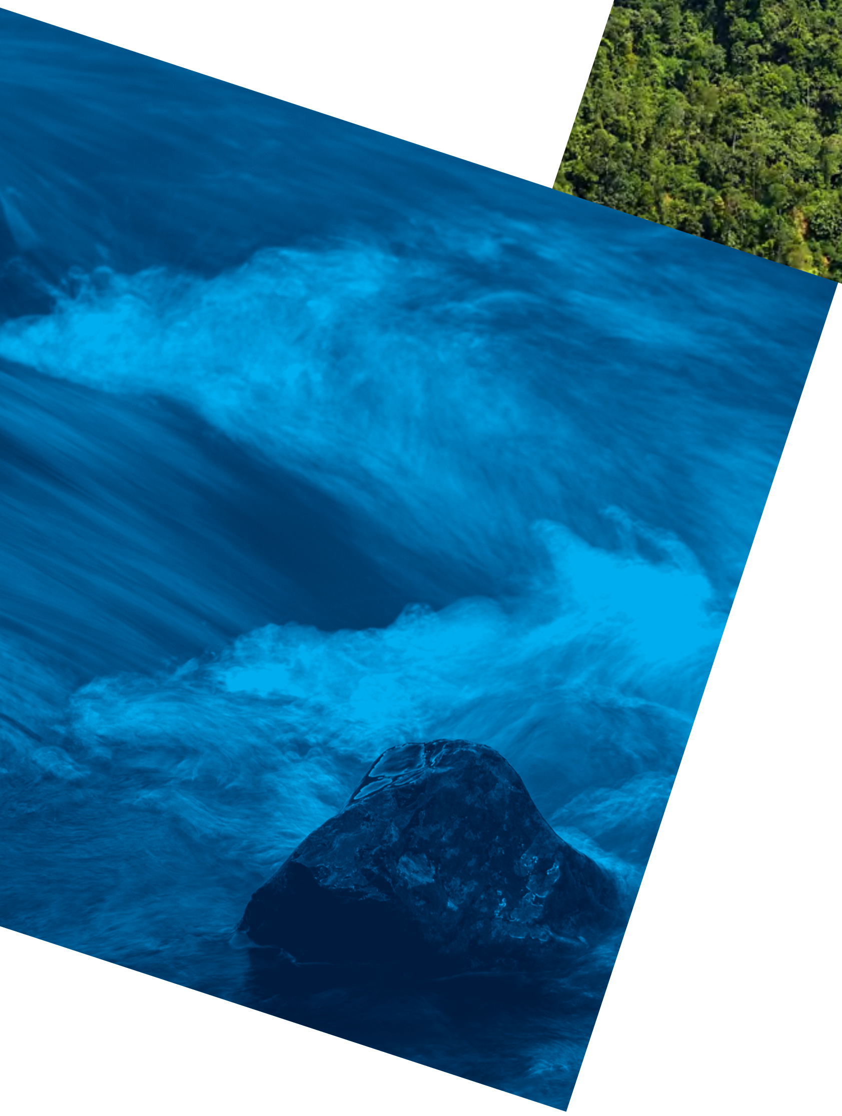
international hydropower association



2018 hydropower status report

sector trends and insights

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This August 2018 edition of the Hydropower Status Report includes latest 2017 world electricity generation data provided by REN21.

Cover Image: The 944 MW Murum hydroelectric plant Malaysia. Credit: Sarawak Energy.

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In 2017 the Brazilian-Paraguayan Itaipu Binacional hydropower project reached a landmark 2.5 billion megawatt hours (MWh) of generation since becoming operational in 1984.
Credit: Alexandre Marchetti

CONTENTS

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 approximately 12,000 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.

Foreword

The 2018 Hydropower Status Report, now in its fifth edition, is IHA's flagship publication on hydropower statistics and an authoritative guide to the future of the sector.

We publish the 2018 Hydropower Status Report at a time of significant change in global energy markets, with the contribution of renewables such as hydropower, wind and solar growing at a rapid rate.

During 2017, an additional 21.9 gigawatts (GW) of installed hydropower capacity was added worldwide, with China once again making up for the largest share of newly commissioned projects. Total installed capacity worldwide has now reached 1,267 GW, producing an estimated 4,185 terawatt hours (TWh) in clean electricity – two-thirds of all renewable electricity generation.

While the capacity added last year was lower than the 31.5 GW recorded the previous year, importantly, USD 48 billion of final investment decisions were committed to hydropower projects in 2017 – nearly double the amount recorded in 2016. This indicates that there is a strong pipeline of projects in development.

In this report, we are honoured to share contributions from four leading government ministers, each of whom has a major role to play in shaping energy policy, both within their countries and across their respective regions. In their articles, these esteemed policy-makers underline hydropower's role in achieving carbon reduction targets, as articulated in the Paris Climate Agreement, as well as broader social, economic and environmental aspirations encapsulated in the Sustainable Development Goals.

The report also offers insights on many of the factors influencing the growth and development of the hydropower sector, regionally and globally, from the need to build climate-resilient facilities, to new technologies being adopted and creative solutions for operations and maintenance.

For years, researchers have struggled to accurately assess the carbon footprint of hydropower. Within this report, we are publishing the results of the largest and most comprehensive study of the greenhouse emissions of nearly 500 reservoirs globally. The results indicate that hydropower is among the cleanest sources of electricity generation in the world.

If hydropower was replaced with burning coal, analysis by IHA suggests that 4 billion tonnes of additional greenhouse gases would have been emitted in 2017, and global emissions from fossil fuels and industry would have been 10 per cent higher. In addition, using hydropower instead of coal last year avoided the generation of 148 million tonnes of air polluting particulates, 62 million tonnes of sulphur dioxide, and 8 million tonnes of nitrogen oxide – avoiding many more health and environment impacts.

This year, 2018, is shaping up to be a milestone year for the hydropower sector. Firstly, IHA and partners are preparing to launch an expanded Hydropower Sustainability Assessment Protocol covering climate change mitigation and resilience, as well as a new tool for undertaking targeted, cost-effective assessments of projects. This represents an important development in the toolbox available for reviewing, understanding and communicating the social, economic, environmental and technical performance of hydropower.

In addition, during 2018 we expect to see the completion of new green bond eligibility criteria for hydropower, which will provide much needed clarity for this important financial market. Projects which can demonstrate they follow good international industry practice should become eligible as a result of this work.

Hydropower development is integral to the growth strategies of many fast growing economies around the world. Heralding its low running costs and long lifetime, the Chief Minister of Sarawak, Malaysia, writes in this report that "hydropower development makes for good business sense" as a way of securing a stable supply of sustainable energy.

In Ethiopia, which has initiated a Climate Resilient Green Economy strategy, increasing energy access through hydropower is seen as a "vital catalyst to wider social and economic development, enabling education, health and sustainable agriculture as well as creating jobs", according to the country's Minister for Water, Irrigation and Electricity. It also serves as an "entry point" for regional collaboration and integration, he says in his article.

Many mature markets, as well as developing countries, are turning to hydropower thanks to its storage capabilities, as well as its vital water management services. Hydro is now a "priority agenda item" for Australia, writes the Minister for the Environment and Energy, highlighting a "game-changing" project announced in 2017: Snowy 2.0, which will expand the iconic Snowy Mountains Scheme by an additional 2,000 MW of capacity with 350,000 MWh of storage.

The policy emphasis given to storage, and especially pumped storage, is shared by Scotland's Minister for Business, Innovation and Energy, who believes that investment in new capacity could "greatly enhance the flexibility and resilience" of his country's electricity network.

We launch the 2018 Hydropower Status Report almost exactly one year ahead of the World Hydropower Congress in Paris. This important event will bring together leading policy-makers, experts and innovators from across the hydropower sector, including representatives from business, civil society, government and academia to debate, and shape, the future of hydropower.

Membership of IHA – and attendance of the World Hydropower Congress – is open to all individuals interested in advancing sustainable hydropower. If you are not already a member, please consider applying. It will give you access to exclusive resources and an opportunity to influence vital discussions and decisions. Highly experienced professionals can also apply to be recognised as a Fellow of IHA, and join a global network of hydropower leaders.

We wish to extend our gratitude to all those members and other reviewers who contributed to the production of this year's Hydropower Status Report, as well as the analysts and staff team of IHA Central Office who have worked tirelessly to bring it to publication. As always, we welcome your observations and comments, as we look to expand and further develop this report in future years.

1,267GW

global hydropower installed capacity in 2017

4,185TWh

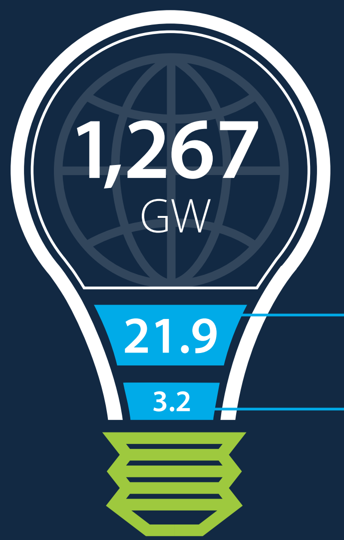
estimated electricity generated from hydropower in 2017

Itaipu Binacional
Image credit: Alexandre Marchetti

Ken Adams
President

Richard Taylor
Chief Executive

Hydropower key facts

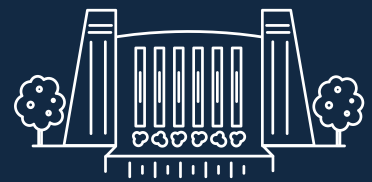


Worldwide hydropower installed capacity in 2017

New capacity added (GW)

including pumped storage (GW)

Source: IHA 2018



Source: IHA 2018

4,185 TWh

Clean electricity generated by hydropower in 2017

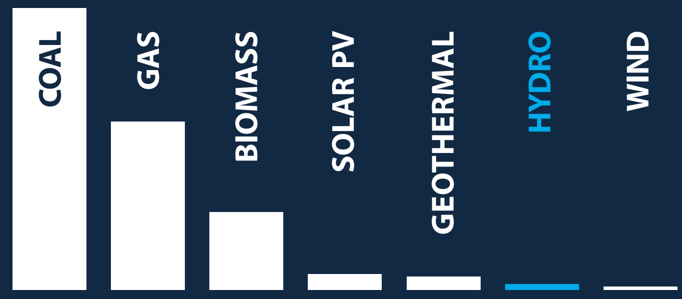
THAT'S ENOUGH ELECTRICITY FOR ONE BILLION PEOPLE

HYDROPOWER BENEFITS

- Clean, affordable and reliable energy
- Enabling solar, wind and other renewables
- Responsibly managed freshwater
- Protecting from floods and drought
- Boost to economic growth and jobs
- Avoiding pollutants and emissions
- Improved infrastructure and waterways
- Enhancing cooperation between countries
- Community investments in rural areas
- Recreational activities and tourism

CLIMATE ACTION

Source: IPCC 2014 / IHA 2018



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

If hydropower was replaced with burning coal, approximately **4 BILLION TONNES** of additional greenhouse gases would have been emitted in 2017

and global emmisions from fossil fuels and industry would have been at least **10% HIGHER**

AVOIDING POLLUTION

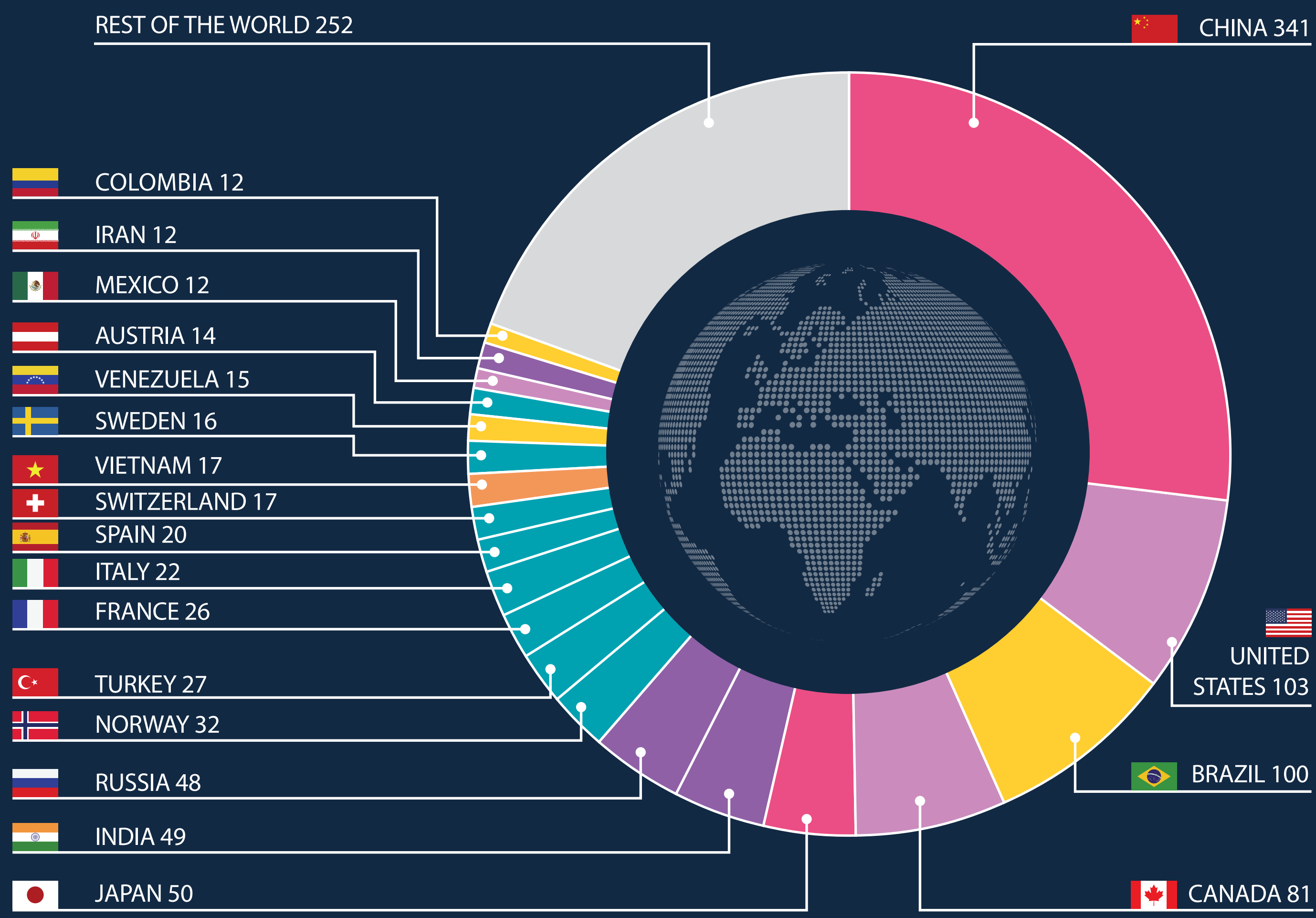
Source: IHA

PM2.5 PM10 SOx NOx

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

WORLDWIDE HYDROPOWER INSTALLED CAPACITY

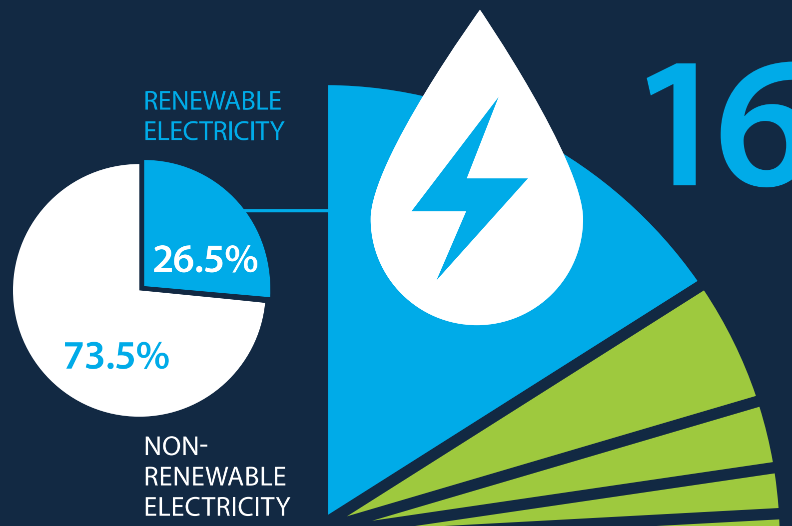


Hydropower installed capacity (GW) of top 20 countries including pumped storage in 2017. *Source: IHA 2018*

SHARE OF GLOBAL ELECTRICITY GENERATION

Source: REN21 2018

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



16.4% of electricity was produced by hydropower

- 5.6% WIND POWER
- 2.2% BIOPOWER
- 1.9% SOLAR PV
- 0.4% OCEAN, CSP AND GEOTHERMAL POWER

MORE THAN ALL OTHER RENEWABLES COMBINED

Executive summary

The Reventazón project in Costa Rica was assessed under the Hydropower Sustainability Assessment Protocol in 2017. Credit: World Bank / Mario Lacayo

The world's largest source of clean electricity generation, hydropower is an enabler of other renewable energy sources while providing vital services to manage water and mitigate climate change.

Key trends and developments

IHA can report that electricity generation from hydropower reached an estimated 4,185 TWh in 2017, the highest ever contribution from a renewable energy source.

A total of 21.9 GW of hydropower capacity was put into operation last year, including pumped storage, bringing the world's total installed capacity to 1,267 GW.

The East Asia and Pacific region was again fastest growing last year, with 9.8 GW of hydropower capacity added, followed by South America (4.1 GW), South and Central Asia (3.3 GW), Europe (2.3 GW), Africa (1.9 GW) and North and Central America (0.5 GW).

The five countries with the largest individual increases were China (9.1 GW), Brazil (3.4 GW), India (1.9 GW) and Portugal (1.1 GW) and Angola (1.0 GW).

See the map and the tables on pages 42-45 for data for each country and region.

Cities powered by hydroelectricity

Around the world, 93 cities with a combined population of more than 80 million report that at least half of their electricity generation comes from hydropower, while 31 cities generate 100 per cent of their electricity from hydropower.

Source: CDP 2018

The world's water batteries

Hydropower accounts for more than 95 per cent of worldwide energy storage capacity. By absorbing surplus electricity and supplying it when needed, hydropower is seen as an enabler of variable renewable energy sources such as wind and solar power.

In November 2017, IHA launched the Hydropower Pumped Storage Tracking Tool, which maps the locations and statistics for existing and planned pumped storage projects. Throughout 2017, 3.2 GW of pumped storage hydropower capacity was added worldwide, bringing global pumped storage capacity to 153 GW.

More than 100 pumped storage hydropower projects totalling some 75 GW of new capacity are in the pipeline. These projects will increase existing global storage capacity by 50 per cent to almost 225 GW by 2030.

Study shows hydropower's low carbon footprint

A study of the greenhouse gas (GHG) footprint of 500 reservoirs worldwide, published for the first time in this Report, indicates that hydropower is one of the cleanest sources of electricity generation.

The researchers applied the GHG Reservoir (G-res) Tool which was developed by IHA and UNESCO with researchers from the University of Quebec at Montreal in Canada, the Norwegian Foundation for Scientific and Industrial Research and the Natural Resources Institute of Finland. Launched in 2017, the tool was devised to more accurately estimate the net change in emissions attributable to the creation of a reservoir.

The G-res tool takes into account the condition pre-impoundment, considering naturally occurring emissions and emissions related to other human activities over the lifetime of the reservoir. It also provides a method for apportioning the net GHG footprint to the various freshwater services that a reservoir provides, such as water supply for irrigation and cities, flood and drought management, navigation, fisheries and recreation.

The study by IHA estimated the GHG footprint of 178 single purpose hydropower reservoirs and more than 300 multipurpose reservoirs. This data was coupled with project-specific average annual hydropower generation data to obtain the emissions intensity of each site's hydropower operations.

This report found the global median GHG emission intensity of hydropower reservoirs to be 18.5 gCO$_2$-eq/kWh. This is the grams of carbon dioxide equivalent per kilowatt-hour of electricity generated allocated to hydropower over a life-cycle. Three-quarters of the reservoirs were estimated to have emissions less than 60 gCO$_2$-eq/kWh.

Read more on pages 28-29.

2017 HIGHLIGHTS

4,185 TWh	1,267 GW	153 GW	21.9 GW	3.2 GW
Electricity generated from hydropower in 2017	Global hydropower installed capacity	Global pumped storage installed capacity	Capacity added in 2017, including pumped storage	Pumped storage capacity added in 2017

Criteria to unlock green bonds as a funding source

More than a decade after the world's first labelled green bond was issued, the burgeoning green bond market is heralded as an important source of investment in hydropower. A coalition of organisations, including the United Nations Framework Convention on Climate Change, have set a target of USD 1 trillion worth of issuances by 2020, up from USD 160 billion last year.

More than 100 heads of organisations and senior decision makers in the hydropower sector say they expect to finance or refinance a hydropower project through the green bond market over the next five years, according to a survey by IHA. However, more than three quarters of respondents say greater clarity on the eligibility criteria for hydropower is required.

Proposed criteria under development by the Climate Bonds Initiative, due for completion in 2018, should give investors the confidence they require to invest in environmentally sustainable and socially responsible hydropower projects.

Read more on pages 30-31.

Expansion in tools for sustainability assessments

Since its launch in 2011, the Hydropower Sustainability Assessment Protocol has become established as the primary tool for evaluating sustainability performance. To date, the Protocol has been applied at more than 40 sites around the world.

In 2018, the Protocol is to be expanded by its multi-stakeholder governance council to include a new climate topic to assess a project's carbon footprint and resilience to climate change. The council includes the World Bank, WWF, Women for Water Partnership, the International Institute for Environment and Development, the Inter-American Investment Corporation, the Norwegian Agency for Development Cooperation and Switzerland's State Secretariat for Economic Affairs, and is supported by IHA as the council's management entity.

As a complement to the Protocol, to support more targeted, cost-effective project assessments, the council asked IHA to launch a new tool for reviewing projects against basic good practice across key environmental, social and governance criteria. The Hydropower Sustainability Environmental, Social and Governance Gap Analysis Tool (ESG Tool), to be launched in 2018, will be compatible with IFC environmental and social performance standards and the World Bank's new Environmental and Social Framework.

Read more on pages 26-27.

FASTEST GROWING COUNTRIES BY NEW INSTALLED CAPACITY IN 2017

China 9.12 GW
Brazil 3.38 GW
India 1.91 GW
Portugal 1.05 GW
Angola 1.02 GW
Turkey 0.59 GW
Iran 0.52 GW
Vietnam 0.37 GW
Russia 0.36 GW

New climate resilience guidelines being tested

Planning and operating hydropower assets requires that they will not be compromised by the impacts of climate change. New hydropower sector guidelines being developed and tested by the World Bank, the European Bank for Reconstruction and Development and IHA will provide good practice guidance on climate resilience for project owners, governments, financial institutions and private developers.

Read more on pages 34-35.

Regional interconnections to widen access to hydropower

The emergence of regional energy networks has created new opportunities to widen access to clean electricity generated by hydropower. Central America's integrated regional electricity grid, SIEPAC, which covers a distance of 1,830 kilometres, provides a model for other regions seeking to achieve renewable targets and boost national development.

Read more on pages 32-33.

Technology to optimise hydropower operations

The revolution in digitalisation which has swept through sectors to encompass algorithmic trading, artificial intelligence and blockchain is becoming increasingly important to hydropower. It is being used to extend the lifetime of facilities and support other renewables such as wind and solar.

Read more on pages 36-37.

Surveying the hydropower sector

The Hydropower Status Survey gauges insights from a broad pool of senior decision-makers and expert professionals working in the hydropower sector, both IHA members and non-members, in all regions of the world.

The 2018 Hydropower Status Survey, conducted between 14 March and 1 May 2018, invited respondents to share their views about some of the most pressing issues facing the sector. It gathered insights about business confidence in hydropower growth and investments. Respondents were asked about the policies and other factors influencing hydropower development.

In addition, questions looked at hydropower project preparation and financing, including green bonds, and the impact of new technologies, climate mitigation and sediment management. The survey also covered work programmes priorities for the International Hydropower Association.

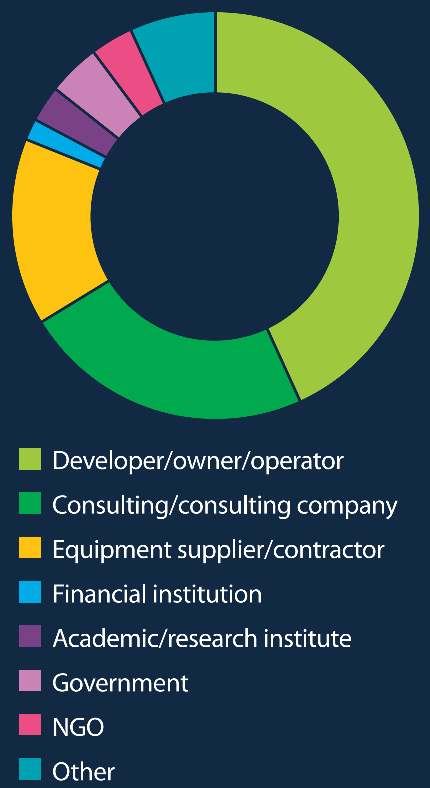
Demographic profile

A total of 236 respondents participated in the survey, of which the large majority were representatives of business. Some 43.2 per cent worked at developers, owners or operators. Other respondents included consultants or those working in a consulting company (22.9 per cent), equipment suppliers/contractors (14.8 per cent), or other organisations, including governments, NGOs, academic or research institutes or financial institutions (19.1 per cent).

Most of the respondents were senior decision makers or influencers in their organisations, with 40 respondents (17.0 per cent) reporting that they were the head of their organisation. Fifty-four respondents (23.0 per cent) were senior executives, while 49 people (20.9 per cent) were programme or project managers. Other categories included technical specialist (13.6 per cent), engineer (10.6 per cent), analyst/adviser (6.8 per cent) and other (8.1 per cent).

More than half of the respondents (58.5 per cent) had over 15 years of hydropower industry experience.

Organisations surveyed:



91%

of respondents said hydropower will increasingly provide a peaking and support role for power systems over baseload services

The changing role of hydropower

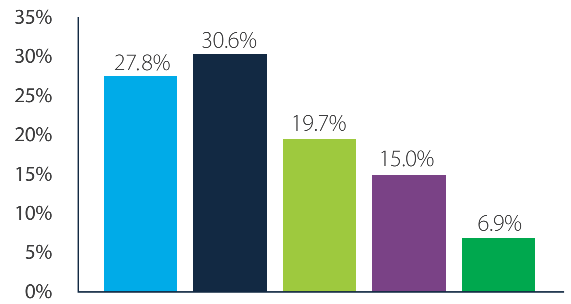
Hydropower facilities which incorporate storage reservoirs can be used to provide significant flexible balancing and ancillary services for power systems. Reflecting increased global demand for these services, 91 per cent of survey respondents stated that hydropower increasingly provides a peaking and support role for power systems, over baseload services, to ensure a reliable electricity supply.

As intermittent and variable renewable energy sources like wind and solar continue to grow in market share, the survey showed a high level of enthusiasm among the hydropower sector about these technologies. Rather than seeing a threat to the hydropower business, the survey demonstrates that the sector's decision-makers see renewables working together, with 71.2 per cent saying they were optimistic about their emergence and only 13.6 per cent disagreeing.

