities through our events, knowledge networks and working groups.

Network and connect

Our membership comprises some of the world's most reputable hydropower sector organisations, active in more than 100 countries.

We also work in partnership with a range of influential organisations from government, finance, the scientific and academic communities, and civil society.

Members can connect, join specialist networks and access resources through our new Hydropower Pro online community and mobile app: hydropower.org/pro

Raise your profile

IHA membership enhances your visibility to an international audience of leading stakeholders from the hydropower sector and beyond. By joining our association, you can demonstrate your ambition, unlock new markets and reach new audiences.

Stay on trend

Our experts share updates on hydropower policy developments, good practice and new trends from around the world, offering insights on a range of specialist topics. These communications are supported by IHA's hydropower database which monitors sector growth and development in all regions.

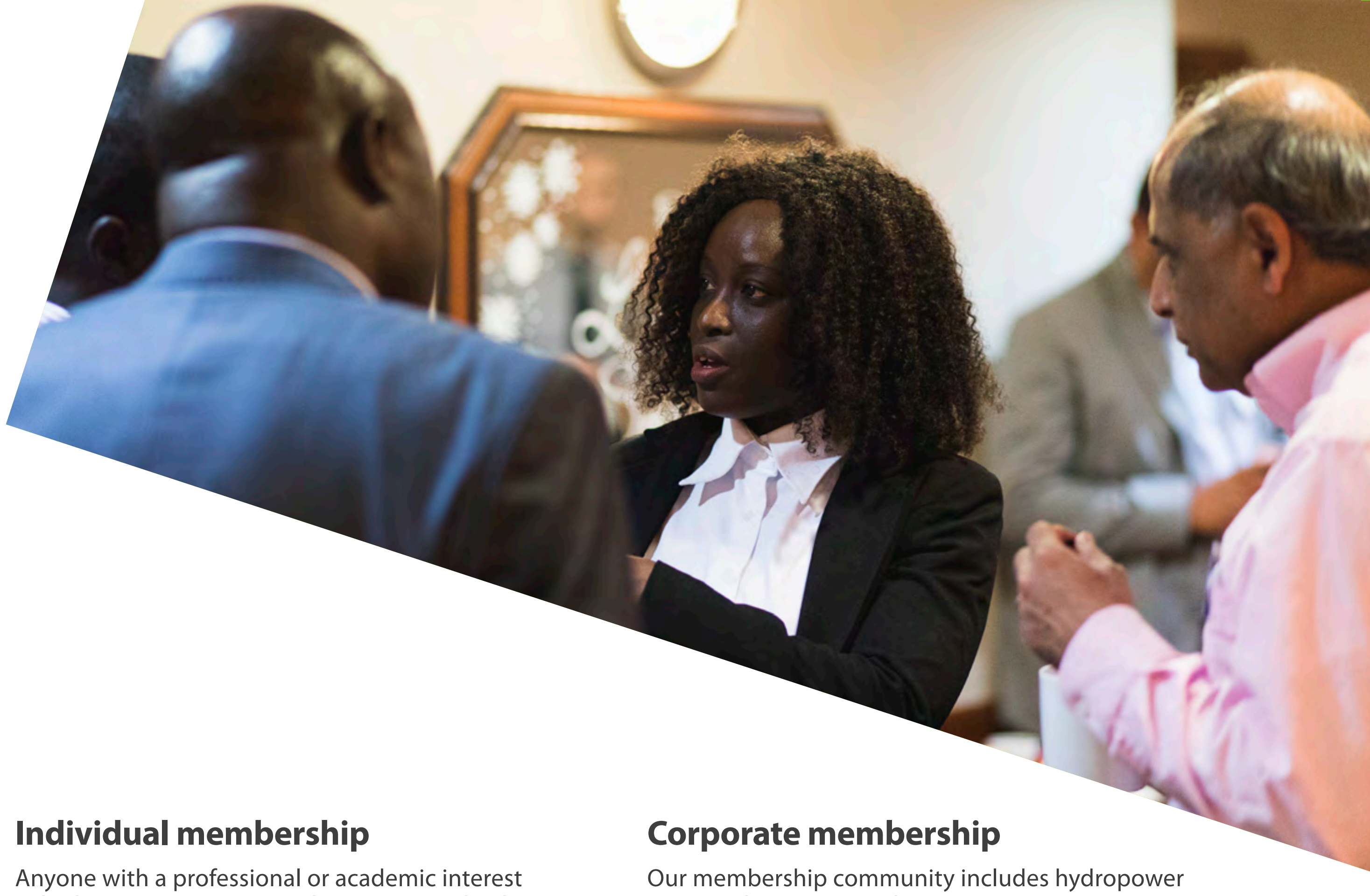
Gain access

We offer members priority treatment and discounted registration to IHA events, workshops and training programmes, as well as privileged and exclusive access to essential publications, briefings and knowledge networks.

Online:

To view all benefits, membership rates and apply online, please visit:

hydropower.org/join



Individual membership

Anyone with a professional or academic interest in hydropower can apply to become an individual member of IHA.

Become an individual member:

hydropower.org/individual-membership

Become a Fellow

Fellowship is a new tier of IHA membership which recognises the expertise of leading professionals within the hydropower sector.

Awarded on the basis of proven experience, Fellow membership provides an opportunity to collaborate with industry leaders through online groups, training sessions, workshops, webinars and other events.

With their wealth of knowledge and experience, our Fellows help to shape IHA's work programmes. Fellow members are entitled to use the letters 'F.IHA' in their professional title.

Become a Fellow of IHA:

hydropower.org/fellow-iha

Corporate membership

Our membership community includes hydropower owners, developers and operators, equipment manufacturers, government agencies and utility companies, non-government organisations and national membership associations.

We have three levels of corporate membership, which are recommended based on an organisation's size or total installed capacity:

- Platinum (more than 10,000 MW)
- Gold (more than 2,000 MW)
- Silver (less than 2,000 MW)

Our corporate members nominate up to 40 employees, dependent on membership level, as corporate representatives to enjoy the full benefits of IHA membership.

Corporate members can also nominate up to 10 employees, dependent on membership level, to become Fellows of IHA free of charge.

Become a corporate member:

hydropower.org/corporate-membership

www.hydropower.org

The International Hydropower Association (IHA) is a non-profit organisation that works with a vibrant network of members and partners active in more than 100 countries.

Our mission is to **advance sustainable hydropower by building and sharing knowledge** on its role in renewable energy systems, responsible freshwater management and climate change solutions.