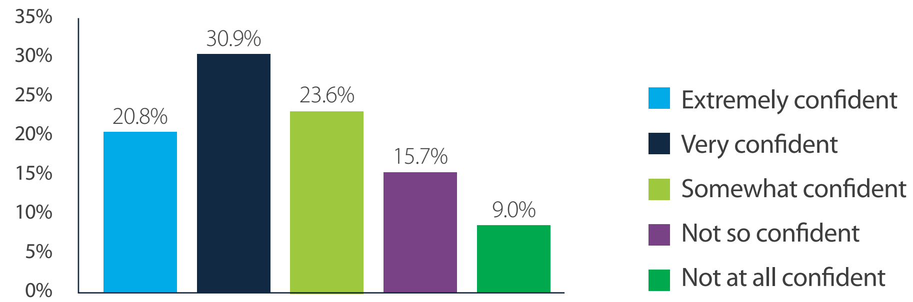
In terms of hydropower's broader benefits, the survey showed a near consensus view that investment in hydropower is essential in achieving societal and environmental objectives, in particular the United Nations Sustainable Development Goals (SDGs) and the Paris Climate Agreement, with 96.4 per cent and 92.0 per cent of respondents, respectively, in agreement or strong agreement.

Industry confidence

My organisation will expand its installed hydropower capacity over the next 3 years



My organisation will increase total investments in hydropower over the next 3 years



Business confidence

Survey respondents displayed a high level of confidence in their organisation's growth prospects over the coming years across three key indicators, namely: growth in installed capacity, business revenues and total investments in hydropower.

Some 58.4 per cent of respondents responsible for hydropower projects said they expected to expand their installed capacity in the next three years, next to just 22.0 who were not confident. Meanwhile 51.7 per cent of relevant respondents said they expected to increase investments in hydropower, next to 24.7 per cent who were not confident.

This balance arguably reflects the increasing demand for clean, reliable and affordable electricity, particularly following the signing of the Paris Climate Agreement and the adoption of the Sustainable Development Goals in 2015. Hydropower continues to be the energy choice for a number of emerging economies in Africa and Asia where there is significant untapped potential coupled with positive economic growth prospects. This is driven by domestic demand and cross-border power trade, as well as growing appreciation of the wider benefits that hydropower provides such as water management services.

In addition, as the energy mix continues to evolve, there is a need for more energy storage and flexible capacity to balance grids which is providing growth opportunities, notably in mature markets. A further contributing factor is the requirement to upgrade or modernise an ageing fleet of hydropower plants.

BRIEFING FOR IHA MEMBERS

The full survey results and analysis will be shared exclusively with IHA members. The member briefing will cover, among other topics:

- Insights into sector confidence on future business revenues and predictions for the next 10 years for the fastest and slowest growing regions.
- Factors influencing hydropower development and policies recommended by respondents.
- Ease of obtaining project finance and approval for greenfield and modernisation hydropower projects, and much more.

Regional trends in brief

North and Central America

Although growth in hydropower in North and Central America remains modest compared to other regions, there is increased focus on pumped storage projects.

510 MW of new installed capacity was added in 2017, around a quarter of which came from pumped storage, to take total installed capacity to 203.1 GW.

In Canada, major storage projects under construction include Keeyask generating station in Manitoba, Site C in British Columbia, Muskrat Falls in Newfoundland and Labrador, and Romaine-4 in Quebec.

In the United States, 140 MW of installed capacity was added through retrofits to existing facilities: 139 MW of pumped storage capacity was added at the Northfield Mountain Unit in Massachusetts and the Ludington facility in Michigan.

In the Dominican Republic, work is underway at the Hatillo small hydropower plant (10.7 MW), located on the Río Yuna, to add a new powerhouse together with a new generation unit.

Read more on pages 50-51.

South America

The hydrological variability caused by El Niño across South America in 2017 may lead to the strengthening of long-distance regional interconnections across the continent.

4,069 MW was added in 2017, bringing total installed capacity in South America to 167.0 GW.

Brazil, despite adding 3.38 GW in 2017, has removed several large hydropower projects from its 10-year pipeline in favour of pursuing more decentralised renewable energy.

Colombia saw hydropower installed capacity increase to 86 per cent of total generation in 2017, far exceeding the 70 per cent average generation of the past four years.

In Peru, there are 39 hydropower plants planned that would add 2,900 MW to the national energy grid.

In Argentina, the new government is favouring the development of hydropower projects with the 1,740 MW complex of dams named after Dr. Néstor Carlos Kirchner and Jorge Cepernic in Patagonia and the approval of the Portezuela del Viento plant (210 MW) in Mendoza.

Read more on pages 58-59.

Africa

Africa has among the largest untapped potential for hydropower development, however new projects are steadily increasing capacity.

1,924 MW was added in 2017, bringing Africa's total installed capacity to 35.3 GW.

Angola commissioned two power generating units for the Laúca hydropower station (2,070 MW) and a second power station at Cambambe, raising its installed capacity to 960 MW.

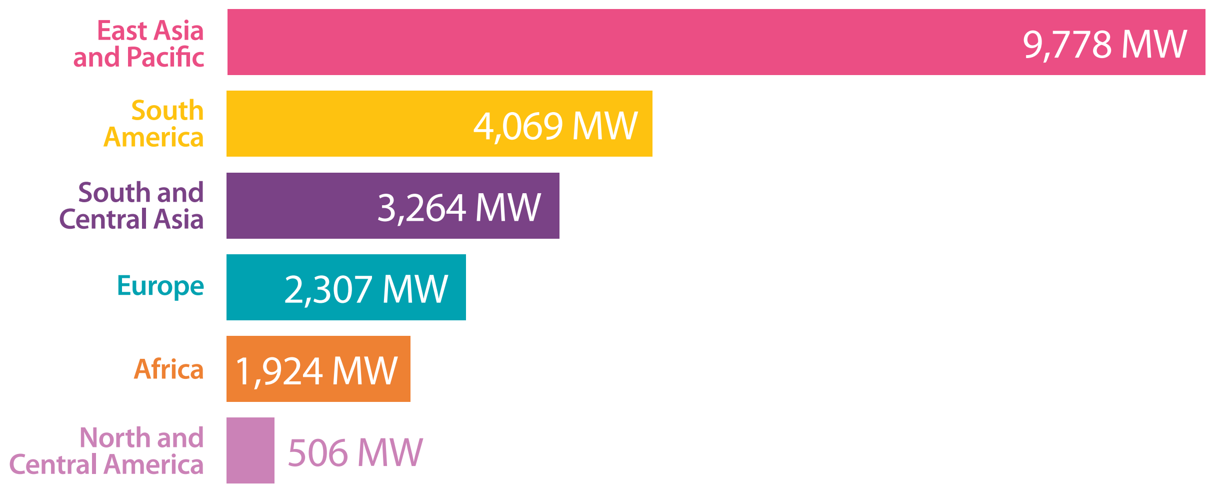
Côte d'Ivoire commissioned the Soubré plant (275 MW), making it the largest hydropower plant in the country. The government is working to double power generation by 2020.

Sudan completed the Upper Atbara and Setit dam (320 MW). Besides increasing the country's installed capacity, the project will provide water storage and supply for over 300,000 hectares of land.

The first unit of the Kariba South extension project was commissioned in Zimbabwe.

Read more on pages 66-67.

FASTEST GROWING REGIONS BY NEW INSTALLED CAPACITY IN 2017



Europe

Hydropower remains the single largest source of renewable electricity across Europe, generating an estimated 600 TWh of clean electricity in 2017.

2,307 MW was added in 2017, with over half of added capacity coming from pumped storage. A significant amount of additional capacity is also from upgrades and modernisation, bringing total capacity to 248.6 GW.

Portugal commissioned two pumped storage projects: Foz Tua (270 MW) and Frades II (780 MW), the latter of which is one of the largest variable speed projects in Europe.

Albania, which relies almost entirely on hydropower for its power supply, brought the Fangu station (74.6 MW) online in 2017. The project, by Turkish company Ayen Energy, is the country's largest privately-owned power project and fourth largest hydropower station.

Switzerland completed the second stage of the Hogrin-Leman pumped storage project. The 240 MW addition doubled the project's total installed capacity to 480 MW, making it the country's second largest pumped storage project.

Read more on pages 74-75.

South and Central Asia

South and Central Asia saw 3,264 MW of capacity added in 2017, with over half of new projects commissioned in India. The region's total installed capacity now stands at 144.7 GW.

In India, new installs included the 1,200 MW Teesta III project in the Himalayan north-eastern state of Sikkim.

Russia commissioned the Nizhne-Bureyskaya project (320 MW) in the far east, while total hydropower generation remained stable.

Iran commissioned the Rudbar Lorestan dam comprising a 450 MW powerhouse.

Construction of the Rogun dam (3,600 MW) in Tajikistan and other projects in Kyrgyzstan received support from Uzbekistan, and progress has also been made on CASA 1000 to interconnect with Pakistan.

Georgia commissioned the Dariala (108 MW) and Khelvachauri 1(47 MW) plants, and has plans to modernise the Enguri (1,300 MW) dam amongst other investments in hydropower.

Nepal's total capacity reached almost 1,000 MW in 2017, and new projects under construction include 456 MW Upper Tamakosi and 900 MW Arun III.

Read more on pages 82-83.

East Asia and Pacific

Once again East Asia and the Pacific region saw the highest annual increase in hydropower installed capacity in 2017.

9.8 GW was added last year, bringing total installed capacity across the region to 468.3 GW.

Over 90 per cent of the capacity added in 2017 came from China, which increased its total installed capacity to 341,190 MW.

The Trung Son project (260 MW) in Vietnam was fully commissioned and is the first hydropower plant in the country to have received funding from the World Bank.

Australia announced plans to expand the Snowy Mountains Scheme (4,100 MW). Known as Snowy 2.0, the pumped storage project involves linking two large dams and would act as a giant 2 GW battery.

Two units representing 100 MW of the Lower Sesan II project (400 MW) in Cambodia were put into operation. Once completed, it will be the largest hydro project in the country.

In Papua New Guinea, the Edevu project (50 MW) is being constructed, with commissioning expected in 2020.

Read more on pages 90-91.

View from Australia

The Australian government has put hydropower back in the spotlight

The Australian government has made hydropower a priority agenda item, to help deliver a more reliable and affordable energy system for all Australians, writes Minister for the Environment and Energy, Hon Josh Frydenberg MP

Guthega dam on Snowy river, Australia

Since the 1890s, hydropower has been a source of energy in Australia, primarily in our southernmost state of Tasmania. It was in 1974, however, when it took on "iconic" status with the completion of the Snowy Mountains Hydro-Electric Scheme, our largest ever engineering project.

Only two per cent of construction was visible above ground, yet the scheme included 16 major dams, seven power stations, a pumping station and 225 kilometres of tunnels, pipelines and aqueducts. It was an engineering feat of international renown that provided a platform for Australia's economic development for decades to come.

Today, hydropower is our largest contributor to renewable energy. In 2016, it provided 42 per cent of total renewable electricity supplied and seven per cent of Australia's total electricity.

Australia's energy system, however, is currently undergoing its biggest transition in a century. As more intermittent renewables namely wind and solar penetrate the grid, more backup supply is needed to boost reliability and prevent price volatility.

This point was highlighted by our Energy Security Board's recent Health of the National Electricity Market report which found that despite the unprecedented amounts of renewables being delivered before 2020, "very few megawatts of power that can always be dispatched has been added to the NEM".

While storage can come in many forms, including lithium-ion batteries and hydrogen fuel cells, pumped hydro technology is the most dominant, responsible for 97 per cent of the world's energy storage. Indeed, in a recent report on energy storage by Australia's Council of Learned Academies, it was said pumped hydro is "the most cost effective for delivering energy reliability".

A study by the Australian National University and supported by the Government's Australian Renewable Energy Agency identified over 22,000 possible off-river pumped hydro energy storage locations nationwide, but no large-scale facilities have been built in Australia in the last 30 years.

In 2017 though, the Australian Government put hydropower back in the spotlight.

Announced by Prime Minister Malcolm Turnbull in March 2017 and now underway is the game-changing project that will expand the capacity of the iconic Snowy Mountains Scheme by 50 per cent. Dubbed Snowy 2.0, the additional 2,000 MW of capacity and 350,000 MWh of storage represents the largest energy storage project in the southern hemisphere and the largest renewable energy project in Australia.

Creating up to 5,000 jobs and producing enough power for 500,000 homes, it will involve 27 kilometres of tunnels and a new power station that will be up to one kilometre underground. Ten-and-a-half hours of pumping the 650 metres uphill will deliver eight hours of generation downhill. Cheap energy in the middle of night – especially windy nights – will be used to pump uphill and then on a hot Australian afternoon, Snowy 2.0 will provide electricity right when it is most in demand.

With the capacity to store enough energy to run for seven consecutive days at its maximum output, Snowy 2.0 will be Australia's biggest battery.

In Tasmania, where hydropower has been a source of energy for more than 100 years, pumped hydro energy storage offers the island state the potential to become the "battery of the nation".

The Australian Government is exploring whether expanded pumped hydro technology in Tasmania, backed by a second Tasmanian interconnector to the mainland, would deliver similar benefits for our National Electricity Market that Snowy 2.0 promises to deliver. This includes examining pumped hydro projects that can deliver an additional 2,500 MW of capacity.

In Queensland, we are supporting the redevelopment of a mine site which will co-locate a large scale solar farm with a large scale pumped hydro project and use two former mining pits as the upper and lower reservoirs. We have also undertaken a feasibility study into a pumped hydro facility in South Australia that would be the first in Australia to make use of seawater.

Pumped hydro not only provides energy storage, but also can provide grid stabilisation services, such as voltage and frequency control.

This flexibility makes it a particularly valuable player of the National Energy Guarantee – our energy policy that will not only improve reliability in the National Electricity Market, but also help us meet our Paris Agreement commitment to reduce emissions by 26 to 28 per cent by 2030 on 2005 levels at the lowest possible cost.

With an energy system undergoing its biggest transition in a century and no large-scale pumped hydro facilities having been built in the last 30 years, energy storage in Australia has never been more important.

That is why the Australian Government has made hydropower a priority agenda item, to help deliver a more reliable and affordable energy system for all Australians.

Energy storage in Australia has never been more important

View from Ethiopia

Hydropower development in Ethiopia to attain sustainable growth

Hydropower based development in Ethiopia provides a gateway to economic transformation through industrialisation, urbanisation and through the provision of access to modern energy to rural areas, writes Hon Seleshi Bekele, Minister of Water, Irrigation and Electricity.

Gibe III dam, Ethiopia. Credit: Salini Impregilo

Renewable energy provides one of the most effective strategies to simultaneously promote clean development, sustainable access and energy security with its irreplaceable role in climate change mitigation at all levels.

Today, more than two-thirds of the world's renewable electricity comes from hydropower dams. Investment in hydropower generation very often has multiple water resources development benefits. It has a benefit to provide regulation and storage structure, enhance capacity to mitigate the adverse impact of climate change resulting in pronounced flood and drought, play crucial roles in stabilising the energy mix, easily take peak loads, and enable access to relatively cheap electricity in many countries of Africa.

Hydropower generation can serve as a catalyst and entry point for regional collaboration, regional integration and the formation of broader regional markets and industrialisation in trans-boundary rivers. It also provides a platform for inter-riparian win-win cooperation to engage in terms of energy and power trade, in the coordination and regulation of water infrastructure, and in the maintenance and rehabilitation of ecosystems.

In the past two decades, electric power development policies and activities have played a pivotal role in achieving economic growth and prosperity in Ethiopia with the ultimate goal of facilitating regional economic cooperation and integration through the additional mission of interconnecting neighbouring countries with electricity.

Hydropower is also sensitive to climate change because of its dependence on river runoff, a resource which is dependent on a climate-driven hydrological cycle. Run-off depends on meteorological parameters such as precipitation and temperature. Studies using global circulation show that, in the future, some regions of the world will experience increased runoff while others will have reduced runoff as a result of global warming.

Ethiopia, like many other countries, is impacted by the effects of climate change. The government has initiated the Climate-Resilient Green Economy (CRGE) strategy to protect the country from the effects of climate change and to build a green economy. The Green Economy Strategy identified and prioritised more than 60 initiatives to achieve development goals while limiting greenhouse gas emissions in 2030 to the levels of 2010 base (150 $MtCO_2e$) with 64 per cent equivalent of CO_2 reduction. The key to attaining green and low-carbon development is clean energy development, where hydropower plays the major role. Developing hydropower for domestic consumption and exporting the excess amount to neighbouring countries would mean to take the leading role to meet the ambition of the Paris Climate Agreement of reducing $MtCO_2e$ in 2030 in the region.

The role that energy, or Sustainable Development Goal (SDG) 7, plays is immense in the overall future sustainability of our planet. Particularly, hydropower plays the lion share, especially in developing countries due to its proven technical and technological ease and relatively low cost per MW investment. It also encompasses other services such freshwater management, climate mitigation, climate adaptation services, firm energy, energy storage and other ancillary services which could contribute to other SDGs including water (SDG 6), resilient infrastructure (SDG 9), and climate change (SDG 13).

Energy access is increasingly seen as a vital catalyst to wider social and economic development, enabling education, health and sustainable agriculture as well as creating jobs. By 2025 electricity access is expected to reach 100 per cent in both rural and urban areas of Ethiopia. To attain this, electrification enables the provision of affordable electricity to poor households who are forced to use fuel-wood to meet their energy needs, over 85 per cent of which is used for cooking and heating.

Because of this, thousands of square kilometres of deforestation takes place annually for fuel wood collection and charcoal burning, which also triggers massive land degradation and soil erosion.

Ethiopia's hydropower potential is estimated at up to 45,000 MW and is the second highest in Africa. Hydropower based development provides a gateway to economic transformation through industrialisation, urbanisation as well as through the provision of access to modern energy to rural areas. The current electricity installed capacity of 4,284 MW is 97 per cent renewable of which effective hydropower installed capacity is 3,810 MW. Furthermore, 8,864 MW of hydropower development is under construction.

Development of hydropower started in the early 1930s with the first Aba Samuel dam commissioned in 1932 with an installed capacity of 6.6 MW. After that, the country has not made significant progress in hydropower development up until the last decade when the construction of dams saw a significant boom.

Since 2009, the country has commissioned five hydro dams with a total capacity of 3,147 MW. The latest commissioned is the Gibe III Dam with an installed capacity of 1,870 MW with the largest roller compacted concrete dam technology in the world. Among the dams under construction, the Grand Ethiopian Renaissance Dam (GERD), with an expected installed capacity of 6,450 MW on completion, will be the largest hydropower dam station in Africa. It is also important to note that Ethiopia has about 17 identified sites of hydropower potential sites ranging from 60 MW to 2,000 MW in the pipeline and expected to be largely developed by the private sector as independent power producers.

Renewable energy mixes from wind, solar and geothermal sources are expected to be increased significantly in the coming future in Ethiopia.

Ethiopian policy and strategy emphasises the diversity of the energy mix by developing wind, solar and geothermal, etc, to complement hydropower. On the other hand, it is equally important to guard against the negative impacts of hydropower development and to pay close attention to climate resilience, social inclusion and environmental services.

Energy access is increasingly seen as a vital catalyst to wider social and economic development

View from Sarawak, Malaysia

Hydropower and Sarawak's journey in renewable energy development

With Sarawak being unique and blessed with an abundance of natural resources, it is only logical to explore and harness renewables from these resources, writes Chief Minister Yab Datuk Patinggi Dr Abang Haji Abdul Rahman Zohari Bin Tun Datuk Abang Haji Openg.

Energy is what drives development and underpins economic growth. Global energy demand is forecasted to grow by 58 per cent between now and 2040 and we hear of countries racing to secure energy. Sarawak is no different.

We are aware that we need to detach from being reliant on non-renewable resources if Sarawak is to achieve energy security for sustainable economic growth.

The International Energy Agency (IEA) reports that by 2022, global renewables electricity generation is expected to grow by over one-third to over 8,000 terawatt hours, equal to the total power consumption of China, India and Germany combined. As a result, the share of renewables in power generation will reach 30 per cent in 2022, up from 24 per cent in 2016.

The report also states that in the next five years, growth in renewable generation will be twice as large as that of gas and coal combined. While coal remains the largest source of electricity generation in 2022, renewables halve their gap with coal, down to 17 per cent in 2022.

Despite slower capacity growth, hydropower will remain the largest source of renewable electricity generation in IEA's forecast, followed by wind, solar PV and bioenergy.

With Sarawak being unique and blessed with an abundance of natural resources, it is only logical to explore and harness renewables from these resources to further boost our generation figures and secure a stable supply of energy in the state.

Our many rivers, plentiful rainfall and mountainous terrain have enabled Sarawak to embark and focus on hydropower development which at present represents 75 per cent of the state's generation mix. Fossil fuel, coal and alternative renewables like solar and mini-hydro make up the rest of the mix.

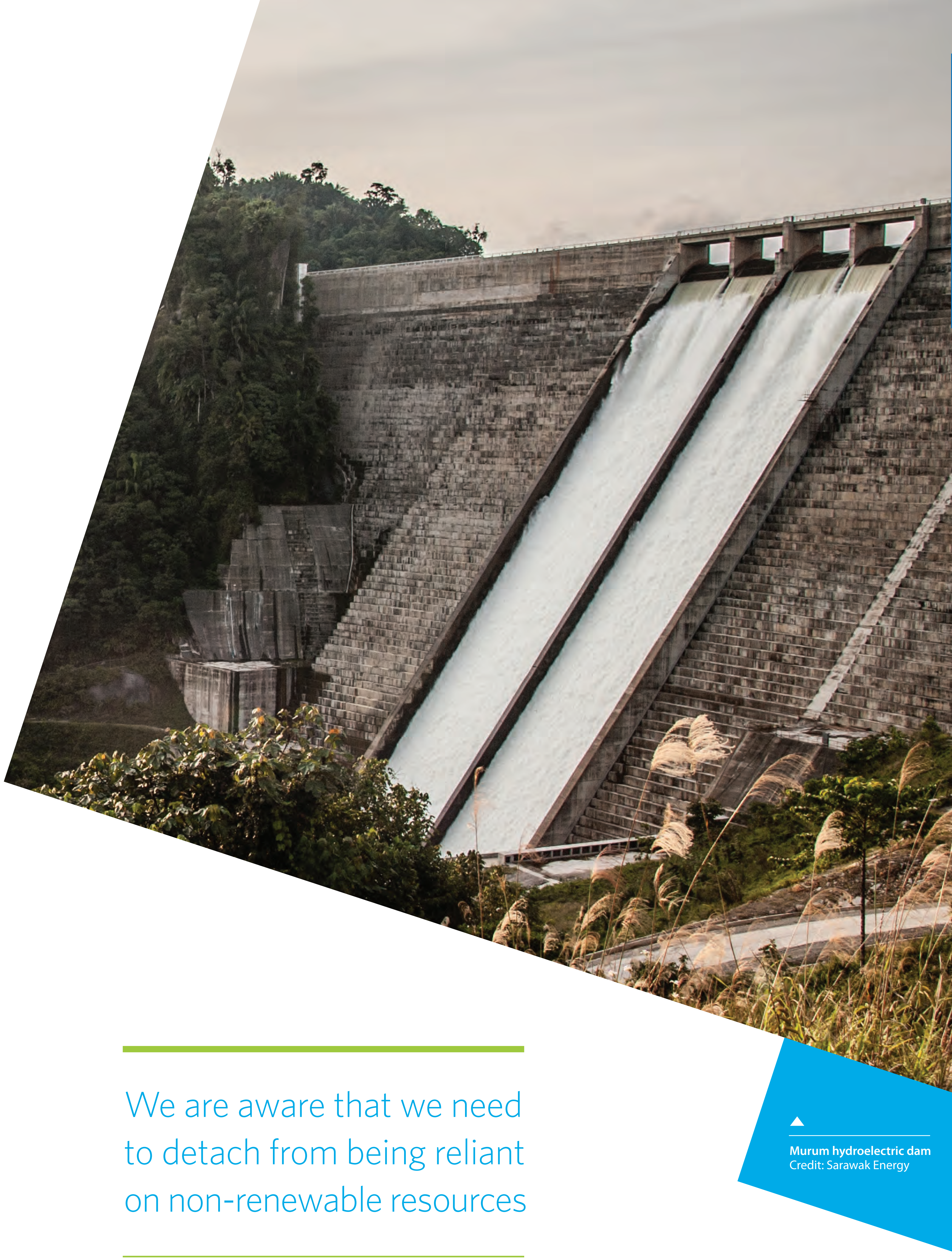
Hydropower, being a sustainable source has since reaped benefits as it allowed the State Government to develop the state's development strategy - the Sarawak Corridor of Renewable Energy, or SCORE, attracting energy intensive industries and investors to our shores by offering security of supply at a globally competitive price.

With SCORE, the state's energy demand took a quantum leap as it triggered a number of downstream businesses and opening up the state's rural areas giving rural towns a boom effect. In addition, hydropower also allowed the State government to lower electricity tariffs for domestic, commercial and industrial consumers making Sarawak the state with the lowest tariffs in Malaysia and one of the lowest in the region, and reducing carbon emission from supply generation by 72 per cent.

Other than being a natural resource, hydropower development makes for good business sense as hydropower projects do have a high upfront outlay during the construction phase, but they have very low running costs and can operate for many decades – up to a hundred years in certain cases, making it a viable option that works for Sarawak.

Sarawak now has three hydroelectric power plants under its belt - Batang Ai, Murum and the recently acquired Bakun with another, Baleh, currently under construction and expected to be completed by 2026.

As we continue to be on track in our efforts in energy security which will also establish our reputation as the ASEAN (Association of Southeast Asian Nations) Powerhouse, Sarawak continues to explore on developing new energy supply options through research and adopting new technologies. Advances in technology promote energy efficiency and has opened up many new energy supply options making this sector more competitive.



Murum hydroelectric dam
Credit: Sarawak Energy

We are aware that we need to detach from being reliant on non-renewable resources

View from Scotland

Investment in pumped hydro could greatly increase network resilience

Investment in new pumped hydropower storage capacity could greatly enhance the flexibility and resilience of the electricity network, writes Paul Wheelhouse MSP, Minister for Business, Innovation and Energy in the Scottish Government.

Early development of the hydropower sector in Scotland arose from a unique combination of landscape, climate, and the drive of a handful of innovative and pioneering engineers, architects and politicians. The growth of Scotland's aluminium industry with its need for cheap electricity helped make large scale hydropower a reality with the establishment of many schemes such as Kinlocheven built in 1907.

An Act of Parliament in 1943 saw the establishment of the North of Scotland Hydro Electric Board. In the years that followed, the Board embarked upon an ambitious hydropower development programme, with a view to delivering power and improving the lives of people across the Highlands and Islands regions. At its peak, it generated employment opportunities for more than 12,000 people.More recently by 2016, the low carbon and renewable energy sector as a whole supported 49,000 jobs across Scotland, generating a turnover of £11 billion.

The 2050 vision for energy in Scotland was recently outlined in the Scottish Energy Strategy (published December 2017). It incorporates a flourishing competitive, local and national energy sector, delivering secure, affordable, clean energy for households, communities and businesses alike. The hydro sector, alongside wind, wave and other emerging technologies has a key role to play in its realisation.

Ninety-two per cent of the UK's power from hydro is generated in Scotland, and the sector continues to retain its importance to the growing economy, both in terms of generating investment into the construction industry, and in creating valuable local jobs often in the most remote rural geographical areas. Of the 9.7 GW of installed renewable electricity capacity in Scotland in 2017, 1.65 GW came from hydro.

Two of the UK's four pumped storage hydro facilities are located in Scotland; Cruachan (operated by Scottish Power) an amazing feat of engineering located deep within the 1126 metre high Ben Cruachan mountain, on the shores of beautiful Loch Awe, and Foyers (operated by SSE remotely from their Perth renewable operations centre) on the eastern shore of the world famous Loch Ness. The sites have generating capacity of 8.8GWh (440 MW) and 6.3 GWh (300 MW) respectively, making a significant contribution to the UK's 24 GWh of pumped storage capacity.

Looking to the future, further investment in new pumped storage capacity could greatly enhance the flexibility and resilience of Scotland's electricity network and power supplies. However these are major infrastructure projects and further work is needed to reduce risks and remove barriers to investment to facilitate successfully delivery. To this end the Scottish Government continues to actively engage and work with the UK Government.

Glendoe Hydro Scheme, Scotland, UK.
Credit: Scotavia Images.

New pumped storage capacity could greatly enhance flexibility and resilience

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, a new tier of membership launching in 2018.

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

Hydropower issues in focus

Sustainability

A landmark year in the development of assessment tools

New tools to be launched in 2018 will support targeted, cost-effective assessments of hydropower projects, enable reporting on climate mitigation and resilience, and promote the adoption of industry good practice.

Costa Rica's Reventazon project was classed as an example of good international practice under the Hydropower Sustainability Assessment Protocol in 2017. Image Credit: World Bank - Mario Lacayo

The Hydropower Sustainability Assessment Protocol is internationally recognised as the primary tool for evaluating sustainability performance in hydropower. Since its launch in 2011, the Protocol has been applied at more than 40 sites in both developed and developing countries.

It offers a framework for assessing a project at different stages of its development - from early stage to preparation, implementation and operation - against more than 20 sustainability topics, including siting and design, finance and safety, as well as impacts on biodiversity and local communities, among other topics.

The Protocol is not only applied during an assessment, it is also used as a resource for capacity-building, as an internal reference guideline and a guide to hydropower planning decisions in countries around the world.

IHA acts as the management body for the Protocol with a multi-stakeholder group of organisations providing executive direction and oversight, as its Protocol Governance Council. This group includes the World Bank, WWF, the Inter-American Investment Corporation, the Norwegian Agency for Development Cooperation, and Switzerland's State Secretariat for Economic Affairs.

Expanded Protocol covers climate mitigation and resilience

During 2018, the Protocol is set to be expanded to cover a new climate topic to assess a project's carbon footprint and resilience to climate change. Climate change had previously been dealt with as a cross-cutting issue but, given the importance attached to both mitigating the effects of greenhouse gas emissions and increasing the resilience of projects, the Protocol Governance Council considered a dedicated topic necessary.

In addition, the council asked IHA to develop a more targeted, cost-effective tool, based on the Protocol, which would allow a project to be assessed against basic good practice across key environmental, social and governance criteria. This recognised increasing demands from developers and international investors, who have requested a simplified screening mechanism to gauge eligibility for green financing, such as through the green bond market.

Simplified gap analysis tool for targeted assessments

The new Hydropower Sustainability Environmental, Social and Governance Gap Analysis Tool (ESG Tool) is designed to identify gaps against good practice and provides an action plan that will help project teams to address them within a reasonable timeframe. The tool 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.

The consultation process to review both the expanded Protocol and the ESG Tool by the multi-stakeholder council was the largest and most significant consultation since the forum that was assembled to draft the original Protocol in the late 2000s. After formal adoption by the Protocol Governance Committee in December 2017, both the expanded Protocol and ESG Tool are set for launch in 2018. With the Protocol and the ESG Tool, developers, owners and operators will have two powerful means of building a clear and objective picture of their project.

Next steps: international industry guidelines

Although the Protocol provides a definition of good and best practice in sustainable hydropower, and includes some guidelines, it is presented as a methodology for assessment and scoring, and the guidance it contains is for completing an assessment. However there is no widely recognised document providing comprehensive guidelines on international industry good practice for sustainability in hydropower.

Under the mandate of the Protocol Governance Committee, IHA has been developing comprehensive guidelines covering all the topics of the Protocol. As of May 2018, the draft Good International Industry Practice Guidelines were completed and were undergoing expert review. The guidelines will jointly address the preparation, implementation and operation stages of a project, but will refer to the stages clearly within each topic section.

These guidelines are based on the same definitions of basic good practice, additional guidance developed by IHA in recent years for capacity building purposes, and practice observed during numerous protocol assessments over the past decade.

A crucial part of developing guidelines is to provide examples of where good practice has been successfully applied. For this reason, IHA intends to combine the guidelines with more detailed technical handbooks and case studies, most notably through IHA's Better Hydro series, funded by the World Bank.

The Better Hydro series, which was launched at the World Hydropower Congress in Addis Ababa in May 2017, is available as an online resource on the IHA website. It showcases projects that have demonstrated excellence in specific aspects of sustainable hydropower development, based on assessments carried out under the Hydropower Sustainability Assessment Protocol.

ESG Tool

To be launched in 2018 and based on the Hydropower Sustainability Assessment Protocol, the ESG Tool will allow a focused, cost-effective analysis of a project to assess any gaps against good practice across key environmental, social and governance criteria, including climate change mitigation and resilience.

While focusing on a more limited range of topics, the ESG Tool goes beyond a Protocol assessment insofar as it provides a management plan to close identified gaps, providing any project developer with a clear pathway to reaching good practice.

Become an accredited assessor

IHA is training and accrediting assessors to complete Protocol and ESG Tool assessments. Information on eligibility and how to apply can be found on the IHA website.

Online

hydropower.org/sustainability

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Climate mitigation

Study shows hydropower's carbon footprint

A new study of the greenhouse gas footprint of almost 500 reservoirs worldwide, which applied the G-res tool for assessing net emissions, indicates that hydropower is one of the cleanest energy sources.

Coal	820
Gas	490
Solar PV (Utility)	48
Hydropower*	18.5
Wind Offshore	12
Nuclear	12
Wind Onshore	11

Figure 1: Median life-cycle carbon equivalent intensity (gCO_2-eq/kWh)

Source: IPCC 2014 / IHA 2018 *IHA STUDY

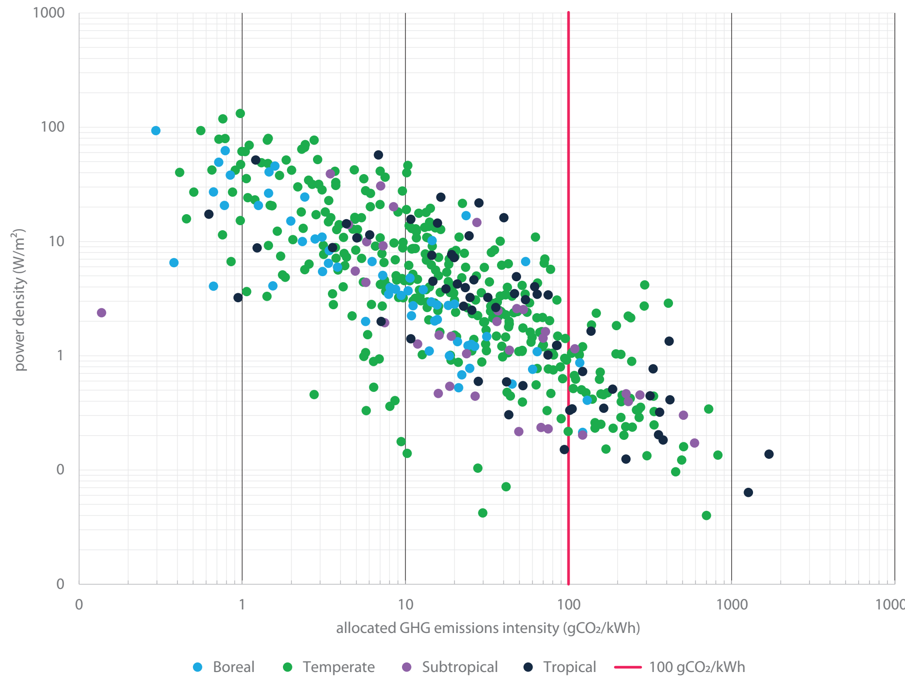

Figure 2: Relationship between GHG emissions intensity (gCO_2-eq/kWh) and the power density of projects (W/m²)

The greenhouse gas footprint of hydropower has long been questioned in both scientific and policy spheres, especially with regard to emissions caused by the creation of a reservoir. There has been a lack of scientific consensus on how to quantify this footprint, and this uncertainty has proved a significant obstacle for policy and decision makers concerning the financing of hydropower projects and whether they achieve the designation of being climate-friendly.

The Intergovernmental Panel on Climate Change (IPCC), in its Fifth Assessment Report published in 2014, noted that only onshore and offshore wind and nuclear power have lower median lifecycle greenhouse gas emissions than hydropower. However the panel cautioned that few studies had appraised the net emissions of freshwater reservoirs, allowing for pre-existing natural sources and sinks and unrelated human emission sources.

The challenge of assessing net climate emissions

Over the years, a number of researchers have measured gross reservoir emissions at sites around the world, but the results of each study cannot be reliably applied to other reservoirs, even in the same region. The biochemical processes leading to emissions from a reservoir are highly complex, and life-cycle emissions are very specific to the siting and design of each hydropower facility.

Emissions relating to the construction and operation of a dam, due to fossil fuel combustion and cement/steel production, can vary depending on its type and size. Once filled, factors such as a reservoir's depth and shape, the amount of sun reaching its floor, and wind speed, affect the different biogeochemical pathways by which CO_2 and CH_4 are created and released to the atmosphere.

The process of taking measurements to determine the greenhouse gas (GHG) footprint of a hydropower facility or reservoir can be cumbersome or prohibitively expensive. Calculating the net change in emissions caused by a reservoir is highly challenging.

Development of the G-res tool

Against this backdrop, the GHG Reservoir (G-res) Tool was developed by IHA and UNESCO in cooperation with researchers from the University of Quebec at Montreal (UQÀM) in Canada, the Norwegian Foundation for Scientific and Industrial Research (SINTEF) and the Natural Resources Institute of Finland (LUKE). This research was supported by the World Bank and sponsors from the hydropower sector.

The tool was devised to enable companies, investors and other stakeholders to more accurately estimate the net change in GHG emissions attributable to the creation of a specific reservoir. It takes into account the state of the land pre-impoundment, considering naturally occurring emissions and emissions related to other human activities over the lifetime of the reservoir. It also provides a method for apportioning the net GHG footprint to the various freshwater services that a reservoir provides, such as water supply for irrigation and cities, flood and drought management, navigation, fisheries and recreation.

The G-res tool was formally launched, after more than a decade of development work, at the World Hydropower Congress in Addis Ababa, Ethiopia, in May 2017.

Worldwide study of hydropower reservoirs

During 2017, researchers from IHA undertook a study of 498 reservoirs worldwide using the G-res tool. The study looked at reservoirs in boreal, temperate, subtropical and tropical climates more than 50 countries in North and Central America, South America, Europe, Africa, South and Central Asia, East Asia and the Pacific.

The study used the G-res tool to estimate the GHG footprint of 178 single purpose hydropower reservoirs and 320 multipurpose reservoirs, excluding emissions caused by construction activity. This data was coupled with project-specific installed hydropower capacity and average annual generation data to obtain the emissions intensity of each site's hydropower operations.

The global median GHG emission intensity of the hydropower reservoirs included in the study was 18.5 gCO_2-eq/kWh; this is the grams of carbon dioxide equivalent per kilowatt-hour of electricity generated allocated to hydropower over a life-cycle. The majority, or 84 per cent of reservoirs, exhibited emissions less than 100 gCO_2-eq/kWh. For a comparison with the median values of other electricity sources, see figure above.

Temperature is one of the variables that has, in theory, a significant effect on reservoir emissions. However mean annual temperature is only one of many variables that influence GHG emissions. The G-res tool includes other input variables such as the soil carbon content of the reservoir, depth of the thermocline, reservoir drawdown area and the catchment annual run-off. The second figure above shows the emissions intensity attributable to hydropower reservoirs categorised by their respective climate zones.

The IHA study, which is to be submitted for peer review, confirms in part that the vast majority of hydropower reservoirs are producing very low-carbon power, some reservoirs in every climate category can potentially have high emissions exceeding 100 gCO_2-eq/kWh (defined by the Climate Bonds Initiative to be an important threshold).

Figure 2 shows the relationship between the GHG emissions intensity (gCO_2-eq/kWh) plotted against the power density of the projects (W/m²). High emissions intensities are possible from hydropower reservoirs, even on the same order of magnitude as fossil fuel generators, but only at extremely low power densities. Low power density however does not necessarily translate to high emissions intensity, as many projects with low power densities have emissions intensities well below 100 gCO_2-eq/kWh (left of the red line).

It bears noting that the emissions intensity identified from this study applies only to hydropower projects with large reservoirs; many hydropower projects, often run-of-river, do not flood significant areas of land and consequently will have even lower emissions. It should also be noted that hydropower facilities equipped with reservoir storage provide many other valuable power and water benefits. By storing water in a reservoir, a project can offer balancing and ancillary services, delivering dispatchable power when needed. A reservoir also provides water for vital non-power uses such as flood control and drought management, and water supply for municipalities and agriculture.

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Green bonds

New criteria to unlock the market to hydropower

New hydropower sector-specific criteria for green bond issuers and investors should open up the burgeoning market to sustainable and socially responsible hydropower projects.

Investors are increasingly looking to shift their capital flows towards sustainable projects and assets, a trend which is reflected in the rapid growth of the green bond market over the past couple of years, albeit from a small base. In 2017, USD 160 billion of labelled green bonds were issued, nearly double that of the previous year, and expectations are that 2018 will see issuances exceed USD 250 billion.

As the market matures, the various definitions of what constitutes a labelled green bond will become more standardised and robust. This will only further whet the appetite of investors as a growing coalition of organisations, including the United Nations Framework Convention on Climate Change, have set a target of USD 1 trillion worth of issuances by 2020.

Notwithstanding, existing standards have largely excluded hydropower, the world's largest source of renewable electricity. This is creating uncertainty and stifling the sector's access to this growing source of finance as highlighted by the 2018 Hydropower Status Survey, which found that nearly three-quarters (72.5 per cent) of respondents – comprising mainly of senior decision-makers from hydropower businesses - believe that greater clarity on green bond eligibility is needed.

Emergence of the green bond market

In order to address threats from climate change and other environmental risks, coupled with an ever widening infrastructure gap, a significant realignment of capital markets is required. More than a decade after the European Investment Bank (EIB) issued the world's first labelled green bond, the green bond market is now billed as an important catalyst for the transition to a low-carbon economy, reflecting the growing attractiveness of bond financing for renewable energy projects.

While the market was initially dominated by issuances from supranational organisations such as the EIB and World Bank, this is changing as corporates and commercial banks recognise that promoting and operating sustainable business activities is not simply about being good corporate citizens, in fact it's critical to adequately manage risk into the future.

National, provincial and municipal governments, buoyed by the Paris Agreement and the need to meet their Nationally Determined Contributions, are also entering the green bond market to finance low-carbon infrastructure and build resilience to incorporate the impacts of climate change.

Poland was the first sovereign to issue a green bond in 2016 and has since been followed by France, Nigeria, Belgium, Fiji and Indonesia, with several other countries developing plans to follow suit.

Green bonds for financing hydropower

To date, concerns surrounding the level of methane emissions from tropical hydropower reservoirs have led to all new hydropower development with a capacity of more than 20 MW being excluded from the CBI's classification of a labelled green bond, no matter the location or type (i.e. storage, run-of-river and pumped hydropower).

This has had major implications across the green bonds ecosystem as issuances from many corporates, commercial banks, development banks and governments have excluded the proceeds from being used to finance medium and large hydropower developments. Green bond indices such as S&P and Solactive also rely on the CBI's taxonomy to determine a bond's eligibility. Other standards have similar exclusions, and while the Bloomberg Barclays MSCI Green Bond Index allows large hydropower, it cannot represent more than 10 per cent of the bond's proceeds, ruling out most projects.

As a result, existing standards are severely limiting green finance being directed to a technology, which provides two-thirds of the world's renewable electricity and will be critical to meeting the goals set out in the Paris Agreement. As well as being a renewable, low-carbon source of electricity, due to its operational flexibility and storage capabilities, hydropower also enables the greater penetration of variable renewables such as wind and solar.

Hydropower-specific criteria: a breakthrough?

The key to unlocking the full potential of the green bond market for hydropower financing is the development of sector-specific eligibility criteria, which gives issuers and investors the confidence to invest in climate-aligned and socially responsible hydropower development. The demand is there, with over half of the respondents to the 2018 Hydropower Status Survey stating that their organisation expects to finance or refinance a hydropower project via the green bond market over the next five years.

Reflecting the role that hydropower can play in the transition to a low-carbon economy, in June 2016 the CBI established the Hydropower Technical Working Group (TWG). Bringing together a host of industry, environmental, technical and water experts drawn from international NGOs, government and academia, the TWG has taken a robust, science-based approach to develop criteria that identifies climate-aligned hydropower investments and assets across all sizes, types and locations.

Towards the future

Later this year, the CBI is due to publish its draft hydropower criteria for public comment. The criteria is expected to cover three main elements, namely climate mitigation, climate adaptation and resilience and adherence to broader environmental, social and governance good practice.

In addition, a new tool developed by IHA and partners – the Hydropower Sustainability Environmental, Social and Governance Gap Analysis Tool, or ESG Tool – which is soon to be launched (see article on Sustainability page 26), will be used to assess a project's performance against these elements. The ESG Tool is based on the internationally recognised Hydropower Sustainability Assessment Protocol, and aligns with the World Bank's new Environmental and Social Framework and the International Finance Corporation's Environmental and Social Performance Standards.

The development of the CBI's criteria, together with the forthcoming launch of the ESG Tool, will provide investors with practical, transparent and cost-effective means to evaluate projects, giving them the confidence they require to invest in environmentally sustainable and socially responsible hydropower.

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Regional interconnections

Cross border transmission in Central America

Central America's integrated regional electricity grid provides a model for other regions seeking energy interconnections and market integration.

The Central American Electricity Interconnection System (SIEPAC) integrates six countries into a regional grid and has been operating for five years. It is used to enable the Regional Electricity Market (MER) and works as a regional power pool for trading partners.

Starting in Guatemala, the system branches out through El Salvador and Honduras, and then passes through Nicaragua, Costa Rica and Panama. The grid uses a single-circuit 230kV transmission line with a number of substations installed, and covers a distance of 1,830 km.

Representing a major achievement for the region, the SIEPAC project was developed under a partnership between host governments and financing institutions at a total cost of USD 506 million.

When considering the high share of renewables in Central America's energy mix, the SIEPAC provides a model for other regions around the world which are seeking energy interconnections and options for market integration.

Market trends

Trading activity has increased over the last five years, according to statistics compiled by the SIEPAC steering committee (Director Council of the Regional Electricity Market of Central America - CDMER). The total volume of transactions in the MER was 478 GWh in 2013, a figure which had

Country	Transmission (km)
Guatemala	281.8
El Salvador	282.3
Honduras	369.4
Nicaragua	293.5
Costa Rica	462.4
Panama	140.3
Total	1,829.7

Figure 3: SIEPAC transmission map

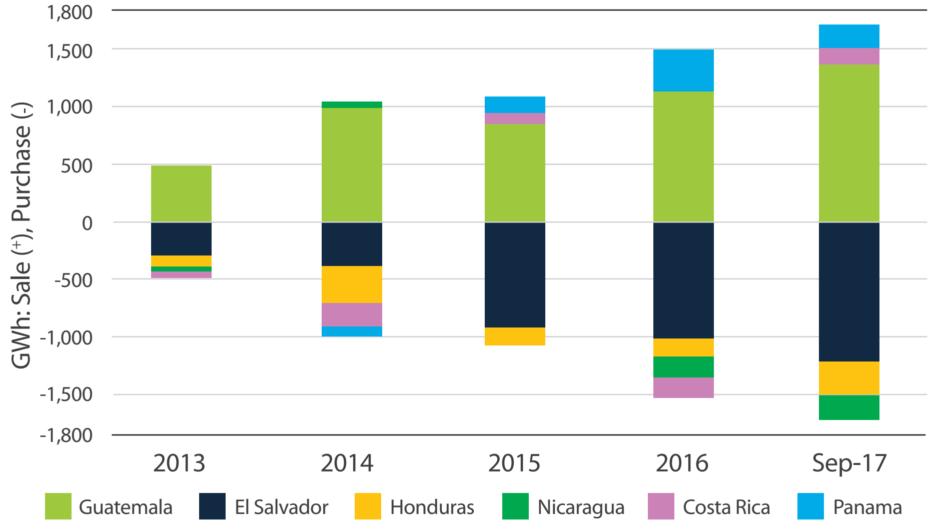

Figure 4: Net annual electricity exchange in the regional wholesale market

doubled by the end of 2014 and multiplied by nearly five times to 2,232 GWh by the end of 2017.

While transactions have risen, wholesale prices in the regional market have come down over the last few years. Electricity nodal prices in the MER showed an initial spike at the beginning of 2014, but then progressively reduced and, since 2015, monthly average prices have generally remained below USD 100 per MWh. Some months in 2016 and 2017 saw fluctuations in prices, due for example to excess hydropower in Panama and Costa Rica spilling onto the regional grid and pulling down regional wholesale prices.

Net electricity exchanges

The SIEPAC is increasing power exchange between countries and continues to improve security of power supply. At times a country can pool its spare capacity in the regional market (MER) so that consumers in neighbouring countries can purchase electricity by contracts or using the spot market. At other times, the same country could buy from the regional market to meet domestic demand. The difference between a country's total sales and purchases from the MER, over a given time period, gives the balance of its cross-border trades.

Figure 2 shows the net annual electricity exchanges in the regional market: the top area of the chart is net sales (positive) and the bottom area is net purchases (negative). The green bars across the top represent Guatemala and show the country was a net exporter into the MER over the last five years. The dark blue bars across the bottom represent El Salvador, showing it has been a net importer along with Honduras and, recently, Nicaragua. This indicates generators located in Guatemala were supporting power demand in El Salvador through the SIEPAC. Costa Rica was a net exporter in 2017, as well as 2015, and was a net importer in 2013, 2014 and 2016.

Power generation

Across the SIEPAC countries, renewable capacity has been growing steadily over the last few years and is increasing its proportion in the energy mix. In 2016, renewables contributed 67 per cent of the total 51,000 GWh generated across the six countries, with the majority coming from hydropower.

Guatemala, Panama and Costa Rica, which have been net exporters, each generated a similar total volume of electricity in 2016 at approximately 10,800 GWh each. In the case of Guatemala, 36 per cent came from hydropower and most of the remainder from thermal; Panama produced 61 per cent from hydropower; and Costa Rica supplied the largest amount of hydropower at 74 per cent share of national output.

Costa Rica, which interconnects with Nicaragua to the north and Panama to the south, relies on hydropower for three quarters of its total generation mix of 10,800 GWh. In 2016 the country's imports increased from January to April during the dry season when hydropower generation was constrained, whereas in other years its excess hydropower generation resulted in a net export balance.

Generation is not exclusively renewable in Guatemala and Panama, but exports from these countries are clearly supporting the smaller grids of El Salvador and Nicaragua, as well as Honduras, with a significant proportion coming from hydropower reserves. In 2013, the SIEPAC was credited with helping Panama recover from an energy crisis due to an extreme drought, using power supplied from El Salvador, Honduras and Nicaragua.

A model for regional interconnection

With increasing power exchanges and competitive wholesale prices, the SIEPAC is showing how regional interconnection can benefit trading partners. For the countries with relatively small installed capacities, the SIEPAC provides access to new supplies and is improving energy security right across the region. Much of the shared energy is clean power, given the growing contribution from renewables in Central America, which will help offset fossil-fired generation and reduce emissions, operating costs and inefficiencies.

The CDMER-SIEPAC steering committee is working with the regional network operating and regulatory institutions on improvements. These include adding a second circuit to double transmission line capacity, and implementing firm contracts and long-term transmission rights. These measures will support the case to build and connect larger power plants in the future, including new hydropower projects, which is another strategic objective of the SIEPAC. Continued harmonisation of regulations is also a priority, to ensure common standards are applied across all parts of the network.

Contact us

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Developing guidelines for the hydropower sector

New hydropower sector climate resilience guidelines being developed by IHA, the World Bank and EBRD in consultation with the hydropower sector will provide good practice guidance for project owners, governments, financial institutions and private developers.

Hydropower systems are characterised by their longevity and are traditionally designed on the basis of long-term historical hydrological data and forecasts. Hydropower projects are, nonetheless, susceptible to the impacts of climate change due to their dependency on precipitation and runoff, and exposure to extreme weather events.

In 2013, the International Development Association, part of the World Bank Group, at its IDA17 Replenishment Meeting called for screening all new operations for short- and long-term climate change and disaster risks, and where risks exist, to develop appropriate resilience measures. The World Bank thereafter published the Decision Tree Framework in 2015 to outline a pragmatic process for robust risk assessment and decision making for water resource projects.

In response, and recognising the increased focus given to climate risk and resilience among its members, IHA carried out a survey of members in 2015 to receive insights on climate-related risks and actions. The surveyed hydropower organisations agreed that climate change would impact their operations and requested guidance to become more resilient.

Joining forces, the World Bank and IHA organised a workshop at the end of 2015 to engage with other international financial institutions (IFIs) such as the European Bank for Reconstruction and Development (EBRD) and hydropower organisations that were incorporating resilience assessments in their proposals and projects.

With increasing awareness of the need to develop guidance to build hydropower infrastructure which can cope with the risks of variable climatic conditions, the World Bank took the initiative to develop a set of guidelines relevant to the hydropower sector on industry good practice in building climate resilience into new and existing projects.

The beta version of the Hydropower Sector Climate Resilience Guidelines was released in September 2017 after multiple consultations and engagement with key stakeholders ranging from IFIs, major hydropower developers, owners and operators, intergovernmental and not-for-profit organisations, to international consultancies and independent experts.

> Climate resilience is the capacity of a hydropower project or system to absorb the stresses imposed by climate change, and in the process to evolve into greater robustness.

The guidelines will assist hydropower companies to consider climate-related risks in project design and operations and address the needs of the wider financial community, policy-makers and local communities.

Path forward

Planning hydropower systems from a long-term, climate-resilient perspective will ensure that future generations inherit infrastructure that will not be compromised by climate change.

The aim of the Hydropower Sector Climate Resilience Guidelines is to provide practical and workable international good practice guidance for project owners, governments, financial institutions and private developers. The guidelines will incorporate climate change resilience and hydrological risk management into hydropower project appraisal, design, construction and operation, resulting in more robust and resilient projects.

Process for developing the guidelines

PROJECT PHASES

- **SECTOR ASSESSMENT** (OCT. 2015) – Sector survey to identify stakeholders preparedness and main issues
- **PROJECT CONCEPTION** – Face-to-face meetings to refine needs and programme of work
- **PREPARATION OF BETA VERSION** (JAN. 2016) – Selection of consultant, with regular status meetings
- **STAKEHOLDER ENGAGEMENT** – Outreach, consultation and feedback from operators & developers
- **RELEASE OF BETA VERSION** (SEPT. 2017) – First viable version prepared by a consultancy
- **TESTING CAMPAIGN (2018)** – Apply guidelines and receive feedback from operators around the world
- **REFINEMENT** – Analyse feedback and update the guidelines as required.
- **GUIDELINES LAUNCH** (MAY 2019) – Launch of tested guidelines at the 2019 World Hydropower Congress in Paris

ACTIVITIES TO DATE

2015

- October 2015 – Global survey to IHA members
- November 2015 – WBG / IHA workshop on Resilience of Hydropower and Dams to Climate Change and Natural Disasters (London, UK)

2016

- January 2016 – Call for consultancy to elaborate a beta version for the climate resilience guidelines
- October 2016 – Project kick-off meeting (Washington, DC)

2017

- February 2017 – Mid-term status meeting (London, UK)
- PRESENTATIONS AND OUTREACH
  - May 2017 – Hydrovision 2017 (Denver, USA); World Hydropower Congress (Addis Ababa, Ethiopia)
  - August 2017 – Sustainability in Hydropower Forum (Oslo, Norway)
  - September 2017 – UNFCCC Forum on the Standing Committee on Finance (Rabat, Morocco)
  - October 2017 – Hydro 2017 conference (Seville, Spain); Forum on building climate resilience (Dushanbe, Tajikistan)
- July 2017 – Final status meeting (Washington, DC)
- September 2017 – Release of beta version
- November 2017 – Stakeholder meeting on the outcomes of the beta version Washington, DC

2018

- January 2018 – Establishment of secretariat to manage the testing phase

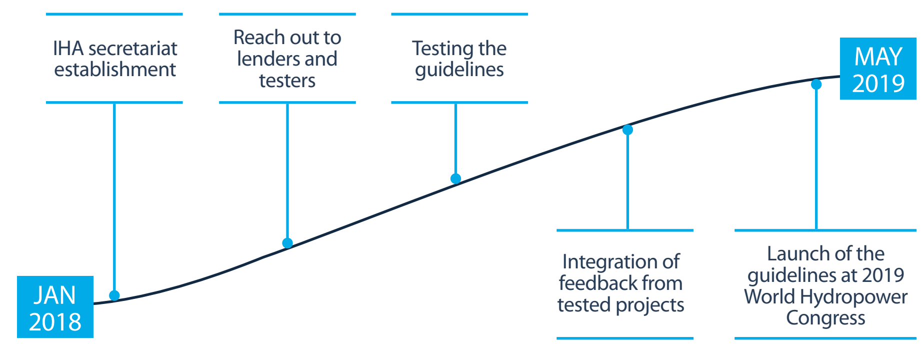
2019

- January 2019 – Workshop to share the outcome of the climate resilience guidelines testing phase
- 14-16 May 2019 – World Hydropower Congress: launch of climate resilience guidelines

Following the workshop in November 2017, the stakeholders agreed to test the guidelines on pilot projects during 2018. The objective is to apply the guidelines to real projects worldwide to gather useful feedback and ensure their applicability and viability.

The World Bank and EBRD are supporting IHA to coordinate the testing of the Hydropower Sector Climate Resilience Guidelines. The feedback and recommendations from the testing phase will be used to update the guidelines.

Achieving a major consensus around climate resilience guidelines will be important for the widespread adoption of the guidelines among the hydropower sector worldwide.



Contact us

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Technological headwinds are changing the face of hydropower operations

Image credit: Voith Hydro

Renewable energy targets assume that hydropower will make a significant contribution to carbon reduction for decades, if not centuries, into the future. Such projections rely on prolonging the life of hydropower assets and optimising performance using new technologies.

Hydropower projects support decarbonisation, provide over 90 per cent of global energy storage for variable renewables such as solar and wind, and offer water management services to mitigate floods and droughts. These assets have a long lifespan and relatively low operating and maintenance costs – typically around 2.5 per cent of the overall cost of the plant.

By 2030 over half of the world's hydropower plants will be due for upgrade and modernisation or will have already been renovated, according to IHA's database. In this year's 2018 Hydropower Status Survey, however, 79 of 95 respondents working at hydropower companies said they expect to contract major upgrading and modernisation works within the next 10 years.

What explains the high percentage of respondents who say major works are just around the corner? Part of the reason is a commitment among industry to adopt best practice in operations and asset management plans: a desire for optimised performance and increased efficiency. Another major driver is the sheer pace of technological innovation in hydropower operations and maintenance, in both developed and developing country contexts.

At a meeting of the African Union's Specialised Technical Committee on Communication and ICT in 2017 in Addis Ababa, governments concluded that digitalisation in particular is "the greatest opportunity for Africa to drive the fundamental changes of the world in the 21st century, if wisely harnessed and mainstreamed."

New digital opportunities

The revolution in digitalisation which has swept through computing to encompass algorithmic trading, artificial intelligence and blockchain technology, has not left hydropower untouched. In the sector, enhanced digital systems are part of a growing trend towards improving the performance of turbines, plants and equipment, by reducing costs, adding flexibility and enhancing asset management.

Equipment manufacturers are embracing digitalisation as a way to widen their scope of services and to extend the life of existing hydropower assets. It is their belief that digital control systems and software can play a major role in improving decision-making and supporting hydropower operations to work more efficiently with other renewable technologies.

As an example of how countries with significant hydropower assets are responding to technological innovation, SINTEF, a leading research institution in Norway, is developing a digital model and prototypes to evaluate the optimal lifetime utilisation of components in hydropower plants. The initiative will incorporate many of the key elements of digitalisation including machine learning, cyber-physical systems, and the Internet of Things. In addition, Portugal's EDP, one of Europe's largest electricity operators, has begun a programme of implementing digitalisation through its entire hydro fleet to more efficiently manage its plants in Iberian peninsula.

Digitalisation of hydropower systems is increasingly being implemented to add enhanced control systems for operations to work together with other renewable resources such and wind power and solar photovoltaics, in order to provide increased flexibility and enhanced control for ancillary services, frequency control and balancing services.

An example of where enhanced digital control systems has been implemented to integrate variable renewables with a pumped hydropower scheme is in the Canary Islands at the El Hierro facility. For this hybrid system, digital solutions have been installed in the control centre to optimise the operator's decisions, resulting in an increased share of renewable energy integrated into the El Hierro electricity system, and ensuring the continuity of power supply on the island.

A new paradigm

A challenge for the global hydropower sector today is the establishment of benchmarking metrics to allow hydropower companies to evaluate their current O&M practices against best in class utilities. For this to evolve, there will need to be a transition to a new paradigm in the hydropower sector, one in which data sharing becomes more prevalent and condition monitoring databases are more transparent and contain much more information.

Several institutions are already advancing knowledge on methodologies that can contribute to a more global system of benchmarking good practice in the O&M of hydropower assets. The Centre for Energy Advancement through Technological Innovation (CEATI), based in Canada, publishes technical papers outlining good practice. One such publication covers a Maturity Matrix (MM) which is utilised as a communication tool and an effective means to document and compare activities with best-known practices.

CEATI also provide technological support for the hydroAMP methodology, a well-known asset management tool developed to identify and develop long-term investment strategies for hydroelectric facilities and to prioritise capital investments in hydroelectric equipment. The hydroAmp tool creates a framework to streamline and simplify methods for objectively evaluating the condition of hydroelectric equipment for the purpose of supporting asset and risk management decision-making.

Software is helping hydropower operators make better informed decisions about where and when to invest capital expenditures, to improve performance and manage risk in their ageing hydropower infrastructure. For example, asset management optimisation software is now being used by many organisations across the world.

The path forward

IHA is committed to advancing knowledge in asset management under three general areas: operations and maintenance good practice, digitalisation of hydropower and modernisation of existing assets. In the next year, IHA will prepare a compendium of O&M models and industry good practice in collaboration with the World Bank Group with the goal of showcasing it at the next World Hydropower Congress in Paris, France between 14-16 May 2019.

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IHA Blue Planet Prize

The International Hydropower Association is now accepting entries for the 2019 IHA Blue Planet Prize.

The IHA Blue Planet Prize is awarded to hydropower projects that demonstrate excellence in sustainable development.

For a project to be considered, it must have undergone an official assessment under the Hydropower Sustainability Assessment Protocol, an internationally recognised tool.

The prize is next due to be awarded at the World Hydropower Congress in Paris, France, between 14-16 May 2019.

Protocol assessment

The Hydropower Sustainability Assessment Protocol is used to assess the performance of a hydropower project according to a range of social, environmental, technical and economic criteria.

The Protocol was developed through cross-sector consensus and is governed by a forum that includes environmental and social NGOs, commercial and development banks, governments and industry.

Information for applicants

Eligible hydropower projects must have achieved or exceeded good practice scores across all Protocol topics and must have been commissioned prior to entry.

Applications will be judged by a panel of experts selected by the IHA Board.

Shortlisted projects not selected for the prize will be recognised as highly commended.

To be considered, applicants should return their application form by 31 December 2018.

For further information on the entry criteria and application process, please download the eligibility and application documents from the IHA website.

Find out more:

hydropower.org/iha-blue-planet-prize

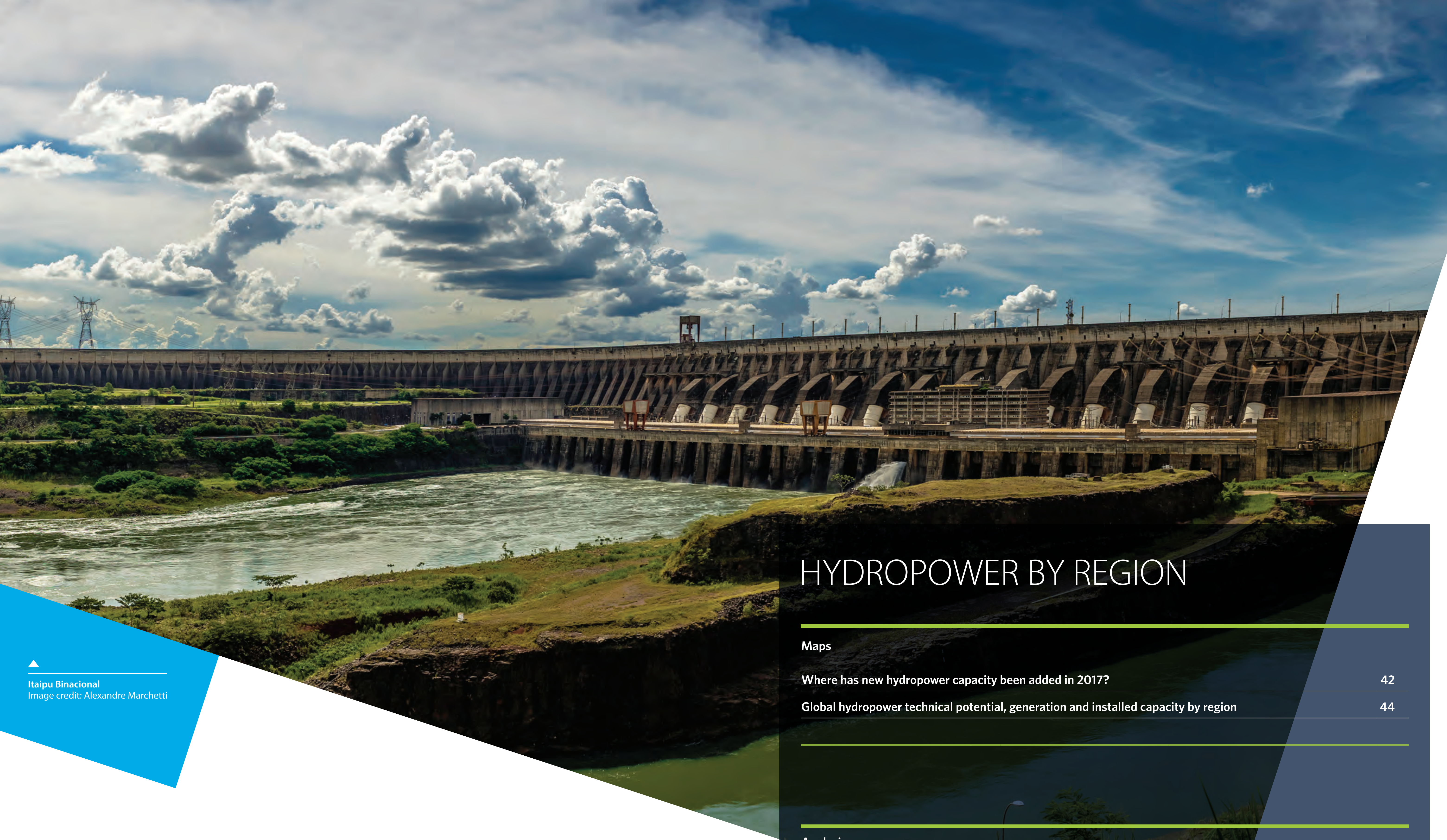
The Blanda hydropower project, Iceland.
Credit: Landsvirkjun

Previous prize winners

The IHA Blue Planet Prize has been awarded to seven hydropower projects since 2001.

It was last awarded in 2017 to the Blanda project in Iceland, which was developed and operated by Landsvirkjun.

A delegation from the company was presented with the award at the World Hydropower Congress in Addis Ababa, Ethiopia.



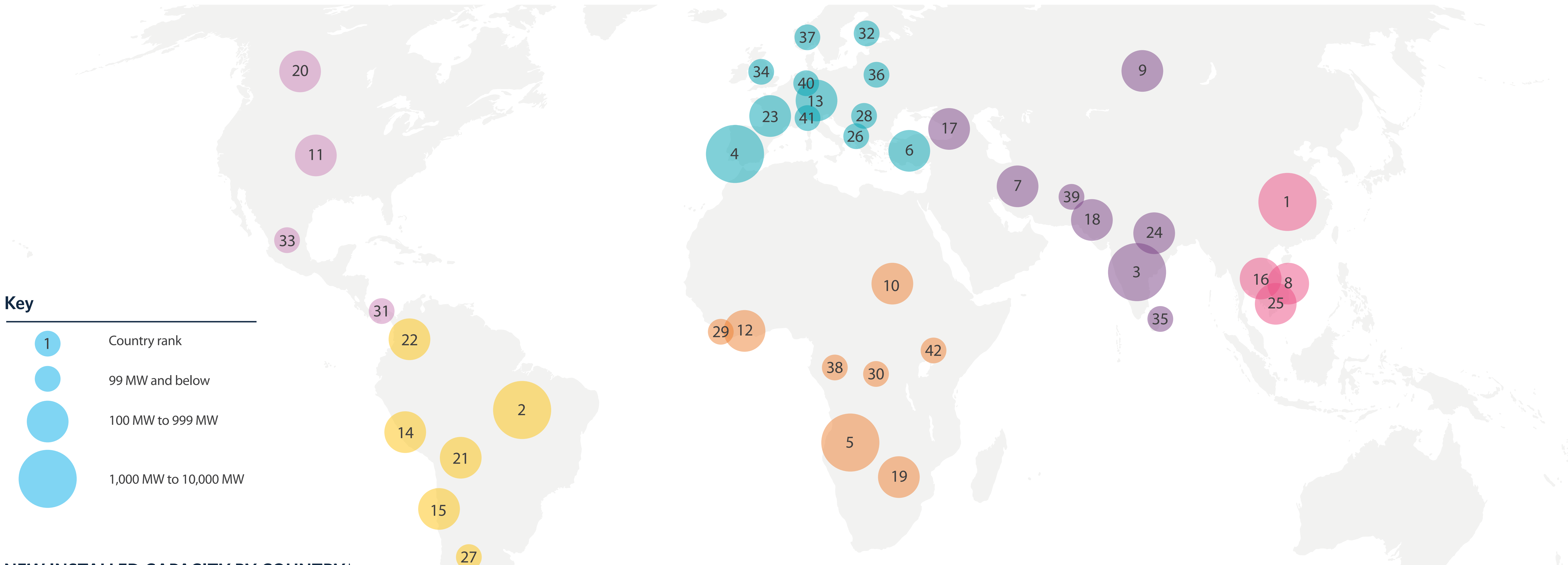
Itaipu Binacional
Image credit: Alexandre Marchetti

HYDROPOWER BY REGION

Maps

Analysis

WHERE HAS HYDROPOWER CAPACITY BEEN ADDED IN 2017?



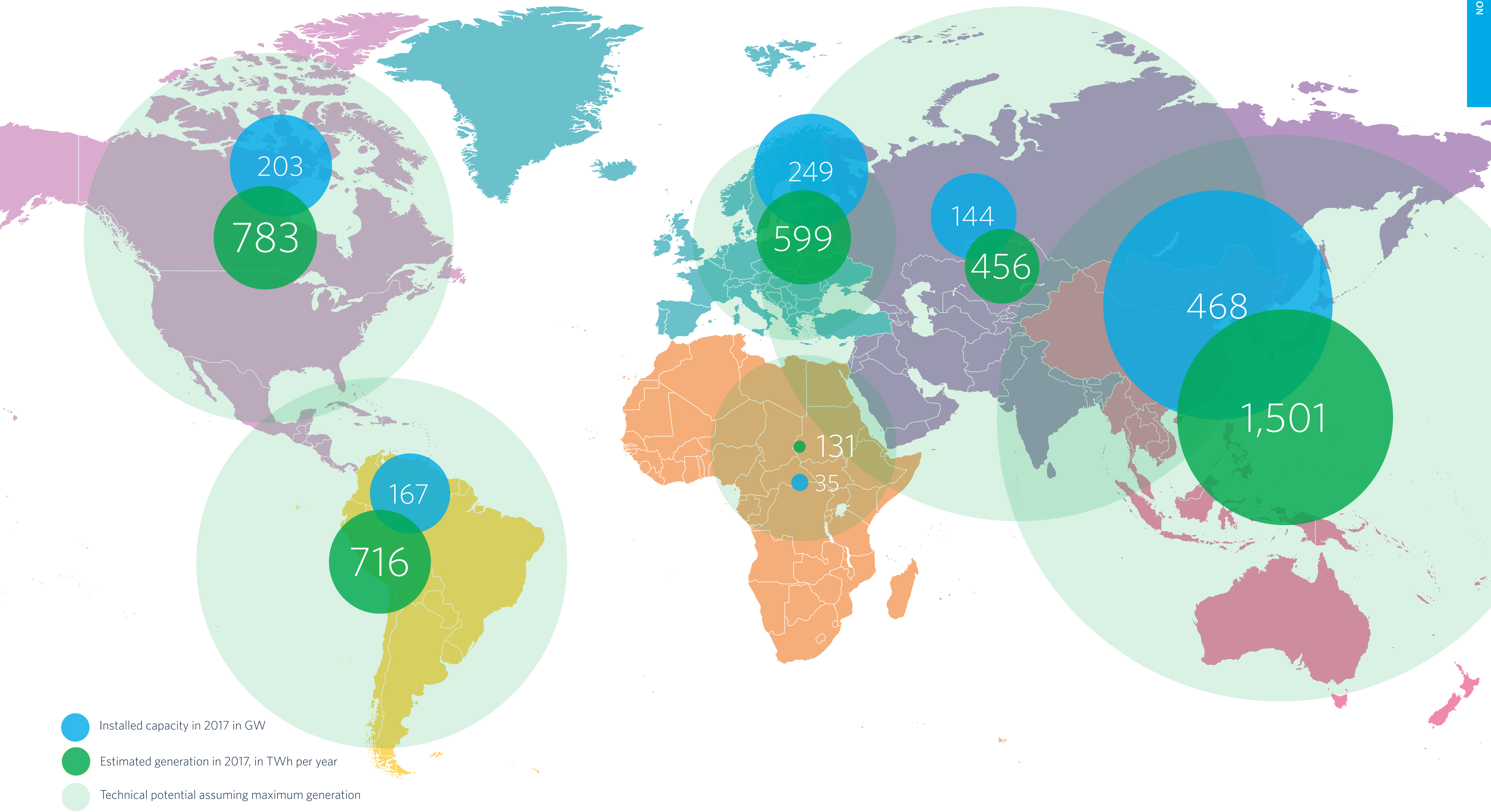
NEW INSTALLED CAPACITY BY COUNTRY*

Rank	Country	Capacity added (MW)	Rank	Country	Capacity added (MW)
1	China	9,120	11	United States	283
2	Brazil	3, 376	12	Côte d'Ivoire	275
3	India	1,908	13	Switzerland	265
4	Portugal	1,050	14	Peru	200
5	Angola	1,018	15	Chile	181
6	Turkey	592	16	Laos	166
7	Iran	520	17	Georgia	163
8	Vietnam	373	18	Pakistan	157
9	Russia	364	19	Zimbabwe	152
10	Sudan	320	20	Canada	139

* including pumped storage

Rank	Country	Capacity added (MW)	Rank	Country	Capacity added (MW)
21	Bolivia	120	32	Finland	38
22	Colombia	119	33	Mexico	33
23	France	112	34	United Kingdom	32
24	Nepal	100	35	Sri Lanka	29
25	Cambodia	100	36	Belarus	24
26	Albania	75	37	Norway	20
27	Argentina	72	38	Congo	19
28	Serbia	68	39	Afghanistan	19
29	Liberia	66	40	Austria	14
30	Democratic Republic of the Congo	61	41	Romania	12
31	Panama	51	42	Uganda	12

HYDROPOWER CAPACITY AND GENERATION BY REGION

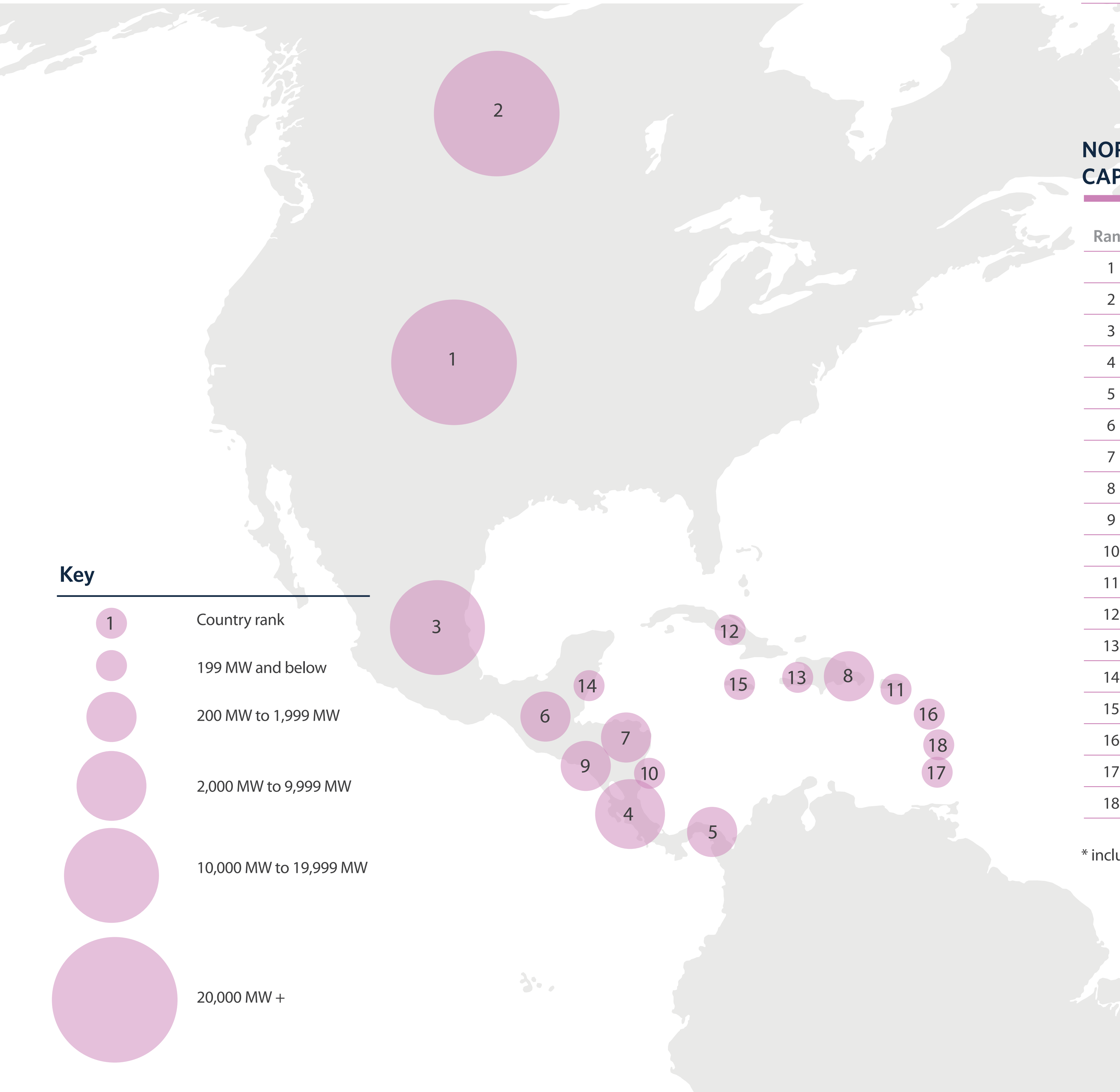


BY REGION

NORTH AND CENTRAL AMERICA

Shawinigan Falls dam, Canada

NORTH AND CENTRAL AMERICA INSTALLED CAPACITY



TOP SIX COUNTRIES BY INSTALLED HYDROPOWER CAPACITY (MW*)

1	2	3	4	5	6
United States	Canada	Mexico	Costa Rica	Panama	Guatemala
102,867	80,985	12,125	2,123	1,777	1,156

NORTH AND CENTRAL AMERICA CAPACITY BY COUNTRY*

Rank	Country	Total installed capacity (MW)
1	United States	102,867
2	Canada	80,985
3	Mexico	12,125
4	Costa Rica	2,123
5	Panama	1,777
6	Guatemala	1,156
7	Honduras	558
8	Dominican Republic	543
9	El Salvador	471
10	Nicaragua	123
11	Puerto Rico	100
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

Bipole III transmission line.
Credit: Manitoba Hydro

Hydropower remains a critical energy resource for North and Central American countries as well as several Caribbean island nations. The United States and Canada account for more than 90 per cent of the region's installed capacity and continue to be among the world's leading countries in terms of installed hydropower capacity, with 102.9 GW and 80.8 GW respectively (including pumped storage) at the end of 2017. Hydropower currently contributes around 6 per cent to total electricity generation in the United States, while the figure in Canada is 64 per cent.

In Canada, 139 MW of new hydropower, comprised of several run-of-river projects, came online in 2017. These include the 28 MW Peter Sutherland project developed by Ontario Power Generation in partnership with Taykwa Tagamou Nation, as well as two smaller projects in British Columbia, the 25 MW project on Boulder Creek, and an 81 MW installation on the Upper Lillooet River. Work continues on three major storage projects: Keeyask Generating Station in Manitoba, due in 2021, Site C in British Columbia, due in 2024, and Muskrat Falls in Newfoundland and Labrador, due in 2020.

In the United States, the Department of Energy is supporting the advancement of 50 GW of hydropower development by 2050, attained through retrofitting 13 GW of new generation capacity – upgrades to existing plants, adding power at existing dams and canals, and limited development of new stream-reaches – and 36 GW of new pumped storage capacity. In 2017, 140 MW was added to existing facilities, as well as 139 MW of new pumped storage. Shifts in the policy landscape include a comprehensive energy bill to modify the definition of renewable energy to include hydropower and a licensing reform bill. The National Hydropower Association along with other industry representatives have continued to promote growth in the hydro sector, calling for regulatory reform, tax incentives and other market policy changes.

In Mexico, significant reform to the energy market has been imposed in recent years, transforming the energy market to allow public and private companies to participate under equal conditions, in order to offer electricity at competitive prices. In June of 2017, the Ministry of Energy released PRODESEN, a 15-year infrastructure development programme for the National Electric System (SEN) addressing generation, transmission and distribution requirements. While the Secretariat of Energy (SENER) oversees production and regulation, the Comisión Federal de Electricidad (CFE), the state-owned electric utility which once held a monopoly on all power activities, has been restructured to increase private sector engagement and, potentially, encourage independent power producers in hydropower development. CFE was unbundled into separate generation, transmission, distribution, supply and marketing subsidiaries, with power system operations transferred to the Centro Nacional de Control de Energia (CENACE) which now acts as the independent system operator.

In the Caribbean Sea, Puerto Rico is planning to rehabilitate the 3 MW Lago Loiza plant after it was closed 24 years ago. With only 2 per cent of the territory's generation coming from renewable resources, efforts to restore power have remained a top priority after Hurricane Maria struck in September 2017.

In the Dominican Republic, work is underway at the 10.7 MW Hatillo small hydropower plant, located on the Río Yuna, to add a new powerhouse together with a new generation unit. In addition, construction of the Montegrande project is underway consisting of a multipurpose dam on the Yaque del Sur riverbed; the project includes an 18 MW hydropower facility and will provide storage for flood management, as well as domestic water supply, irrigation and the development of aquaculture and tourism activities.

In Guatemala, the utility Instituto Nacional de Electrificacion (INDE) sought bids to perform feasibility studies on the 200 MW Xalala hydroelectric project on Guatemala's Chixoy River. As well, Hidroelectrica Xolhuitz started operating a hydroelectric plant which generates 2.3 MW.

In Panama, Hidro Caisan S.A. submitted an environmental impact statement to expand the El Alto Hydroelectric power plant, located in Chiriquí province, from 63 MW to 73.2 MW at an estimated cost of USD 75 million.

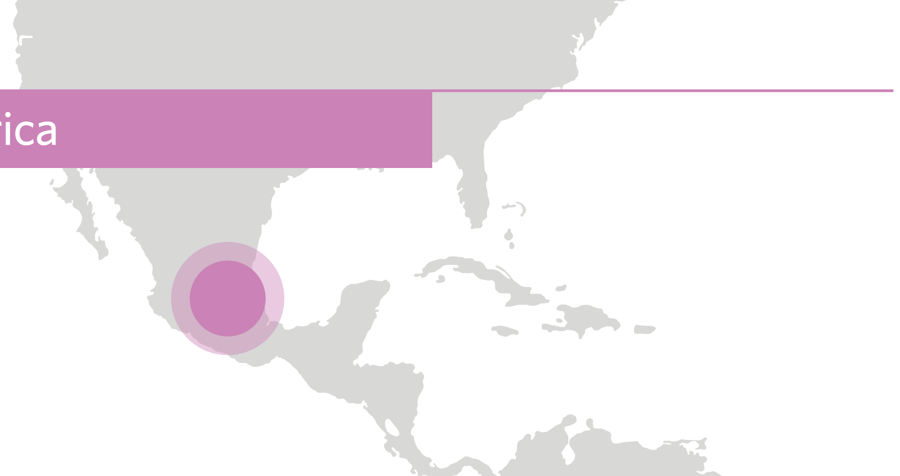
In Costa Rica, the Institute Costarricense de Electricidad (ICE) began a 10-month project that will increase the height of its Sangregado dam. ICE said it plans to increase the core by 1.5 metres, strengthening the 38 year-old structure and increasing the capacity of the reservoir behind it.

The reservoir feeds several hydropower plants including the 174 MW Dengo, 157.4 MW Arenal and 32 MW Sandillal projects. The facilities together provide about a fifth of the country's total power supply.

In Honduras, which has a target to have 95 per cent of energy supplied from renewable sources by 2027, the state-owned power company Empresa Nacional de Energia Electrica (ENEE) issued a tender to design a hydropower resource investment plan for five projects: 270 MW Patuca II, 150 MW Patuca II-A, 98 MW Llanitos, 173 MW Jicatuyo and 212 MW Mixcure.

Several cities in North America report that at least 70 per cent of their electricity is generated by hydropower, according to data published by the CDP (formerly known as the Carbon Disclosure Project) world renewable cities reporting initiative (2018). These include large Canadian cities Winnipeg (100 per cent), Montreal (95 per cent) and Vancouver (92 per cent), as well as Seattle (89 per cent) in the United States.

MEXICO



Hydropower remains the largest source of renewable energy in Mexico, making up about 80 percent of the country's renewable energy supply. At the end of 2017, roughly 17 per cent of the country's total installed capacity was hydropower, accounting for 12 per cent of all sources of electricity generation. The country has an installed hydropower capacity of 12,125 MW and an estimated 27,000 MW of economically feasible hydropower potential.

The government has imposed significant reforms to the energy market in recent years to allow public and private companies to participate under equal conditions and offer electricity at competitive prices . The Comisión Federal de Electricidad, the state-owned electric utility of Mexico, widely known as CFE, once held a monopoly on all power activities. Under the market reform, CFE has been restructured to a competitive market, allowing for increased private sector engagement and increasing the future role of independent power producers in hydropower development.

While the Secretariat of Energy (SENER) oversees production and regulation of energy in Mexico, CFE continues to be the primary retail supplier of electricity in the country. CFE was unbundled into separate generation, transmission, distribution, supply and marketing subsidiaries, with power system operations transferred to the Centro Nacional de Control de Energia (CENACE) which now acts as the independent system operator.

Mexico continues to pursue its ambitious goals for increasing the country's share of renewable energy sources within its overall generation portfolio . The Ministry of Energy released PRODESEN, the fifteen-year infrastructure development programme for the National Electric System (SEN). PRODESEN is a centralised planning initiative addressing important elements of the national electricity system including generation, transmission and distribution requirements.

By 2024, Mexico hopes to supply 35 per cent of power generation through clean energy, a target which will increase to 50 per cent by 2050. These aggressive goals should support hydropower development, including the maintenance and modernisation of existing infrastructure.

Growth in hydropower capacity has however been stagnant over the past two years, while wind power has enjoyed a 33 per cent increase and solar has doubled since 2015. Hydropower development has stalled following opposition to large-scale projects. As an example of this, the only large-scale project, Chicoasen 2, was delayed after public protests.

To address the concerns of protestors and local communities, the government announced a commitment to undertake a comprehensive study of sustainable development of energy infrastructure in Mexico, supported by USD 700,000 in funding from the Inter-American Development Bank. The project involves Mexico's Secretary of Energy (SENER), the Federal Electricity Commission (CFE), The Nature Conservancy-Mexico (TNC) and the Mexican Association of Hydroelectric Energy (AMEXHIDRO).

Mexico's national transmission grid has a total interconnection capacity of 74,208 MW, representing a 4 per cent increase over 2015. Proposals are in place to increase transmission interconnections with tenders to build five transmission lines worth USD 6.6 billion.

Mexico is integrated within the Central American Electrical Interconnection System (SIEPAC). The interconnection between Mexico and Guatemala is already fully operational, whilst that between Panama and Colombia is in the design phase; the extra-regional interconnection aims to establish a 98.6 kilometre long transmission line with a generation capacity of 400 KW. In addition to the Baja California-Sonora, Oaxaca-Mexico City and Baja California-Sonora transmission lines, Mexico is also finalising studies to auction two underwater transmission lines.

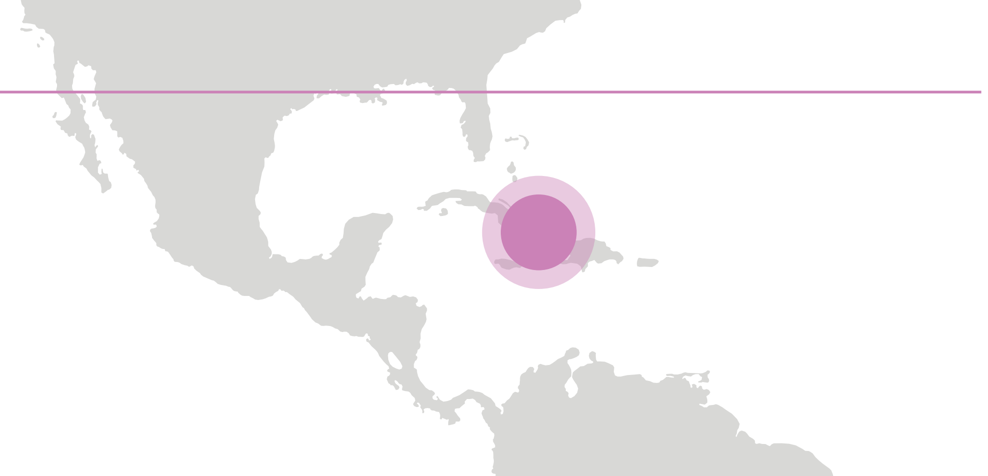
131.5 MILLION
POPULATION

12,125 MW
INSTALLED HYDROPOWER CAPACITY

31,370 GWh
HYDROPOWER GENERATION

17%
HYDROPOWER SHARE OF ELECTRIC POWER INSTALLED CAPACITY

CUBA



Energy supply in Cuba is largely based on thermal sources of electricity generation, with oil and gas making up 96 per cent of energy supply and only 4 per cent made up of renewable generation including biomass (3 per cent) and small-scale hydropower (1 per cent). Cuba has over 170 small hydro plants spread throughout the country, the largest being the 43 MW Hanabanilla plant.

The Cuban government has aspirations to increase the share of renewables significantly over the next two decades, to generate 24 per cent of the country's electricity by 2030. This will be comprised largely of biomass and wind, with additional small hydro playing a lesser role.

With no major rivers or large bodies of inland water, Cuba's development of hydropower will remain focused on small projects. Small hydro technical potential is estimated to be 135 MW. The government has drawn up plans for the development of 74 small hydropower plants, representing over 56 MW in capacity (274 GWh). This would nearly double the country's current hydropower capacity, producing an estimated 274 GWh of renewable generation annually and offsetting up to 230,000 tonnes of CO_2 emissions.

Cuba has signed a deal with the Kuwait Fund for Arab Economic Development that will see KFAED provide USD 30 million in financing for the construction of 34 small hydropower projects. KFAED has said the 34 small hydro projects will be constructed on existing infrastructure and have a cumulative capacity of about 14.6 MW. The initiative will also include construction of three linking substations that will transmit to Cuba's national grid, along with about 75 km of transmission lines. KFAED did not specify when it expects the first small hydro plant to come on-line, but that the initiative should be completed within seven years.

Cuba is one of the few countries in the world that does not belong to any major international finance institutions (IFIs), including the International Monetary Fund (IMF), the World Bank, and the Inter-American Development Bank (IDB). When a distressed macroeconomic situation is coupled with weak institutional capacity in the energy sector, IFIs can provide a guarantee that is critical to addressing the risks associated with these factors.

Cuba's electricity grid was developed in the early 2000s when older Russian systems began to fail, and is the second most decentralised grid in the world after Denmark.

11.4 MILLION
POPULATION

64 MW
INSTALLED HYDROPOWER CAPACITY

100 GWh
HYDROPOWER GENERATION

<1%
HYDROPOWER SHARE OF ELECTRIC POWER INSTALLED CAPACITY

UNITED STATES OF AMERICA

The United States is second only to China in terms of the generating capacity of its hydropower plants, with a total installed capacity of almost 103,000 MW. This comprises about 80 GW of conventional hydropower and almost 23 GW of pumped storage hydropower.

While no new major hydropower projects were commissioned in 2017, the US Department of Energy (DOE) reported a number of retrofit projects were completed, adding 140 MW of new capacity to existing facilities. In addition, 139 MW of pumped hydro storage capacity was added at the Northfield Mountain Unit in Massachusetts and Ludington facility in Michigan.

An additional 50 GW of hydropower capacity could be added nationwide by 2050, according to the DOE. The department envisions an aggressive programme that could see up to 6.3 GW added through upgrades and the optimisation of existing hydropower plants, 4.8 GW by retrofitting existing non-powered dams, 1.7 GW through in-stream-reach developments and up to 35 GW with pumped storage projects.

The DOE said it would award up to USD 30.6 million in Recovery Act funding for seven hydropower projects that modernised existing facilities. The selected projects are to be environmentally friendly and should increase electric generation by an estimated 187 GWh per year. The department estimates the incremental energy from these seven plants will reduce carbon dioxide emissions by over 110,000 tonnes per year.

Retrofit projects under construction include the 36.4 MW Red Rock7 project which involves a new powerhouse to contain two Kaplan turbine-generator units on the downstream side of the dam and an intake structure on the upstream side of the dam, being built at an existing dam on the Des Moines River in Iowa.

Other planned projects include Absaroka Energy, which received a 5-year operating licence from the U.S. Federal Energy Regulatory Commission in December 2016 for the 400 MW Gordon Butte pumped storage project. Construction on the project could begin in 2018, with a projected on-line date of early 2022.

In addition, the San Diego County Water Authority and the City of San Diego announced plans for an energy storage facility at the San Vicente Reservoir in California and are assessing the potential to develop the 500 MW San Vicente Energy Storage Facility to increase the availability and efficiency of renewable energy for the region.

In 2017, the U.S. House of Representatives approved a pair of bills that would promote the development of pumped storage projects and add hydroelectric capacity to existing non-powered dams. This is projected to cost as much as USD 2 billion and create more than 2,000 jobs through to 2027.

Under the 2018 government funding bill, the DOE's Water Power Technologies Office would be awarded a record USD 105 million with USD 35 million going to hydro-pumped storage programmes and USD 70 million going to marine energy and hydrokinetic programmes. In addition, the Promoting Hydropower Development at Existing Non-Powered Dams Act would enable the retrofitting of existing non-powered, federally-owned dams that have the greatest potential for private sector hydropower development.

Early in 2018, the DOE approved a presidential permit for the Northern Pass transmission project, a 192 mile transmission line that will bring 1,090 MW of hydropower energy from Hydro-Québec to New Hampshire and to the rest of New England. However, subsequent to this announcement, the New Hampshire Site Evaluation Committee voted to deny approval of the project, placing further delays on the proposed interconnection. The project is estimated to cost about USD 1.6 billion.

Plans to develop a Manitoba-Minnesota long-distance transmission line have also encountered delays. The transmission project aims to bring hydroelectricity from generating stations in northern Manitoba, Canada, through the Bipole III transmission line and across the U.S. border as part of a 308 MW deal with the Wisconsin Public Service, in Green Bay, Wisconsin.

325.7 MILLION
POPULATION

102,867 MW
INSTALLED HYDROPOWER CAPACITY

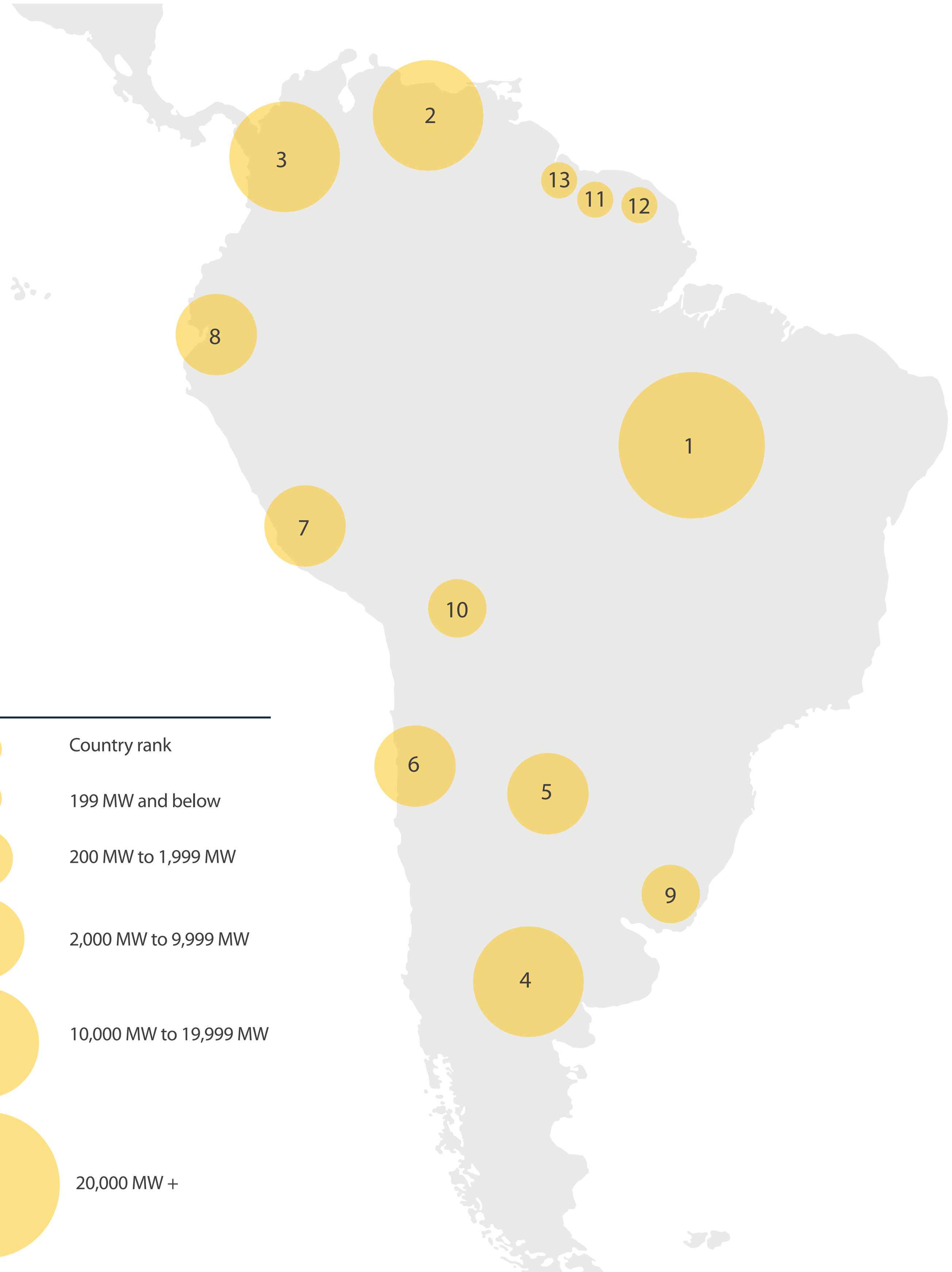
322,390 GWh
HYDROPOWER GENERATION

6.5%
HYDROPOWER SHARE OF ELECTRIC POWER INSTALLED CAPACITY

SOUTH AMERICA

Itaipu Binacional
Image credit: Alexandre Marchetti

SOUTH AMERICA INSTALLED CAPACITY



Key

1	Country rank
	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 +

TOP SIX COUNTRIES BY INSTALLED HYDROPOWER CAPACITY (MW*)

1	2	3	4	5	6
Brazil	Venezuela	Colombia	Argentina	Paraguay	Chile
100,273	15,393	11,726	11,242	8,810	7,271

SOUTH AMERICA CAPACITY BY COUNTRY*

Rank	Country	Total installed capacity (MW)
1	Brazil	100,273
2	Venezuela	15,393
3	Colombia	11,726
4	Argentina	11,242
5	Paraguay	8,810
6	Chile	7,271
7	Peru	5,385
8	Ecuador	4,409
9	Uruguay	1,538
10	Bolivia	603
11	Suriname	189
12	French Guiana	119
13	Guyana	1

* including pumped storage

OVERVIEW

South America's installed capacity of hydropower rose by 3.79 GW in 2017 – the second largest increase of all regions worldwide after the East Asia and Pacific. Most of this increase came from Brazil, which makes up more than 60 per cent of South America's total installed capacity.

The major meteorological event that is El Niño hit South America heavily in 2017, leaving 10 times more rainfall than usual in Ecuador and Peru. As a result of the severe flooding some hydropower plants in Peru shut down operations. The political impact of El Niño may lead to the strengthening and development of long-distance regional interconnections between the region's countries.

Brazil experienced the fourth consecutive year of drought and, as a result, reservoir levels in the country have remained low. The government took measures to prevent electricity shortages by increasing thermo-electric generation and electricity imports from Uruguay and Argentina. The Itaipu Binacional hydropower plant was, conversely, able to boost production due to heavy rainfalls in October 2017. The government is proposing a new law to modernise and liberalise the energy market to attract private investments at the same time that it is moving away from large hydropower projects in support of decentralised renewable energy. As a consequence, the Ministry of Mining and Energy has removed the largest projects from its 10 year pipeline.

Colombia, which experienced higher rainfall, saw hydropower installed capacity increase to 86 per cent of total generation in 2017, far exceeding the 70 per cent average generation of the past four years caused by drought. The World Economic Forum ranked Colombia 8th in the Global Energy Architecture Performance Index (EAPI) which measures countries' ability to deliver secure, affordable and sustainable energy. Being the first non-European country to achieve this ranking, Colombia has positioned itself at the forefront of clean and sustainable energy system worldwide.

In Peru, about 50 per cent of electricity generation is produced by hydropower, however only about 8 per cent of the estimated hydropower resource of 70,000 MW has been utilised. The country's National Energy Plan 2014-2025 forecasts that energy demand growth of 4.5 to 6.5 per cent on average will be satisfied mainly by hydropower. In the pipeline there are 39 hydropower plants that would add 2,900 MW to the National Energy Interconnected Grid. Large transmission lines are needed to connect hydropower plants in the Amazon basin to electricity demand centres in the dry Pacific watershed where 70 per cent of the population lives. The investments needed to cover generation until 2025 range from USD 6.7 to 7.3 billion.

In Argentina, hydropower at 11,242 MW makes up 33 per cent of total installed capacity. The new government is favouring the development of hydropower projects with the 1,740 MW complex of dams named after Dr. Néstor Carlos Kirchner and Jorge Cepernic in Patagonia and the approval of the Portezuela del Viento plant (210 MW) located in Mendoza. Argentina and Paraguay finally came to a new agreement about the shared costs of building Yaciretá, the construction of which was originally agreed in the 1970s during an era of dictatorships in both countries; this new agreement ends an ongoing dispute and opens a pathway for the upgrade and modernisation of the power plant.

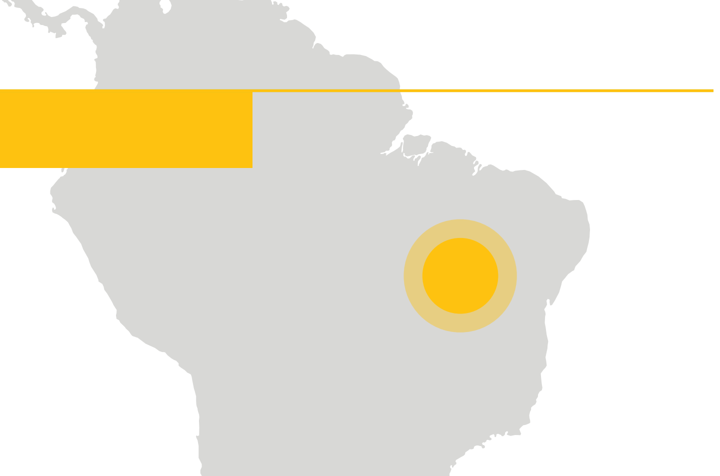
Itaipu Binacional
Image credit: Alexandre Marchetti

In Bolivia, the Ministry of Energy was formed by decree in January 2017 to centralise and implement power sector laws and policies. Its plan for 2016-2025 aims to increase the share of hydropower in the energy mix from 25 per cent to 78 per cent in order to decrease the dependency on thermoelectric plants, which currently account for 80 per cent of electricity generated. This would mean an increase of hydropower installed capacity from 614 MW in 2017 to 11,725 MW in 2025, which would position Bolivia as an exporter of surplus energy. In September, the multipurpose Misicuni project entered into operation with an installed capacity of 120 MW.

In Guyana, the Amaila Falls hydropower project (165 MW), supported financially by Norway, is a concern due to environmental and institutional capability challenges. The government is prioritising wind and solar energy projects in a new 'Green Strategy'. Developing Guyana's hydropower potential would be a big step towards the decarbonisation of the country's heavily oil-based electricity generation.

In Suriname, after stopping bauxite mining operations in November 2015, Alcoa is in the middle of negotiations with the government to hand over the Afobaka dam (189 MW) which has provided power to the Alcoa's aluminium smelter for over 50 years.

Across South America, 51 cities report that over 70 per cent of their electricity is generated by hydropower, according to CDP which tracks the electricity mix in more than 570 cities worldwide. Thirty cities in the region, including Brasília, Salvador, Curitiba and São Gonçalo in Brazil, and Medellín in Colombia, report generating 100 per cent of electricity from hydropower.



BRAZIL

Brazil has the largest installed hydropower capacity in South America, and comprises two thirds of the continent's installed capacity, at 100,273 MW. The sector makes up 64 per cent of total Brazilian energy capacity and meets more than three-quarters of electricity demand.

The year 2017 marked the fourth consecutive year of a severe drought in many parts of the country, which impacted reservoir levels. To compensate, thermoelectric power plants, which are more expensive than hydropower, and imports from Uruguay and Argentina, have reinforced electricity supplies. Conversely, due to heavy rainfall in southwest Brazil in October 2017, Itaipu Binacional was able to boost hydropower production, meaning it could guarantee and exceed energy supply at a crucial time.

Large hydropower remains the major source of electricity supply, with other renewable energies representing about 10 per cent. Wind, solar and small hydro (defined as less than 50 MW in Brazil) have increased their share of the energy mix since energy sector reforms in 2012 that were enacted under the presidency of Dilma Rousseff.

Despite its contribution to electricity generation, the hydropower sector, which is mainly publicly owned, has struggled financially in recent years. The 2012 energy sector reforms were not welcomed by many large companies, especially state-owned companies that had to accept controversial terms seen as unprofitable. Others, like CEMIG from Minas Gerais state, refused to accept the conditions and, as a result, when the concession of some plants expired, the government auctioned the licenses.

In September 2017, the operating rights of four plants that belonged to CEMIG were auctioned. The 424 MW Jaguara and the 408 MW Miranda plants were acquired by Engie, the 380 MW Volta Grande was awarded to Enel and China's State Power Investment Corp took over the operations of the 1,710 MW São Simão plant.

The new government of Michel Temer has proposed a new legal framework to modernise and liberalise the energy market to attract private investments. Among the proposed measures are: opening the market to new customers, the gradual ending of subsidies, maximising the cohesion between energy prices and operations, introducing a capacity remuneration mechanism, and resolving judicial disputes related to hydrological risk for hydropower plants. The Ministry of Mining and Energy is planning the privatisation of Eletrobras, the state-owned company that developed the main large hydropower projects such as Belo Monte, Jirau and Santo Antônio. The privatisation is expected to go through in 2018.

With Brazil moving away from large hydropower projects in favour of decentralised renewable energy, there are fewer major hydropower projects being prepared in the 10-year pipeline of the Ministry of Mining and Energy.

The 11,200 MW Belo Monte project, in northern Brazil, could be the country's last mega project. When completed, it will become the third largest hydropower plant in the world. The first turbine was commissioned in 2016, and it is expected to become fully operational in 2020.

The 700 MW São Manoel hydropower plant saw its first turbine enter into operation in December 2017. The plant is located over the Teles Pires, a tributary of the Amazon river, that flows along the border of the states of Mato Grosso and Pará. Earlier in the year, in July 2017, works were temporally halted by protests demanding indigenous rights.

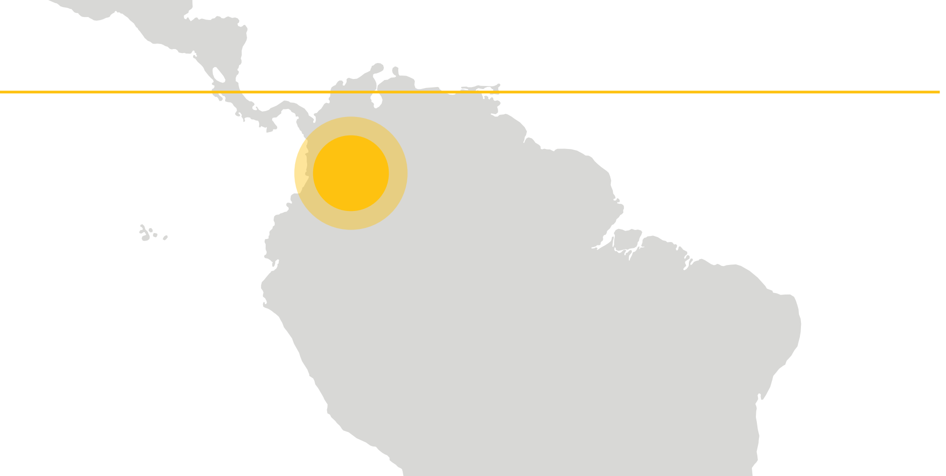
As large assets are ageing, major modernisation works are either planned or underway at hydropower projects across the country, including the 3,440 MW Ilha Solteira (1973) and 1,551 MW Jupia (1969) plants, both of which were privatised in a 2015 power auction. The 14,000 MW Itaipu Binacional (1984) plant, which in 2016 hit the record of over 100 TWh of annual production, is investing USD 500 million in a 10-year upgrade plan.

208.6 MILLION
POPULATION

100,273 MW
INSTALLED HYDROPOWER CAPACITY

401,060 GWh
HYDROPOWER GENERATION

64%
HYDROPOWER SHARE OF ELECTRIC POWER INSTALLED CAPACITY



COLOMBIA

Colombia has the third largest installed hydropower capacity in South America, at 11,726 MW. The sector makes up 70 per cent of national installed energy capacity and, in 2017, produced 86 per cent of national electricity generation, exceeding the 70 per cent average generation of the past four years with continuous droughts and above the 79 per cent recorded in 2012.

Other renewable energies have minimal representation in Colombia's energy market. Gas is the second most used resource, representing 9 per cent of generation in 2017.

Due to hydropower energy, Colombia has positioned itself at the forefront of clean and sustainable energy systems worldwide, and is advancing towards its target to reduce greenhouse gases emissions by 20 per cent by 2030.

The World Economic Forum ranks Colombia 8th in the Global Energy Architecture Performance Index (EAPI). The index measures countries' ability to deliver secure, affordable and sustainable energy. Colombia is the first non-European country in the top ten.

Following a ministerial meeting in September 2017, Colombia's Ministry of Environment and Sustainable Development and China's Ministry of Water Resources announced a Memorandum of Understanding to cooperate and advance shared interests in hydraulic infrastructures and flood protection.

The National Authority for Environmental Licenses (ANLA), under the Ministry of Environment and Sustainable Development, has published new terms of reference for the preparation of environmental impact studies for the construction and operation of hydropower plants. To begin construction, hydropower projects over 100 MW need to obtain an environmental licence from the Ministry of Environment and Sustainable Development, while those under 100 MW need to obtain a licence from the Regional Autonomous Corporation.

In January 2017, ANLA denied, for the second time, the environmental licence to the 960 MW Cañafisto hydropower project. Isagen is already undertaking feasibility studies for an alternative project that would be a smaller version of the original one with 380 MW of installed capacity.

During 2017, Colombia increased hydropower installed capacity by 100 MW, with a focus on smaller capacity hydropower projects.

The 19.9-MW El Eden, 19.9-MW El Molino and 10-MW San Matias projects were commissioned in the first quarter of the year, while Luzma 1 and Luzma 2, each with 19.6 MW, entered into operation in late 2017.

The 2,400 MW Ituango hydropower project, in the Cauca River, will become the largest hydropower plant in Colombia when it is completed. With a consortium led by Empresas Públicas de Medellín (EPM), the project's first unit is expected to enter into operation by December 2018.

In total, 125 hydropower projects are in the pre-feasibility stage according to the Energy and Mining Planning Unit (UPME), under the Ministry of Energy and Mines. These would add about 5,600 MW to existing installed capacity. By comparison, over 300 solar and wind projects are also registered representing 2,775 MW of additional installed capacity.

49.5 MILLION
POPULATION

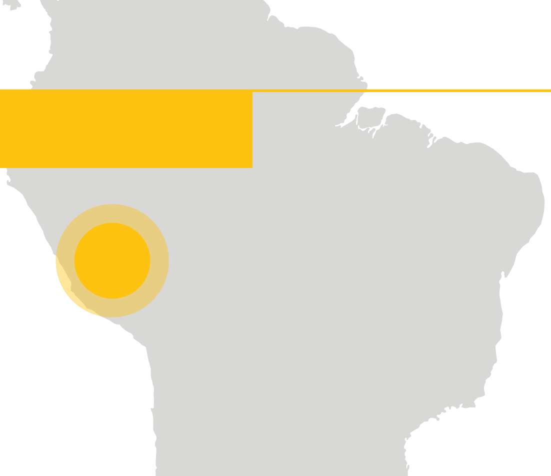
11,726 MW
INSTALLED HYDROPOWER CAPACITY

54,915 GWh
HYDROPOWER GENERATION

70%
HYDROPOWER SHARE OF ELECTRIC POWER INSTALLED CAPACITY

South America

PERU



Peru's government has set a goal to become energy self-sufficient by 2040. The National Energy Policy 2010-2040 outlines its aim to achieve a diversified energy mix with a rising share of renewables, contributing to lower carbon emissions.

In 2017, Peru's installed capacity in hydropower climbed 200 MW to 5,385 MW.

The hydropower sector generates about 50 per cent of electricity for the National Energy Interconnected Grid (SEIN). Yet, the total hydropower potential capacity is estimated at around 70,000 MW. Thermal energy leads way, providing around 9,500 MW of installed capacity, while wind and solar together provide only 3 per cent.

The Amazon basin region holds 97.7 per cent of Peru's water resources where about a quarter of the population lives. Access to electricity in urban areas is close to 90 per cent, while in rural areas it is around 78 per cent.

The National Energy Plan 2014-2025 developed by the Ministry of Energy and Mining (MINEM) expects Peruvian energy demand to grow between 4.5 to 6.5 per cent a year by 2025, which will be satisfied primarily by hydropower and growth in other renewable energies. The investment required to cover the expected generation ranges from USD 6.7-7.3 billion.

In 2008, the government already established a decree to cover the energy demand by incentivising non-conventional renewable energy resources – so called RER – which includes solar, wind, biomass, geothermal and hydropower below 20 MW of installed capacity.

By 2040, Peru aims to increase the contribution of RER to the energy matrix from 5 per cent to at least 20 per cent.

Recent years have seen four RER auctions for the National Energy Interconnected Grid (SEIN) and one for other areas not connected to the SEIN. As a result of these auctions, 22 hydropower plants are under construction (292.48 MW) and 23 are already in operation (274 MW). In April 2017, the Ministry cancelled a fifth auction scheduled for 2018 because several projects from previous auctions were still being developed.

During 2017, the 19.9 MW Potrero plant entered into operation in April, followed by the 18.4 MW Marañón project in June and 17.5 MW Yarucaya project in August. By the end of2017, the 20 MW Renovandes H1 project, the 84 MW La Virgen project and the Angel II and Angel III plants (19.9 MW each) are also expected to enter in operation.

The 2017 increase in installed hydropower capacity of 200 MW was a fifth of the 1,033 MW that entered into operation in 2016. Most of the previous year's increase was accounted for by two new commissioned major projects, the 456 MW Chaglla plant and the 510 MW Cerro del Águila plant.

There now are 39 hydropower projects – including the RER hydropower projects – in the pipeline which will together add an additional 2,900 MW by 2023. The largest of the 39 hydropower projects are Veracruz and Chadin II, both on the Marañón river, at 635 MW and 600 MW respectively.

In August 2017 it was announced that the 456-MW Chaglla, owned by Odebrecht, was purchased by a Chinese consortium led by China Three Gorges (CTG). The hydropower plant is CTG's first asset in Peru and the first plant to apply the Hydropower Sustainability Assessment Protocol in the country.

Large transmission lines are needed to connect hydropower plants to electricity demand centres in the dry Pacific coastal areas inhabited by much of the rest of the population. The Ministry of Energy and Mining is fostering, through the RER framework, investment in rural electrification through off-grid auctions which, it is estimated, will benefit 3.4 million people by 2025.

32.4 MILLION
POPULATION

5,385 MW
INSTALLED HYDROPOWER CAPACITY

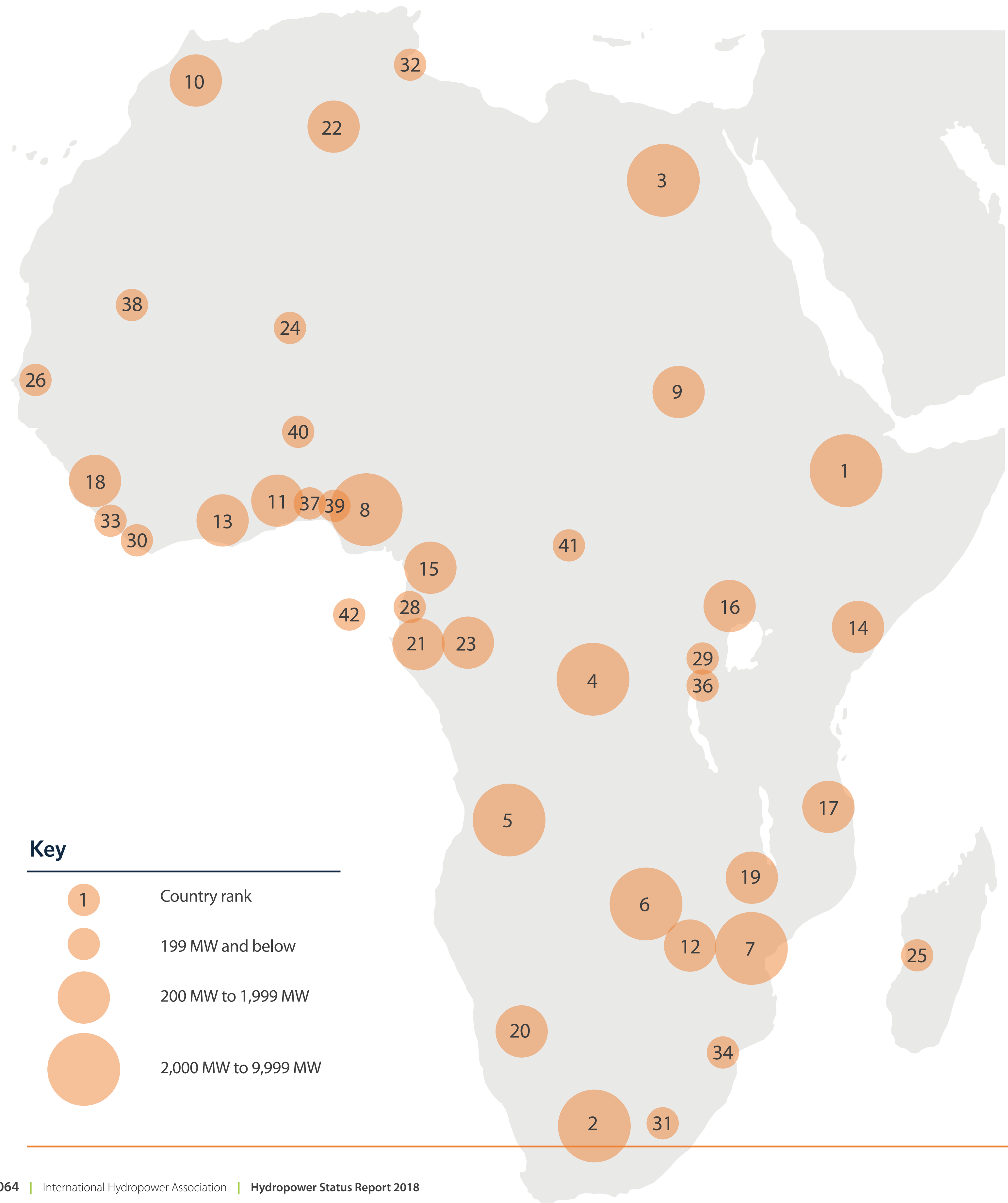
33,400 GWh
HYDROPOWER GENERATION

35%
HYDROPOWER SHARE OF ELECTRIC POWER INSTALLED CAPACITY

AFRICA

Laúca hydropower plant, Angola.
Credit: Odebrecht

AFRICA INSTALLED CAPACITY



Key

1	Country rank
	199 MW and below
	200 MW to 1,999 MW
	2,000 MW to 9,999 MW

TOP SIX COUNTRIES BY INSTALLED HYDROPOWER CAPACITY (MW*)

1	2	3	4	5	6
Ethiopia	South Africa	Egypt	Democratic Republic of the Congo	Angola	Zambia
3,822	3,595	2,844	2,593	2,415	2,397

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	233
3	Egypt	2,844	24	Mali	181
4	Democratic Republic of the Congo	2,593	25	Madagascar	164
5	Angola	2,415	26	Senegal	150
6	Zambia	2,397	27	Reunion	134
7	Mozambique	2,191	28	Equatorial Guinea	128
8	Nigeria	2,062	29	Rwanda	105
9	Sudan	1,923	30	Liberia	93
10	Morocco	1,770	31	Lesotho	72
11	Ghana	1,584	32	Tunisia	66
12	Zimbabwe	941	33	Sierra Leone	64
13	Côte d'Ivoire	879	34	Swaziland	60
14	Kenya	824	35	Mauritius	60
15	Cameroon	761	36	Burundi	55
16	Uganda	743	37	Togo	49
17	Tanzania	572	38	Mauritiana	49
18	Guinea	368	39	Benin	33
19	Malawi	364	40	Burkina Faso	32
20	Namibia	341	41	Central African Republic	19
21	Gabon	331	42	São Tomé and Príncipe	2

* including pumped storage

Africa

OVERVIEW

Despite its vast natural resources, access to electricity across Africa is limited and uneven, with only around 30 per cent of the population having access to electricity. While countries like Egypt have total electricity coverage, in countries like Chad and South Sudan less than nine per cent of the population has access.

In order to exit the poverty trap, African governments are increasingly turning to renewable resources to spur development and improve livelihoods. Among these resources is hydropower, of which only about seven per cent of the continent's economically feasible potential has been developed.

In 2017, 1,924 MW of hydropower capacity was put into operation, with total installed capacity now exceeding 35 GW. In several African countries – Democratic Republic of Congo, Namibia, Zambia, Ethiopia, Togo and Sudan – hydropower accounts for over 90 per cent of electricity production.

Hydropower presents an opportunity for economic development and the achievement of the Sustainable Development Goals. Hydropower potential exceeds current and medium term demand in the region and, according to the International Renewable Energy Agency (IRENA), the cost of electricity from new hydropower projects remains the lowest among renewable energy sources globally.

Several cities in Mozambique, Ethiopia and Cameroon report that 100 per cent of their electricity is generated by hydropower, according to the CDP reporting initiative. Ten cities in the region, including Addis Ababa, Harare, Dar es Salaam and Nairobi generate more than 70 per cent of their electricity from renewable energy of which hydropower provides more than 50 per cent.

Africa has five regional power pools which act as specialised agencies for their respective Regional Economic Community. Regional interconnections across the continent would help mitigate a lack of adequate installed capacity, which is aggravated by severe droughts like the one experienced in 2015. Hydropower could therefore have a major role in buffering against fluctuations in production.

Governments are putting in efforts to increase investment both in hydropower projects and transmission infrastructure, which will enable interconnection projects to have a transformative impact across the region. Major transmission interconnections under construction include the 3,800 km Central African Interconnection Transmission Line Project which will add 4,000 MW in capacity, and the Mozambique-Malawi Transmission Interconnection Project for which the government of Mozambique has received financing from the World Bank. Large-scale hydropower projects in Ethiopia are also driving investment in new interconnections across the Eastern Africa Power Pool.

In Angola, hydropower development is considered a priority, as reflected in its energy security policy and the country's overall 2025 strategy. In 2017, five years after beginning construction of its largest infrastructure project, the first two power generating units of the country's 2,070 MW Laúca hydropower station were commissioned. The Cambambe dam on the Kwanza river raised its installed capacity to 960 MW with the inauguration of a second power station and following a modernisation project. Together, these projects increased the country's installed hydropower capacity by 72 per cent from 2016 to 2017 and are part of an effort to increase electrification to 60 per cent by 2025.

In Côte d'Ivoire, the government has developed a regulatory framework for the power sector to encourage investment as it is working to double power generation by 2020, with on-grid capacity scheduled to reach 4,060 MW. The Soubré project located at Naoua Falls on the Sassandra river is the country's largest hydropower project at 275 MW, having been commissioned in 2017.

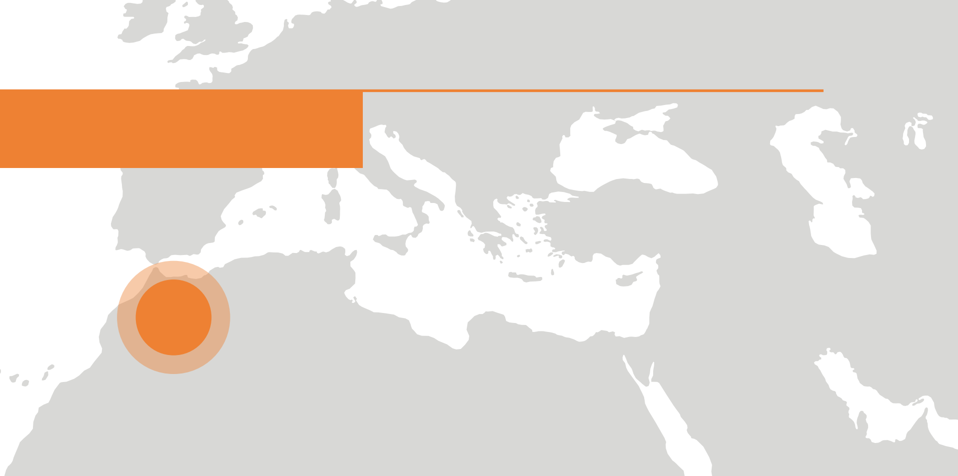
In Sudan, hydropower is the largest source of electricity accounting for almost 75 per cent of generation. In 2017, the 320 MW Upper Atbara and Setit Dam project was commissioned. Besides increasing the country´s installed capacity, the project will provide storage and controlled supply of water for over 300,000 hectares of fertile land.

In Zimbabwe, the first unit of the Kariba South extension project was commissioned in December 2017, with 150 MW expected to come onto the grid during 2018. The extension project forms part of a series of initiatives by the Zimbabwe Electricity Supply Authority to resolve a national power deficit estimated at approximately 60 per cent. Some 1,720 MW of potential capacity in the Zambezi river is still to be developed.

Laúca hydropower plant, Angola.
Credit: Odebrecht

Africa

MOROCCO



Morocco, emboldened by its significant renewable energy resources, was among the first countries in the Middle East and North Africa to cut fossil fuel subsidies. It has significant potential to increase hydropower storage capacity and reinforce its green energy production.

The country's total installed capacity is 8,262 MW of which 1,770 MW is accounted for by hydropower. The government's policy is to increase renewable generation capacity to 42 per cent of the energy mix by 2030 – up from 19 per cent capacity in 2010.

With energy demand expected to double by 2025, the government plans to accelerate the pace of reforms to enable public and private operators to develop 10,100 MW of additional capacity by 2030, including 1,330 MW of hydropower, with 550 MW to be developed by the private sector, and about 100,6 MW in small hydro. This will help the country reach 2,000 MW of installed hydropower capacity by 2020.

By 2020 the country aims to develop 2,000 MW of solar power. With 3,500 km of coastline, Morocco has potential for the development of pumped storage projects which could be coupled with other renewable energy facilities to provide a viable solution to the intermittency of variable renewables such as both solar and wind energy.

The government owned Office National de l'Electricité et de l'Eau Potable (ONEE) is the main player in the power sector. ONEE is implementing an environmental and social management system (SMES) at the Al Wahada and Afourer hydropower plants. Moreover, the Ministry of Energy in cooperation with the German government is undertaking a study to assess the viability of seawater pumped storage.

ONEE is the fourth largest operator in the Spanish electricity market with the Morocco-Spain interconnection, which has an exchange capacity of 2,400 MW. Another interconnection between Mauritania and Morocco is also being assessed.

In 2017 ONEE announced construction of two new pumped storage stations with a total capacity of 600 MW. The first, the El Menzel II station, will be located in the upper Sebou, and the second, the Ifahsa station, will be built on the right bank of Oued Laou. These projects will each have an installed capacity of 300 MW. Ifasha is scheduled to be completed by 2025.

The completion of the Abdelmoumen pumped storage project (350 MW) located about 7 km north-east of Agadir will support the Aferer project (464 MW). Abdelmoumen will become operational in 2020 and will add 350 MW of capacity to the country.

In addition, construction of the Khénifra hydropower plant (128 MW) has begun together with several small hydropower plans: Bar Ouender (30 MW) in Taounate Boutferda (18 MW) in Azilal, Tillouguit aval (26 MW), Tillouguit amont (8 MW) and Tamejout (30 MW) in Benin Mellal.

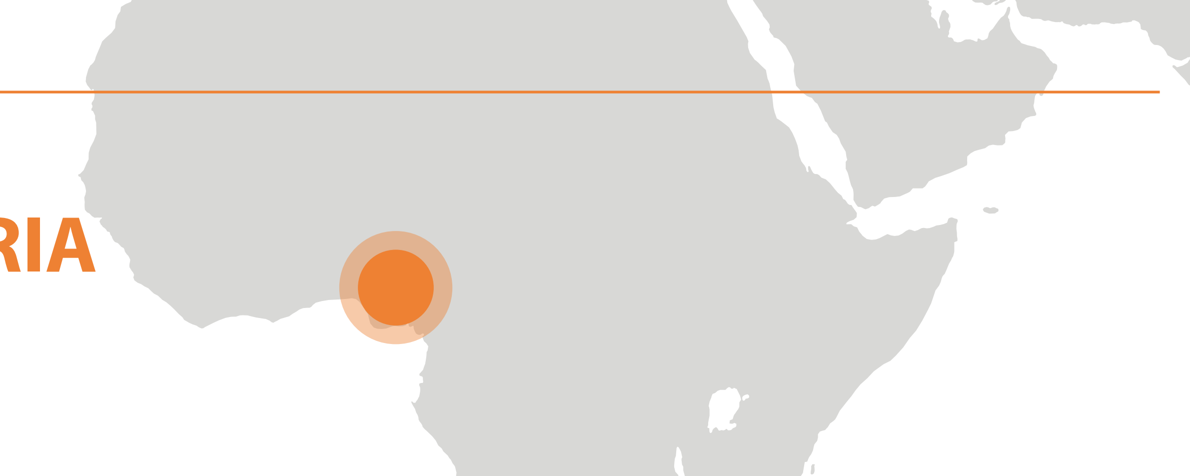
36.1 MILLION
POPULATION

1,770 MW
INSTALLED HYDROPOWER CAPACITY

3,689 GWh
HYDROPOWER GENERATION

22%
HYDROPOWER SHARE OF ELECTRIC POWER INSTALLED CAPACITY

NIGERIA



Nigeria is bestowed with large rivers and natural falls. The main water resources that provide rich hydropower potential are the Niger and Benue rivers as well as Lake Chad basin. With an estimated 1,800 m^3 per capita per year of renewable water resources available, this is not a water poor country, yet it is ranked as an economically water scarce country due to a lack of investment and management to meet demand.

The total installed capacity is 12,522 MW, not including off-grid generation, of which 2,062 MW is hydropower. The total exploitable potential of hydropower is estimated at over 14,120 MW, amounting to more than 50,800 GWh of electricity annually. The roughly 85 per cent of hydropower yet to be developed therefore offers solutions to address existing power shortages.

Nigeria's 2015 National Renewable Energy and Energy Efficiency Policy set out the government's priority to "fully harness the hydropower potential in the country, promoting private sector and indigenous participation in hydropower development". This involves extending electricity to rural and remote areas and pursuing hydropower production in an environmentally friendly and sustainable manner. These goals are aligned with the Sustainable Energy for All (SE4ALL) initiative, of which Nigeria was one of the first countries in the world to embrace. Towards this end, in 2016 a Memorandum of Understanding was signed with PowerChina International Group for the overall planning of Nigerian irrigation and hydropower resources.

Nigeria has envisioned growing its economy at a rate of 11 to 13 per cent in order to be among the 20 largest economies in the world by 2020. To meet this ambitious growth target, the government has hydropower development targets of 6,156 MW for 2020 and 12,801 MW for 2030. It has a target to reach 30 per cent renewable energy by 2030 as well as to have 70 per cent of the energy consumed produced on-grid, compared to the current 74 per cent self-generated. The Energy Commission of Nigeria aims to reach 20,000 MW of grid capacity by 2022.

Since 2005, a privatisation programme has been underway to boost electricity demand and supply, leading to the Transmission System Provider of Nigeria (TSP) being handed over to Manitoba Hydro International of Canada under a three to five year management agreement.

The African Development Bank has been investing USD 100 million in hydropower plant maintenance, repairs and investment. As a result, in 2017 the proportion of hydropower on the grid went up to 26 per cent from 15 per cent in 2015. Under this programme, the 760 MW Kainji and 578 MW Jebba projects were rehabilitated.

The Ministry of Power and Ministry of Water Resources have established a partnership for the development of several existing hydropower plants, including the 30 MW Gurara 1, the 10 MW Tiga, 10 MW Oyan, the 8 MW Challawa and the 6 MW Ikere plants. In addition, the 700 MW Zungeru and the 40 MW Kashimbila hydropower plants are currently under construction.

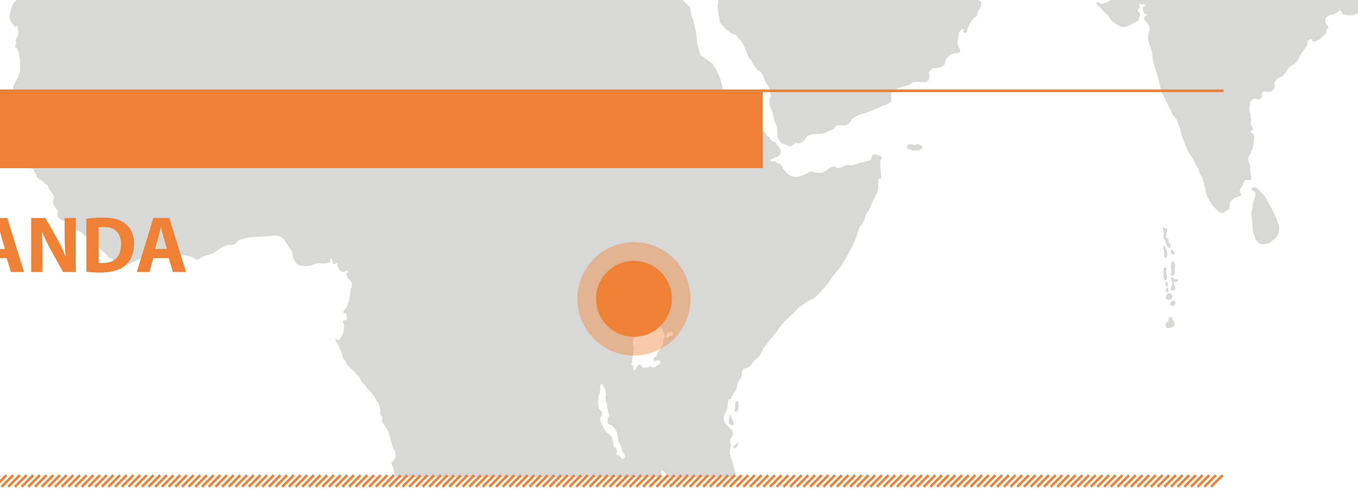
A consortium from China constructing the 3,050 MW Mambilla plant began preparations after an agreement between the Minister of Power, Works and Housing of Nigeria and the consortium was signed last November. Nigeria's so-called 'Three Gorges Project' will include four RCC gravity dams (Nya dam, Sumsum dam, Nghu dam and Api weir) with over 700 km of transmission lines.

194.1 MILLION
POPULATION

2,062 MW
INSTALLED HYDROPOWER CAPACITY

7,310 GWh
HYDROPOWER GENERATION

16%
HYDROPOWER SHARE OF ELECTRIC POWER INSTALLED CAPACITY



UGANDA

Although Uganda is endowed with energy resources distributed throughout the country including hydropower, biomass, solar, geothermal, peat and fossil fuels, less than 15 per cent of the population has access to electricity. Consumption of electricity is among the lowest in the world at 215 kWh per capita per year, less than half that of the Sub-Saharan African average of 552 kWh. Biomass is the most important source of energy for most of the population, accounting for 90 per cent.

Uganda has a total installed capacity of 957.7 MW, including 743 MW for hydropower. The main and base electricity supply is generated from the Nile River, primarily from the 255 MW Bujagali, the 200 MW Kiira and the 180 MW Nalubaale plants. In total, hydropower accounts for 78 per cent of installed capacity, whereas thermal, cogeneration and solar account for 14, 10 and 1 per cent respectively. The total energy power potential is estimated to be 5,300 MW, including an estimated 2,200 MW of hydropower, which can potentially provide the country with sufficient capacity to meet future growth in energy demand.

Since the Bujagali hydropower station was completed by mid-2012, the generation capacity – accounting for 34 per cent of the country's electricity – has been sufficient to avoid load shedding. In order to make electricity in Uganda more affordable, the government has a grant with a five-year corporate income tax break to Bujagali Energy Ltd to reduce electricity prices. Moreover, the International Finance Corporation (IFC) is helping refinance Bujagali to lower the project's tariff under the power purchase agreement with Uganda Electricity Transmission Company.

Extending electricity access nationwide is a primary policy objective for Uganda. This includes increasing access to 30 per cent in 2020 and 80 per cent in 2040 (a 6 per cent annual increase), with off-grid electricity playing only a minor role. While this is expected to be mainly low-carbon due to large hydropower resources, there is potential to achieve 100 per cent access cost-effectively by 2040 with a greater emphasis on small-scale off-grid renewable solutions.

To fast-track the development of on-grid small renewable energy projects, Uganda took an early lead in East Africa in implementing the feed-in-tariff (FIT) system, adopting the Global Energy Transfer Feed-in-Tariff (GET-FiT) Program launched in 2013. The total planned installed capacity from the GET-FiT projects currently under construction is 86 MW. Moreover, 6.5 MW Muvumbe and 5 MW Siti I became operational in March and May 2017 respectively.

The government's grid development plan set a target to increase hydropower generation mix from 78 per cent to 90 per cent by 2030. The government has continued to expand the power transmission network to expand national electrification coverage as envisioned in the national development plan. During 2017 the government completed construction of 167 km of transmission lines, and a total of 948 km of transmission lines are to be finished by the end of 2018.

Uganda is building several new large hydropower facilities, such as the 600 MW Karuma and the 183 MW Isimba Falls plants, and has proposed the 600 MW Ayago plant. The 600 MW Karuma plant construction is 70 per cent complete with construction completion targeted during the financial year 2018/2019. Construction of the 183 MW Isimba project stands at 66 per cent and the project is expected to be commissioned by August 2018.

Other hydropower projects currently under development are the 83 MW Achwa project, the 44.7 MW Muzizi project and the 5.4 MW Nyagak project. On top of that, the GET-FiT portfolio is supporting 17 renewable power generation projects to generate about 156.5 MW, where a total of 69.2 MW is expected by the end of 2018 from nine hydropower projects.

42.1 MILLION
POPULATION

743 MW
INSTALLED HYDROPOWER CAPACITY

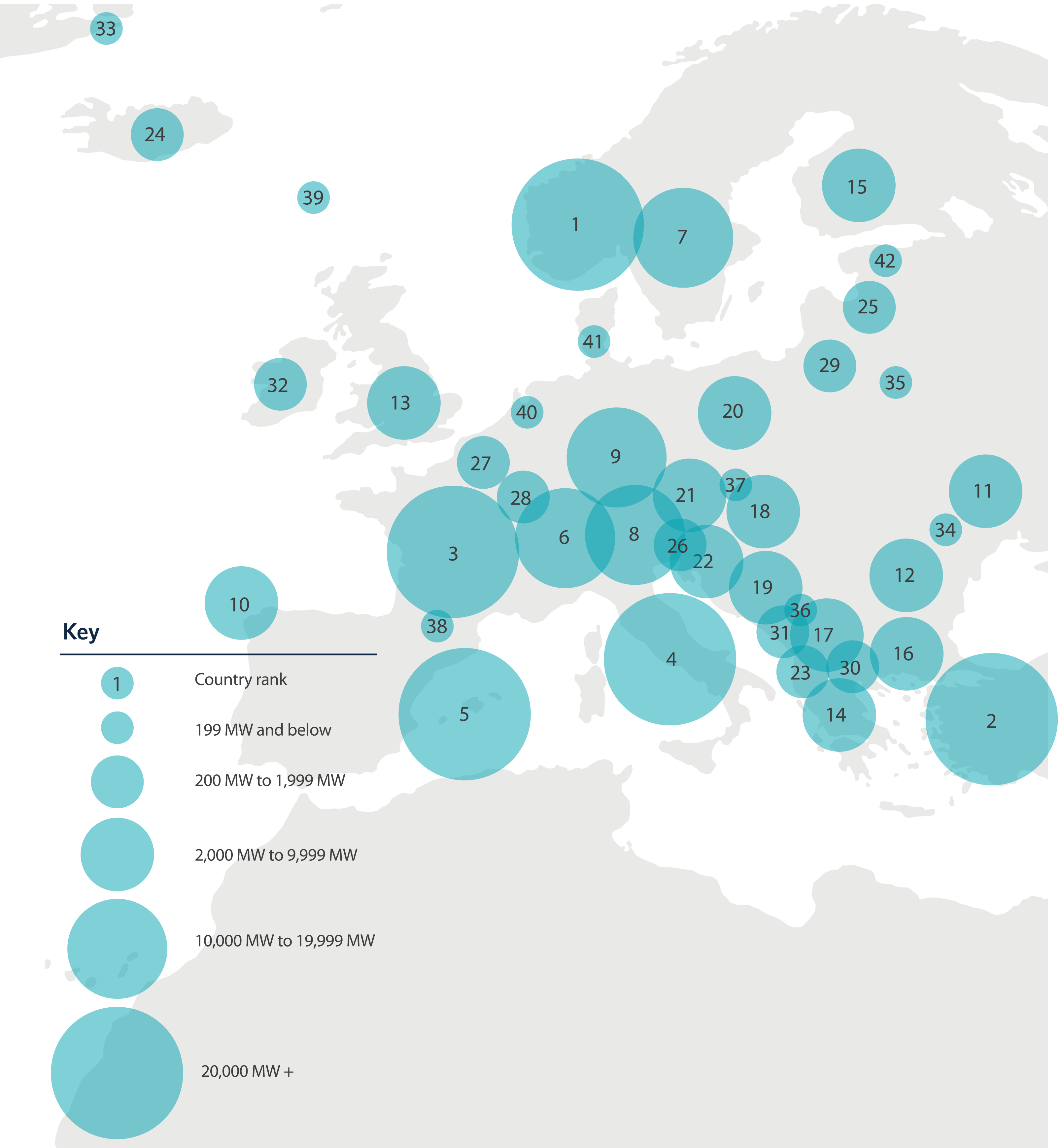
3,330 GWh
HYDROPOWER GENERATION

78%
HYDROPOWER SHARE OF ELECTRIC POWER INSTALLED CAPACITY

EUROPE

Budarhals hydropower plant, Iceland.
Credit: Voith - Landsvirkjun

EUROPE INSTALLED CAPACITY



TOP SIX COUNTRIES BY INSTALLED HYDROPOWER CAPACITY (MW*)

1	2	3	4	5	6
Norway	Turkey	France	Italy	Spain	Switzerland
31,837	26,681	25,517	21,884	20,344	16,657

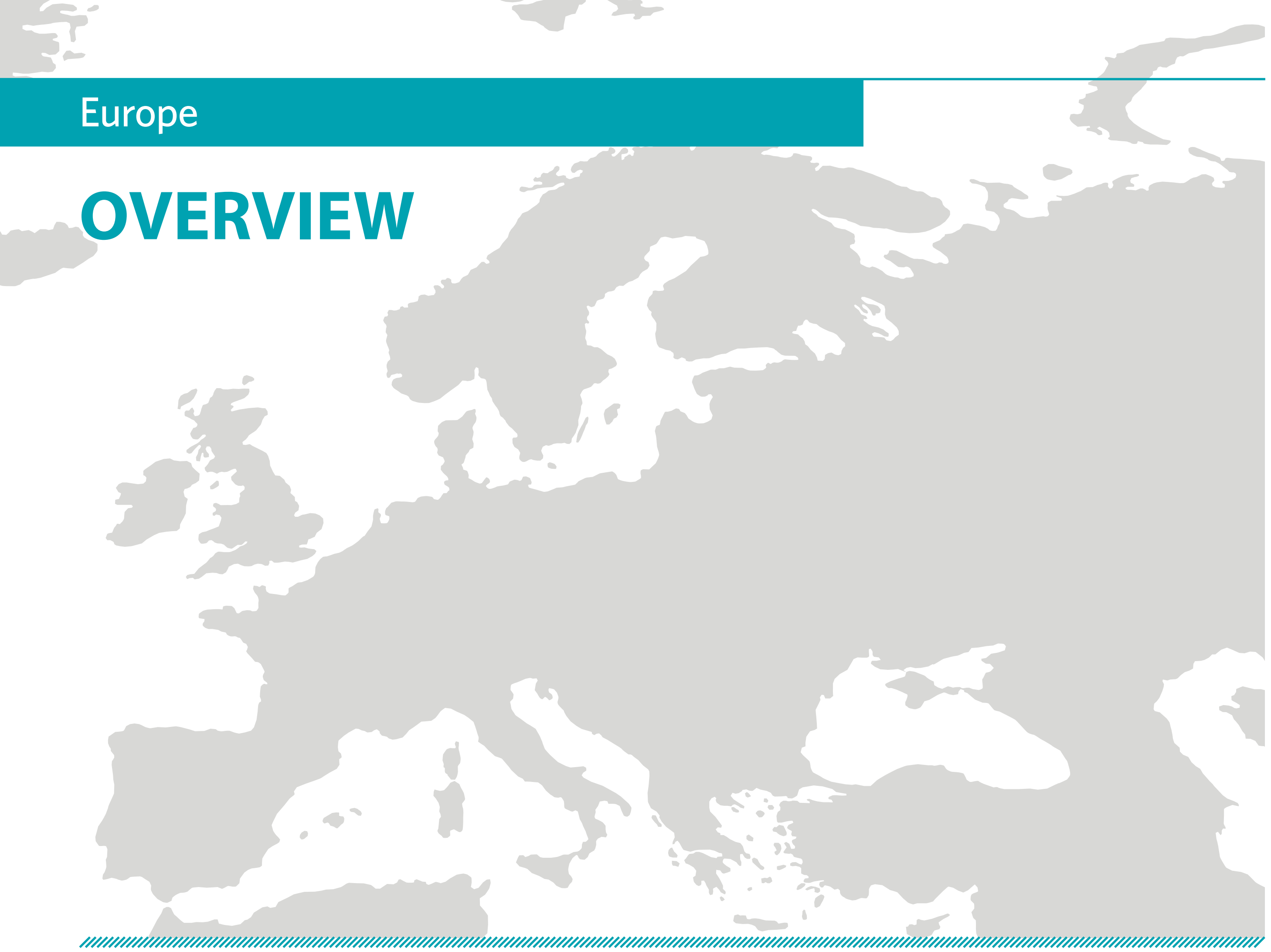
EUROPE CAPACITY BY COUNTRY*

Rank	Country	Total installed capacity (MW)	Rank	Country	Total installed capacity (MW)
1	Norway	31,837	22	Croatia	2,141
2	Turkey	26,681	23	Albania	2,020
3	France	25,517	24	Iceland	1,986
4	Italy	21,884	25	Latvia	1,576
5	Spain	20,334	26	Slovenia	1,479
6	Switzerland	16,657	27	Belgium	1,427
7	Sweden	16,466	28	Luxembourg	1,330
8	Austria	14,116	29	Lithuania	876
9	Germany	11,258	30	Macedonia	674
10	Portugal	7,343	31	Montenegro	658
11	Ukraine	6,785	32	Ireland	529
12	Romania	6,705	33	Greenland	90
13	United Kingdom	4,611	34	Moldova	76
14	Greece	3,396	35	Belarus	73
15	Finland	3,198	36	Kosovo	66
16	Bulgaria	3,129	37	Hungary	56
17	Serbia	2,835	38	Andorra	45
18	Slovakia	2,522	39	Faroe Islands	39
19	Bosnia and Herzegovina	2,504	40	Netherlands	37
20	Poland	2,351	41	Denmark	9
21	Czech Republic	2,212	42	Estonia	8

* including pumped storage

Europe

OVERVIEW



The European Union as well as many non-EU countries including Switzerland, Norway and Turkey have brought forward climate and energy policies over recent years aimed at establishing affordable, secure and sustainable clean energy systems. In order to meet ambitious climate mitigation commitments, European countries will need to rapidly decarbonise their power sectors and increase the share of renewable energy. Toward this end, in early 2018 the EU parliament voted to increase its renewable energy goal for 2040 from 27 per cent to 35 per cent.

The wider European region, including non-EU countries, added 2.3 GW of installed hydropower capacity in 2017, bringing the total installed hydropower capacity in the region to 249 GW. Despite drought and low rainfall throughout most of the continent, hydropower generated an estimated 600 TWh of clean electricity in 2017. It remains the single largest source of renewable electricity in Europe. As wind and solar power continue their growth throughout the region, future energy systems are poised to continue to benefit from and rely upon hydropower's grid services and active and passive storage capabilities.

Hydropower has a long tradition in Europe, with many countries adding significant hydropower capacity following the Second World War in the 1960s and 1970s. Many of these projects are now in need for rehabilitation and modernisation. In many mature hydropower markets, capacity additions are expected to come from upgrades, smaller-scale projects or with retrofitting of existing infrastructure.

Most of the remaining potential for greenfield hydropower development is in eastern Europe, especially in the Western Balkan region, where the EU has taken a strong interest in developing the region's energy sectors by creating frameworks to foster coordinated investment and strengthen coherence and local synergies to ensure positive impacts. Preliminary findings released in 2017 on a Hydropower Master Plan for the region highlighted the need for transboundary river approaches that include shared hydropower potential, but also focused on the shared water services such as flood mitigation for all stakeholders if planned holistically.

Albania, which relies almost entirely on hydropower for its power supply, brought the 74.6 MW Fangu hydropower station online in 2017. The project, owned and constructed by Turkish company Ayen Energy, represents the largest privately-owned power project in the country and fourth largest hydropower station in the country. A net importer of energy, Albanian legislators are working to create a liberalised energy market to stimulate both power trading with neighbouring countries, but also to spur further development of renewable energies. Full liberalisation is expected by 2025.

In Serbia, state-owned Elektrovprivreda Srbije (EPS) announced modernisation plans to increase capacity at Iron Gate 2 from 270 MW to 320 MW. The Danube river project is located between Serbia and Romania and is shared between the two countries, with Romania's Iron Gates power station having completed modernisation a number of years ago with a capacity of 321 MW. EPS completed modernisation efforts at the Iron Gate 1 project in 2017, adding 68 MW to what was already the largest hydropower station on the Danube. Combined, the Iron Gates projects have a total installed capacity of 2,908 MW.

Floating photovoltaics at the Alto Rabagão pumped storage reservoir, Portugal (Credit: EDP)

Romania added the 12 MW Bretea project located on the Strei river to its electricity portfolio, while also announcing plans for the refurbishment and modernisation of a number of ageing hydropower projects, including Calimanesti (78 MW), Slatina (13 MW) and Mariselu (221 MW) projects.

Turkey experienced its most severe drought in 44 years, according to the Ministry of Forestry and Water Management. But hydropower generation contracted only by 12.7 per cent in 2017 to 58.5 TWh thanks to effective use of stored water across the nation's fleet of dams, while also meeting public water and irrigation needs. The country expanded its hydropower capacity by 0.6 GW in 2017, bringing the current total to 27.3 GW. Significant additions during the year included Kiğı (140 MW), Kargı (97 MW), Darıca 2 first unit (74 MW), Doğançay (62 MW), and many other projects.

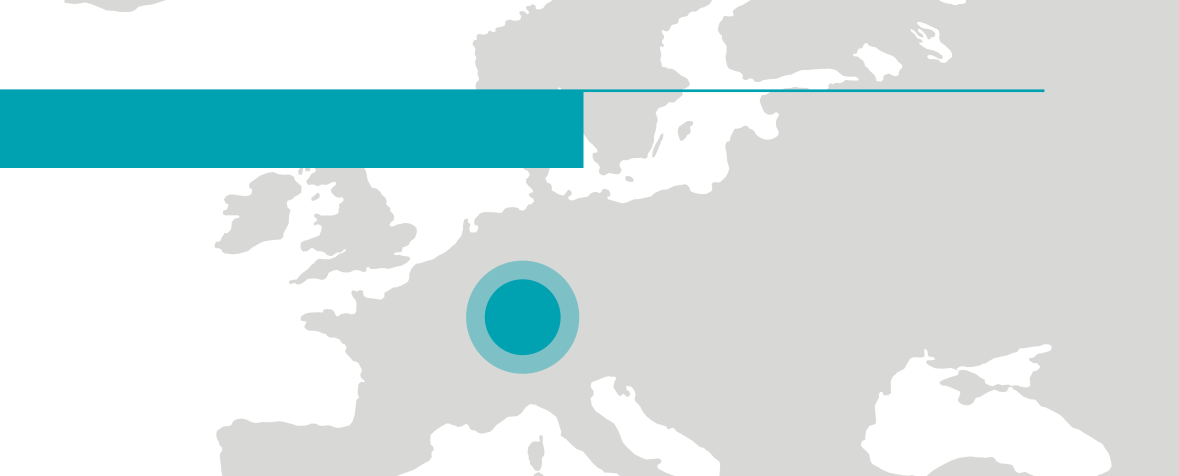
As generation from wind and solar continue to grow, the value of energy storage to provide flexibility to power grids is becoming increasingly recognised. Approximately 1.3 GW of pumped storage was added in 2017. Portugal led the way commissioning the 780 MW Frades 2 and 270 MW Foz Tua projects.

The Frades II project is one of the largest variable-speed pumped storage projects in Europe. Operational since April 2017, the two variable-speed pump-turbines allow for quicker response times, adding additional flexibility while also allowing for frequency control while pumping. The project was added to the Cavado-Rabagao cascade system. The pumped storage projects are forming the backbone of Portugal's transition to rely on wind, solar and hydropower for its power. Positive results are already to be seen, with Portugal producing more than 100 per cent of the country's electricity consumption for the month of March 2018, with 55 per cent coming from hydropower.

Switzerland completed the second stage at the Hogrin-Leman pumped storage project. The 240 MW addition doubled the project's total installed capacity to 480 MW. The project, now the second largest pumped storage project in the country, is in accordance with the country's 2050 Energy Strategy and will help stabilise both the Swiss and European grids.

Across Europe, 12 cities report that at least 70 per cent of their electricity is generated by hydropower, according to data published by the CDP world renewable cities initiative (2018). These include Oslo in Norway (98 per cent), Basel in Switzerland (89 per cent) and Reykjavík in Iceland (70 per cent).

AUSTRIA



Austria's alpine topography, numerous rivers and high precipitation present the country with significant water resources. Hydropower has played an instrumental role in the development of the energy sector, with the first commercial hydroelectric generators powering lights as early as 1884.

Hydropower blossomed after the First World War due to growing electricity demand and a severe shortage of coal resulting from the loss of large coal fields when the Austro-Hungarian Empire was dissolved. The development of hydropower helped to reduce severe unemployment and improved local air quality, so much so that politicians referred to hydropower affectionately as "white coal".

Hydropower experienced another boom after the annexation of Austria to Germany in 1938, when a number of projects were started, only for many to stall during the Second World War. The sector experienced another revitalisation following the injection of funds from the European Recovery Program in the 1950s and continued as the economy strengthened in the 1960s and 1970s.

Large projects came under scrutiny during the 1980s due to environmental and social concerns, and consequently more recent development has focused mainly on small-scale applications, with a few exceptions, notably pumped storage projects.

Austria added at least 15 MW in hydropower installed capacity in 2017, taking its total installed hydropower capacity to 14.1 GW, of which 5.7 GW are run-of-river projects and 8.4 GW are pumped storage projects. More than 3,000 hydropower stations are connected to the national grid, with a further 2,000 very small projects used for on-site consumption off the grid.

Ninety-five per cent of the country's grid-connected plants have an installed capacity of less than 10 MW, delivering about 13.8 percent of total hydropower generation. The remainder, some 158 projects with capacities greater than 10 MW, provide more than 90 per cent of installed capacity and deliver 86 per cent of total hydropower generation.

Hydropower today accounts for about 56 per cent of total installed power generating capacity, down from around 61 per cent a decade earlier. The slight decline can be attributed to a four-fold increase in wind and solar capacity over the same time period. Nevertheless, Austria's 2017 Power Grid Development Plan explicitly identifies hydropower as an enabling pillar to support the projected increase of wind and solar.

In addition to supporting the integration of variable renewables, hydropower development is driven by increasing electricity demand and the will to increase energy security to reduce energy and fuel imports. Forecasts have shown Austrian electricity demand increasing by 14-20 TWh by 2030.

With an estimated technical and economic potential of 56.1 TWh, Austria has exploited some 75 per cent of its potential. According to a 2008 Pöyry study, the remaining economically and environmentally feasible potential totals 12.8 TWh. According to the Austrian Electricity Strategy, Empowering Austria, 6 to 8 TWh could be developed up to 2030.

The country's electricity sector is characterised by strong interconnections with neighbouring countries, especially Germany, Switzerland, the Czech Republic and Slovenia. Since 2002, Germany and Austria have shared a bidding zone, meaning that interconnector capacity for cross-border trade has not been limited or explicitly scheduled. However, in November 2016 it was decided by the European Agency for the Cooperation of Energy Regulators that the market would split on 1 October 2018 because of over-supply of German wind and insufficient transmission capacity within Germany causing surpluses to flow into the Czech Republic and Poland, destabilising their grids.

With strong political will to increase renewable generation and to decrease import dependency, the government plans to expand hydropower generation with new greenfield projects and expansion and retrofitting projects. The 10.4 MW (13.2 MW when pumping) Rellswerk pumped storage project was put into operation in 2017, adding additional balancing capacity to the system on the upper regions of the Ill River in Vorarlberg. Further pumped storage projects include the 130 MW Tauernmoos project planned for commissioning in 2025, and the 360 MW Obervermuntwerk II project, set for commissioning in 2018.

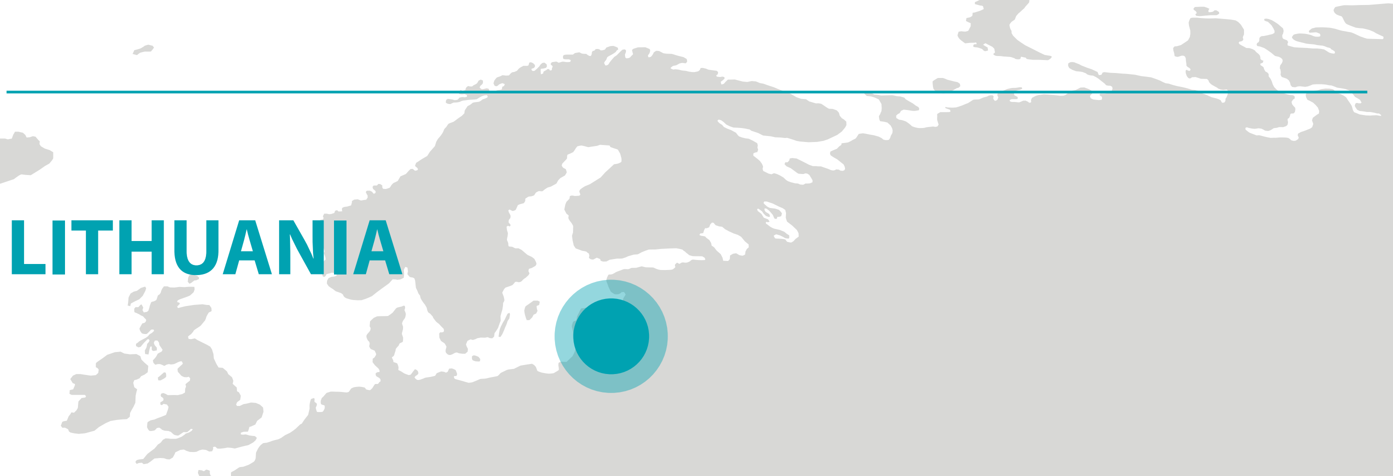
8.7 MILLION
POPULATION

14,130 MW*
INSTALLED HYDROPOWER CAPACITY
*IHA estimate

38,540 GWh
HYDROPOWER GENERATION

56%
HYDROPOWER SHARE OF ELECTRIC POWER INSTALLED CAPACITY

LITHUANIA



Lithuania has one of the highest levels of energy poverty in the European Union. As a result, increasing energy security, efficiency and use of renewables are seen as central pillars for the country's energy transition.

Hydropower, including production from pumped storage projects, accounts for around 20 per cent of total domestic power generation. The country's 100 hydropower plants have a total installed capacity of 1,028 MW, amounting to roughly 28 per cent of total installed capacity.

Generation from hydropower reached record levels in 2017, increasing by almost a quarter over 2016. This high level was partly due to good hydrological flow conditions, but also through improved market exploitation and active engagement in intraday trading by state owned energy company Lietuvos Energia.

Despite realising independence from the USSR in 1990, Lithuania's energy system still relies heavily on its neighbours to the east. The electricity grid was developed during the Soviet era and the power grid is still synchronised to the BRELL (Belarus, Russia, Estonia, Latvia and Lithuania) power grid, which is part of the wider integrated and unified power systems of former soviet states.

The closure of the 2,600 MW Ignalina nuclear power plant in 2009 put additional strain on the energy system and increased dependency on gas and power imports. Before closure, Ignalina met approximately 77 per cent of electricity demand, and 58 per cent of its power generation was exported.

The future development of Lithuania's hydropower and other renewable resources is driven by the 2012 National Energy Independence Strategy, in which the government committed to achieving a 23 per cent renewable energy share of final energy consumption by 2020. While the majority of the increase in renewables is expected to come from biomass and wind, non-pumped storage hydropower should grow by 10 per cent, to a total of 140 MW by 2020.

The majority of Lithuania's hydropower capacity comes from just two projects: the 900 MW Kruonis pumped storage project and the 101 MW Kaunas project. The two projects work in conjunction, with the Kaunas reservoir acting as the lower reservoir for the Kruonis project. With the exception of Balskų (2.9 MW), Angirių (1.3 MW), Kavarsko (1.5 MW), and Antalieptės (2.6 MW), all other hydropower projects are less than 1 MW.

Despite estimated potential hydropower resources totalling 1.9 TWh per year – representing five times what is currently produced on average per year – developers have been struggling to find economically feasible sites that are also compliant with strict environmental legislation. An amendment to national water legislation in 2004 prohibited dam construction for over 170 rivers, including all of Lithuania's major water courses. An assessment of hydropower potential which is compliant with environmental legislation estimates a much lower potential of 117 GWh per year, or roughly 6 per cent of the gross theoretical potential.

In 2017, the EU stated it will work with Lithuania and the other Baltic states to link their electricity grids to the EU via Poland by 2025. This is to diversify their energy trade partners, having previously relied on BRELL system and Russian imports. This diversification builds upon the 700 MW HVDC NordBalt interconnection with Sweden which was completed in 2016.

Lietuvos Energia assessed the possibility of installing a fifth pump-turbine at the Kuronis pumped storage plant. The new pump turbine would use variable speed technology, allowing for better balancing of wind power resources. The assessment found that arbitrage opportunities for revenue generation are expected to decrease as interconnections to western Europe are established.

Despite a reduced business case, the report found that the addition of the fifth unit would be the optimal solution to adding reliability and security of the Baltic electricity system in the shortest possible time. Hydropower's reserve capacity services were in evidence in Lithuania when the NordBalt interconnector experienced an unexpected outage due to a cable malfunction in July 2017. The Kruonis pumped storage facility was able to quickly respond to the power deficit to keep the country's lights on.

2.87 MILLION
POPULATION

1,028 MW
INSTALLED HYDROPOWER CAPACITY

1,165 GWh
HYDROPOWER GENERATION

28%
HYDROPOWER SHARE OF ELECTRIC POWER INSTALLED CAPACITY

Europe

UNITED KINGDOM

The United Kingdom has been a pioneer in hydropower development, using water for electricity generation since 1879 when the first 4.5 KW hydroelectric generator was put into operation to provide electricity for a single incandescent lamp.

Today the UK has a total hydropower installed capacity of over 4,600 MW, including 2,744 MW of pumped storage. The vast majority of installed capacity is located in the wet and mountainous regions of Wales and northwest Scotland.

In 2017, installed capacity additions totalled 32 MW. Notable greenfield projects commissioned in Scotland included Allt Garbh (1.5 MW), Ardtalnaig (2 MW), Grudie (2 MW) and the Nevis Range (1.1 MW).

Over the past 30 years, the proportion of electricity generated by hydropower has remained around 2 per cent of total power generation. Hydropower has however increasingly been called upon to support the development of the UK's variable renewable sector by providing peaking, balancing and other grid services, especially as wind generation has increased over ten-fold since 2007.

The UK's energy transition has its foundations in the 2008 Climate Change Act, which is a legally binding commitment by the UK government to reduce total GHG emissions by at least 80 per cent of 1990 levels by 2050. The 2009 National Renewable Energy Action Plan sets an additional target for the UK to achieve 15 per cent of its energy consumption from renewable sources by 2020, compared to only 1.5 per cent in 2005. The plan estimates non-pumped storage hydropower reaching 2,130 MW by 2020.

Despite an estimated 2.4 GW of viable hydropower potential in the UK, hydropower expansion is likely to be limited to small-scale applications (up to 5 MW), with the exception of pumped storage projects.

The UK currently hosts four pumped storage projects in Scotland and Wales. The largest such project, Dinorwig in north Wales, was commissioned in 1983 with a capacity of 1,728 MW. Since the 1960s, only one non-pumped storage project greater than 20 MW has been commissioned: the 100 MW Glendoe project in 2009.

While these pumped storage projects were initially developed to provide peaking and balancing support for coal and nuclear, the changing energy generation landscape is shifting how pumped storage is utilised. The addition of wind and gas, replacing coal, means that many pumped storage assets in the UK are no longer operating on daily cycles, pumping at night and generating during peak daytime hours. Rather, pumped storage assets have substantially increased ramping and sometimes cycling up to 60 times a day. Since 2007, generation from pumped storage has increased on average by 20 per cent compared to a decade earlier.

Small-scale hydropower projects, including community-led projects, are being developed across the UK. Innovations in small hydropower turbines have allowed for hydropower to be applied at sites with very low heads and low flows by utilising the Bernoulli principle, including the River Mill in Cambridgeshire, England. Other notable community-led projects include the 100 KW Bethesda scheme in Wales, which allows residents to purchase generated power for half the average price of UK electricity, and reduces losses due to transmission.

While there are currently no new pumped projects under construction, the UK government granted electricity generation licences to three proposed projects: in Wales, the 99 MW Glyn Rhonwy project in abandoned mines and, in Scotland, the 600 MW Coire Glas and 400 MW Glenmuckloch projects.

The UK's current interconnection capacity rests approximately at 5 per cent of total installed capacity, about half of the recommended 10 per cent benchmark proposed by the European Commission. A number of new interconnection projects are currently underway, most notably the North Sea Link, a 1,400 MW HVDC interconnection with Norway, which takes advantage of Norway's hydropower while providing an off-taker for excess UK wind production.

65.6 MILLION
POPULATION

4,611 MW
INSTALLED HYDROPOWER CAPACITY

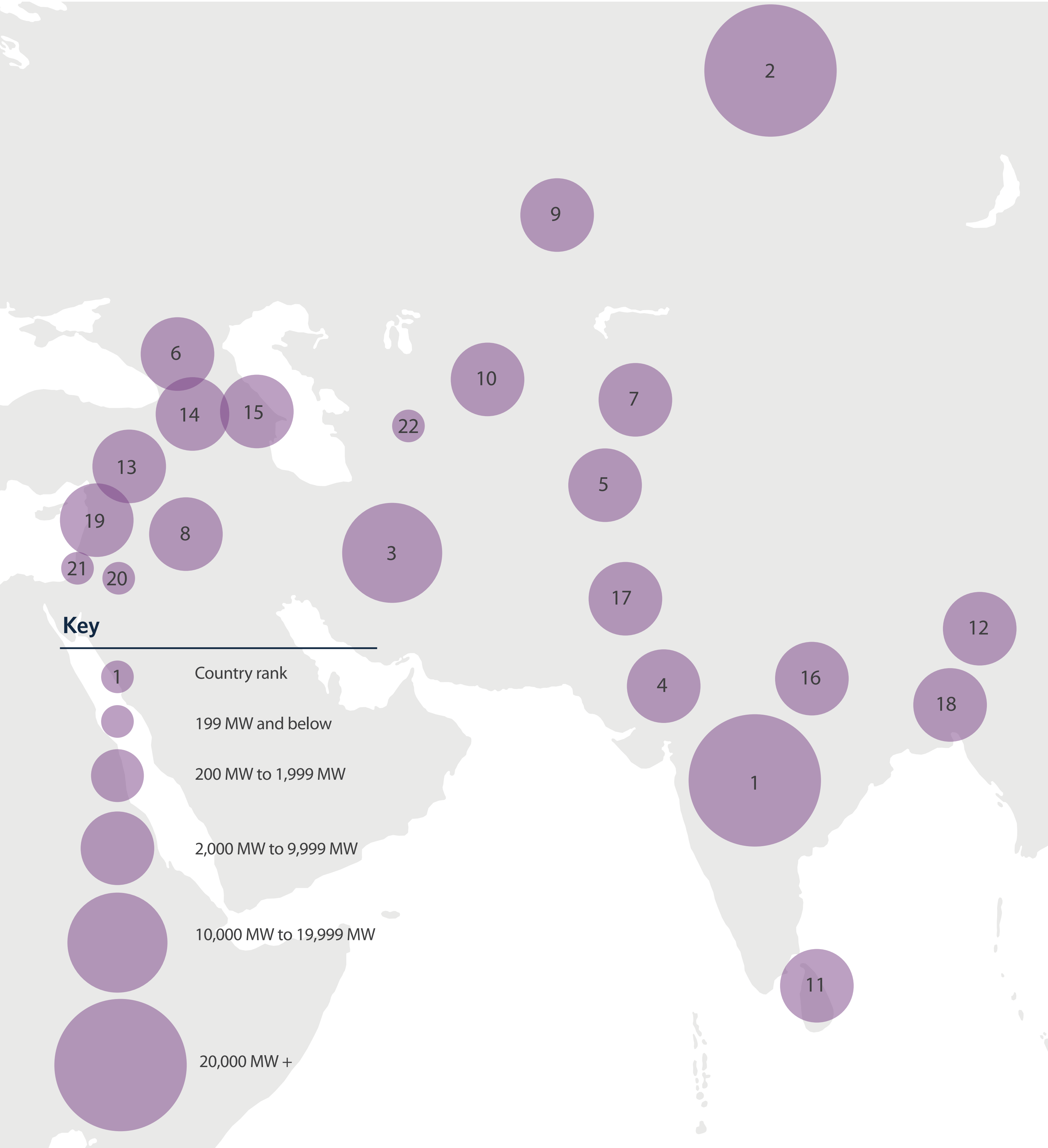
5,186 GWh
HYDROPOWER GENERATION

11.5%
HYDROPOWER SHARE OF ELECTRIC POWER INSTALLED CAPACITY

SOUTH AND CENTRAL ASIA

The Toktogul reservoir in central Kyrgyzstan. Credit: David Trilling

SOUTH AND CENTRAL ASIA INSTALLED CAPACITY



TOP SIX COUNTRIES BY INSTALLED HYDROPOWER CAPACITY (MW*)

1	2	3	4	5	6
India	Russia	Iran	Pakistan	Tajikistan	Georgia
49,382	48,450	11,811	7,477	5,190	3,161

SOUTH AND CENTRAL ASIA CAPACITY BY COUNTRY*

Rank	Country	Total installed capacity (MW)
1	India	49,382
2	Russia	48,450
3	Iran	11,811
4	Pakistan	7,477
5	Tajikistan	5,190
6	Georgia	3,161
7	Kyrgyzstan	3,091
8	Iraq	2,753
9	Kazakhstan	2,554
10	Uzbekistan	1,731
11	Sri Lanka	1,720
12	Bhutan	1,615
13	Syria	1,505
14	Armenia	1,249
15	Azerbaijan	1,122
16	Nepal	968
17	Afghanistan	461
18	Bangladesh	230
19	Lebanon	221
20	Jordan	12
21	Israel	7
22	Turkmenistan	1

* including pumped storage

OVERVIEW

Nurek reservoir in Tajikistan.
Credit: David Trilling

Rising energy demand in Central and South Asia means investment in power infrastructure is high on the political agenda. In 2017 overall hydropower capacity increased by 3.7 GW across the region.

India accounted for over half of new installs including the Teesta III project (1,200 MW) in the Himalayan north-eastern state of Sikkim. Other major projects that became operational include Sainj (100 MW), Tashiding (97 MW) and Tuiral (60 MW). The government's 2016 Third National Electricity Plan (NEP3) has set an ambitious commitment to deliver over 50 per cent capacity from non-fossil fuel sources by 2027. This foresees a central role for hydropower, both for generation and grid balancing, targeting over 20 GW of new capacity. Nonetheless, nearly half the country's large-scale construction projects have faced delays or other challenges. To address this, the Central Electricity Authority's 50,000 MW Hydro Electric Initiative aims to fast-track priority projects, while the Ministry of Power is expected to provide further support for stalled projects.

In Russia, hydropower capacity grew by 364 MW in 2017. The majority of the increase came from inauguration of the Nizhne-Bureyskaya (320 MW) plant in the far east of the country, where most ongoing construction projects are located. Hydropower generation was stable relative to 2016, and overall contributed 17 per cent of total power supply to the Unified Energy System (UES) of Russia. Increased water inflows were seen in hydropower reservoirs along the Volga-Kama cascade, but in other regions, such as the far east, levels declined.

Iran continues to invest in hydropower both at home and abroad. Last year saw the inauguration of the Rudbar Lorestan dam comprising a 450 MW power house and 228 metre reservoir, and the first generating unit at Darian. The Iranian Water and Power Resources Development Company (IWPCO) also has over 4 GW in the pipeline including Seimareh (480 MW), Khersan 3 (400 MW), and Chamsir (110 MW). Beyond its domestic sector, the Iranian Bureau of Administration for Overseas Projects is expanding Iran's hydropower interests and services at the international level.

Pakistan's new Patrind (147 MW) hydropower project connects the rivers Kunhar and Jhelum with a 2.2 km headrace tunnel. The plant incorporates three Francis turbines and a sediment bypass tunnel. Developed as an independent power project (IPP) by interests in the Republic of Korea, the project received certified emissions reduction credits under the Clean Development Mechanism. Other small hydropower developments include the Marala (7.6 MW) project now under completion.

In Georgia, hydropower is attracting renewed interest as the government streamlines its power sector. Last year saw a programme to modernise the Enguri dam (1,300 MW) gain funding and Dariali (108 MW) and Khelvachauri 1 (47 MW) plants were added to the country's 3 GW of capacity. Other construction projects with foreign investment include Nenskra (280 MW) and Khudoni (702 MW), while schemes at an earlier stage include the Georgian Energy Development Fund's Namakhvani project (433 MW).

Elsewhere in the South Caucasus, the last two years have seen small hydropower projects commissioned in Azerbaijan with 15 MW more under construction, and the government of Armenia has approved the Shnokh (76 MW) project. Georgia also has plans to expand its existing grid interconnections with border states which will offer new export opportunities for regional hydropower developers.

Tajikistan and Kyrgyzstan both produced over 90 per cent of their annual electricity from hydropower in 2017. With abundant water resources and over 8 GW existing capacity, neighbouring states also benefit from a seasonal surplus generated from these two countries. At the end of 2017, water levels at the Toktogul reservoir were 12 per cent higher compared to the previous year. The government of Uzbekistan is also signalling support for the 3,600 MW Rogun dam which is under construction in Tajikistan, signifying a major step forward. Further hydropower investments include modernisation of Nurek and Qairokkum in Tajikistan, and the Naryn cascade in Kyrgyzstan.

In neighbouring Uzbekistan, a national investment plan was announced in 2017 to develop its ageing hydropower infrastructure. Modernisation of Charvak was completed in 2016 raising its capacity to over 600 MW, with other refurbishments and new projects planned in Tashkent for example. In Kazakhstan, hydropower generated a total of 11.2 TWh in 2017, slightly higher than the previous year and making up 11 per cent of the country's total power production. The 25 MW Turgusun project has also received backing.

In Afghanistan, modernisation of the Kajaka hydropower facility (50 MW) in Helmand concluded with US support in 2017. After installation of turbine upgrades and a digital control system, full handover to the Afghan national power utility, Da Afghanistan Breshna Sherkat, was completed. Other proposed projects include the Baghdara dam (210 MW) on the Kabul river basin.

The CASA 1000 project advanced in 2017, aiming to interconnect Kyrgyzstan, Tajikistan, Afghanistan and Pakistan through high voltage transmission lines. The scheme will allow surplus hydropower transfers from north to south, alleviating power shortages while also generating revenues for the exporting countries. Tenders were successfully submitted by HVDC equipment suppliers, and construction of line sections is underway.

Nepal has almost 1 GW hydropower capacity, which typically accounts for over 90 per cent of annual generation. Recent additions have been the Upper Madi (25 MW) project and the first unit of the Upper Marsyangdi A (50 MW) plant at the end of 2016, plus a number of smaller projects commissioned in 2017. Power imports from India have, however, been increasing to meet rising demand and domestic supply shortages have been severe. Hence the Nepalese government together with the Nepal Electric Authority and international partners have been working to develop multiple projects, such as the Upper Tamakosi run-of-river hydropower plant (456 MW) near the border with Tibet and Arun III (900 MW) has commenced with support from India. The Upper Tamakosi project is nearing completion, but along with existing facilities suffered setbacks due to a severe earthquake in 2015.

Bhutan continues to advance its hydropower capacity as part of the national growth strategy as it pushes the Mangdecchu project (720 MW) in Trongsa towards completion. Other projects under construction include Punatshangchhu I and II (totalling over 2,220 MW) and Kholongchhu (600 MW), all of which have faced overruns. A trilateral deal between the governments of Bhutan, India and Bangladesh is also on the horizon, supporting the Dorjilung hydropower project (1,125 MW) in Bhutan and export to India and Bangladesh.

In the Middle East, the Dubai Electricity and Water Authority (DEWA) is progressing the Hatta pumped hydropower storage project (250 MW), the first of its kind in the Arabian Gulf, awarding the consultancy contract in 2017 covering design and technical studies.

INDIA

With a population of well over a billion people and a fast growing economy, India's electricity demand is expected to double over the next decade. India currently has 197 hydropower plants above 25 MW, plus nine pumped storage stations and ranks fifth in the world for potential hydropower capacity.

Hydropower's share in the electricity mix has, however, been decreasing over the years, accounting for approximately 10 per cent of generation in 2017, with the majority (80 per cent) coming from thermal.

The year 2017 nonetheless marked a turning point in new clean power installs, at 15.7 GW, including almost 2 GW new hydropower, well exceeding new thermal capacity additions. Most added hydropower capacity came from commissioning the 1,200 MW Teesta III hydropower plant in the north eastern state of Sikkim.

Projects entering service in 2017 were 100 MW Sainj, 97 MW Tashiding, 96 MW Dickchu, 120 MW Pulichintala (first three units adding 90 MW), and 60 MW Tuiral among other projects. India also has a renovation and modernisation programme for ageing hydropower assets, with 21 schemes completed in March 2017 accruing benefits of 549 MW.

In the last quarter of 2017, the Central Electricity Authority (CEA) reported 11.5 GW capacity was under construction, just over 25 per cent by the private sector. The National Hydroelectric Power Corporation (NHPC) is building the 2,000 MW Lower Subansiri project in Arunachal Pradesh and Assam, which has faced delays, the 800 MW Parbatti II project in Himachal Pradesh, and the completed 330 MW Kishanganga project. The government is also investing in the north western state of Jammu and Kashmir through the joint venture Chenab Valley Power Projects Limited, with 1,000 MW Pakal Dul and 624 MW Kiru now at an advanced stage of ordering civil construction and equipment supply.

India has over 90 GW of pumped storage potential, with 63 sites identified and recognised in national energy policies for their valuable grid services. The CEA's priority is to commission pumping capability at three out of the nine installed pumped storage schemes, Kadana I & II, Nagarjuna Sagar and Sardar Sarovar. The 1,000 MW Tehri facility now under construction is due for service by 2019.

India's transmission capacity has grown by 40 per cent since 2014 and has been operating as a single national grid since 2012-13 when the five independent regional grids were integrated. With new high voltage transmission corridors such as the North East Agra Line, India's cross-country power flows are improving and already greatly reducing power shortages.

Many current hydropower projects have been slow going with delays due to complex planning procedures, prolonged land acquisition and resettlement, a lack of enabling infrastructure including transmission, insufficient market scope and the availability of long term financing.

Significant reforms made in recent years include the 2008 Hydro Power Policy encouraging private sector participation and the 2016 National Tariff Policy on frequency response markets and extended certainty of power purchase agreements. The CEA and Ministry of Power have also been actively monitoring and fast-tracking priority schemes, notably the 50,000 MW Hydro Electric Initiative.

Policy proposals mooted by observers include new ancillary service markets, attributing hydropower full renewable status along with separate purchase obligation benefits, and more integrated planning. Draft policies under preparation are expected to support stalled hydropower projects and private sector uptake and could include measures to make hydropower tariffs more competitive.

1.3 BILLION
POPULATION

49,382 MW
INSTALLED HYDROPOWER CAPACITY

135,539 GWh
HYDROPOWER GENERATION

14.8%
HYDROPOWER SHARE OF ELECTRIC POWER INSTALLED CAPACITY

KYRGYZSTAN

Rising in the Tien Shien mountains at the border with China, the Naryn river flows through Kyrgyzstan feeding the huge Toktogul reservoir to the West and a series of downstream hydropower plants.

The country has a great number of large and medium sized rivers offering significant hydropower potential, estimated at 140-170 TWh, of which only 10 per cent has been exploited. The energy mix is highly dependent on hydropower, which produced 93 per cent of total electricity generated in 2017, and output is sensitive to seasonal and annual weather variations. At the end of the year, the water volume at Toktogul sat at almost 18.75 billion cubic metres, which was higher than 2016 by 12 per cent and enabled power exports to neighbouring countries.

While there have been no major additions to hydropower capacity since 2010, residential electricity demand has risen by almost 60 per cent between 2007 and 2016. Five out of Kyrgyzstan's seven main hydropower plants are over 30 years old, and power supply reliability and quality of service is at risk. Investments in the sector are needed to keep pace with a growing economy. This is particularly the case in winter when generation becomes constrained and demand rises, putting pressure on the grid system. The winter supply gap is expected to increase to 883 GWh in 2030 unless investments in capacity and network reinforcement materialise.

In service since 1975, the complete rehabilitation of the Toktogul plant is a priority given it generates around 50 per cent of the country's power and also provides multi-year storage capacity and regulation services to the regional grid. The programme of works will upgrade equipment and plant capacity at the 1,200 MW Toktogul hydropower plant to 1,440 MW, and also support modernisation of all five main dams along the Naryn cascade (800 MW Kurpsai, 450 MW Tashkumyr, 240 MW Shamaldy-Sai, and 180 MW Uch Kurgan). The next phase will be carried out between October and December 2018, and wider international assistance is also planned to improve governance and operational management.

Near-term objectives for new capacity include construction of the remaining two 120 MW units at Kambarata-2. Long-standing plans to develop the 1,860 MW Kambarata-1 HPP and the Verkhne-Naryn HPP cascade (over 200 MW), offering an additional 5 TWh of generation, had been repeatedly stalled due to lack of funds. However, in late 2017 the Uzbekistan and Kyrgyzstan governments came to an agreement to cooperate in the construction of Kambarata.

Other proposed developments include the Kazarman and Suusamyr-Kokomeren hydropower plant cascades which together would add over 2,465 MW. Recent small hydropower projects have also been implemented, including Tehrmertinsky (3.0 MW) commissioned in 2017 in the Keminsky district.

Construction of the 405 km Datka-Kemin 500 KV transmission line and renovations to power supply systems around the capital, Bishkek, will help to mitigate network losses.

The government has undertaken steps toward reforming the power sector over the last three years, including the establishment of an Independent Regulator, a National Energy Holding Company, and a State Committee on Industry, Energy and Subsoil Use, as well as a new settlement and revenue mechanism. Nonetheless, Kyrgyzstan's electricity tariffs are still heavily subsidised and this makes cost recovery a major challenge for power producers. While measures implemented under the 2014-2017 Medium-Term Tariff Policy (MTTP) have made some improvements, renewed efforts will be needed to realise investments in hydropower according to a recent World Bank report.

Opportunities include the planned 2018-2021 MTTP and building on good progress already made in attracting external financing. Calls for broader policy actions include strengthening institutional governance, enforcing regulations, and outreach programmes for vulnerable energy consumers.

6.2 MILLION
POPULATION

3,091 MW
INSTALLED HYDROPOWER CAPACITY

13,456 GWh
HYDROPOWER GENERATION

82%
HYDROPOWER SHARE OF ELECTRIC POWER INSTALLED CAPACITY

SRI LANKA

Hydropower is well developed in Sri Lanka and will continue to play an important role in the island's energy grid. In 2017, hydropower contributed around 20 per cent of total electricity generation, with over 70 per cent coming from thermal sources and a small portion from other renewables.

The state-owned utility, Ceylon Electricity Board (CEB), operates most of the country's hydropower stations and is planning new investments in its Long Term Generation Expansion Plan (2018-2037). To meet rising electricity demand, growing at around 6 per cent annually and expected to reach almost 17 TWh by 2020, the CEB is aiming to increase overall power capacity from 4 GW currently to almost 7 GW by 2025. In addition to hydropower, this includes ramping up solar and wind capacity, alongside added thermal plants.

As a member of the Climate Vulnerable Forum, an international partnership of countries, Sri Lanka has pledged to achieve carbon neutrality by 2050, demonstrating the country's longer term ambitions.

Hydropower output has been impacted by variability in monsoon patterns, which has significantly increased over recent decades due to climate change. Water use for domestic and irrigation purposes also takes precedence over hydropower affecting availability. At the beginning of 2017, reservoir storage recordings across six major dams were below the five previous years, but picked up at the end of the year finishing higher compared to December 2016.

Over the coming years, water management plans and dam rehabilitation will need to consider the potential for heavier rainfall and flood situations due to a changing climate.

Operating as a multi-purpose system, the Mahaweli cascade was mostly developed in the 1980s and totals just over 800 MW including the country's three largest hydropower plants. A recent addition is the new Moragahakanda reservoir, comprising a 25 MW plant with its first generating unit now under commissioning. The 120 MW Uma Oya project is also under construction, as a trans-basin project planned for 2020.

The 360 MW Laxapana complex on the Kelani river-basin was developed between 1950 and 1975. Now due for modernisation, works at the Polpitiya, New and Old Laxapana and Wimalasurendra stations are expected to increase efficiency. The 35 MW run-of-river Broadlands project is currently under construction, and will be the first hydropower plant developed under the Carbon Development Mechanism. Ground and tunnelling issues have caused delays and completion is expected by 2020.

Other projects on the horizon include Thalpitigala (15 MW), Moragolla (30 MW), Seethawaka (20 MW), Gin Ganga (20 MW) and a potential 600 MW pumped storage project which could help balance wind and solar power. In addition, 16 new small hydropower plants totalling 27 MW were brought online in 2017, supporting a total of 353 MW of small hydropower projects already commissioned as independent power projects (IPPs).

Recent sector reforms have included the National Energy Policy and Energy Sector Development Plan for a Knowledge-Based Economy (2015-2025). Policies focus on promoting the island's indigenous energy resources, developing competitive pricing, improving the quality of power supply (now regulated by the Public Utilities Commission of Sri Lanka), and notably rehabilitating outdated hydropower plants.

Sri Lanka is moving away from feed-in tariffs to competitive bidding for renewables, which will impact the returns expected by project investors. Hydropower plants developed by independent power producers in 1996 and after are also either at or nearing expiry of their 20 year power purchase agreements. Applicable tariff and ownership arrangements are yet to be established with relevant authorities to ensure continuity of operations. Observers have made calls for further reforms, including outreach efforts for national and international funding and the establishment of ancillary markets to reward balancing services.

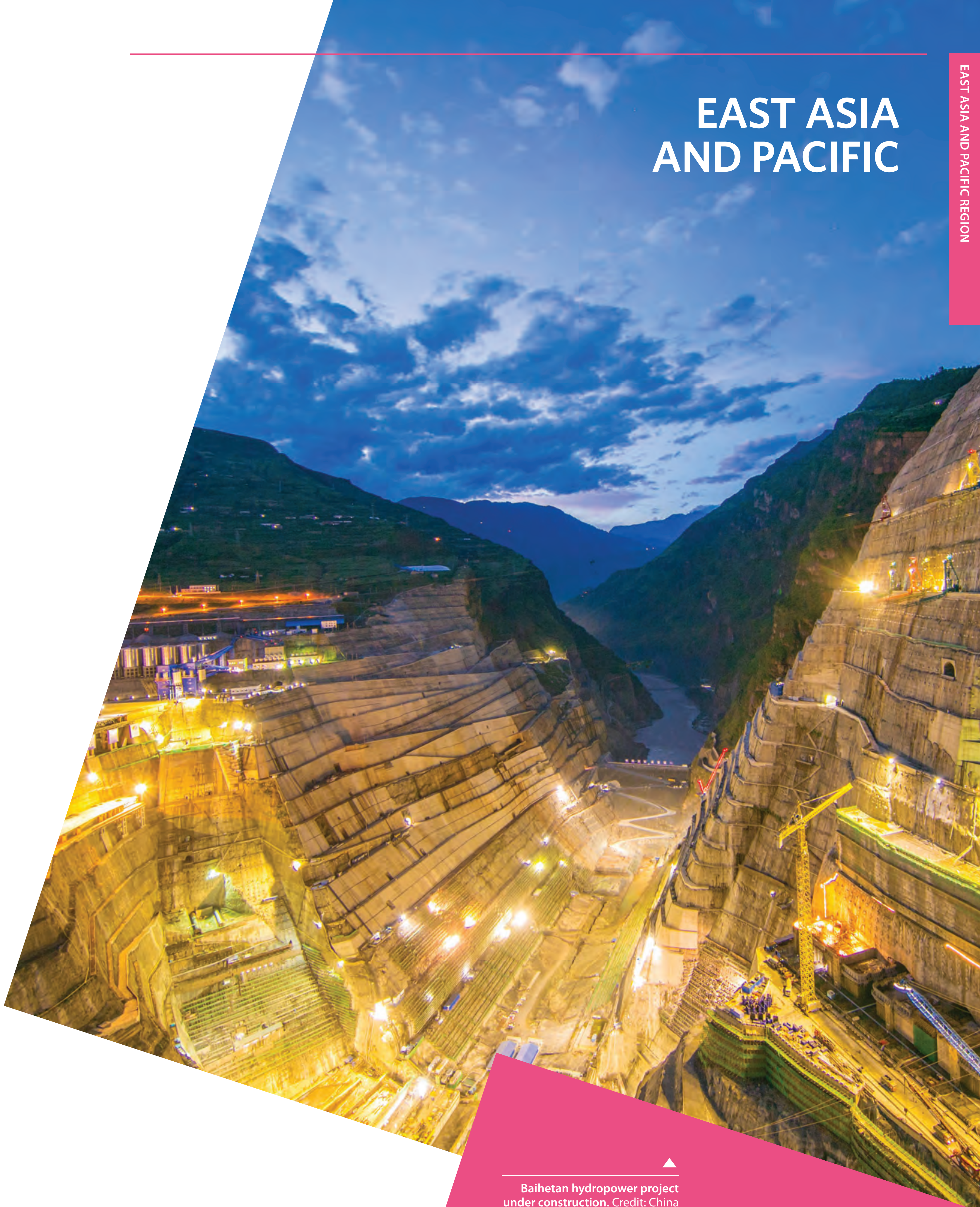
21 MILLION
POPULATION

1,720 MW
INSTALLED HYDROPOWER CAPACITY

2,785 GWh
HYDROPOWER GENERATION

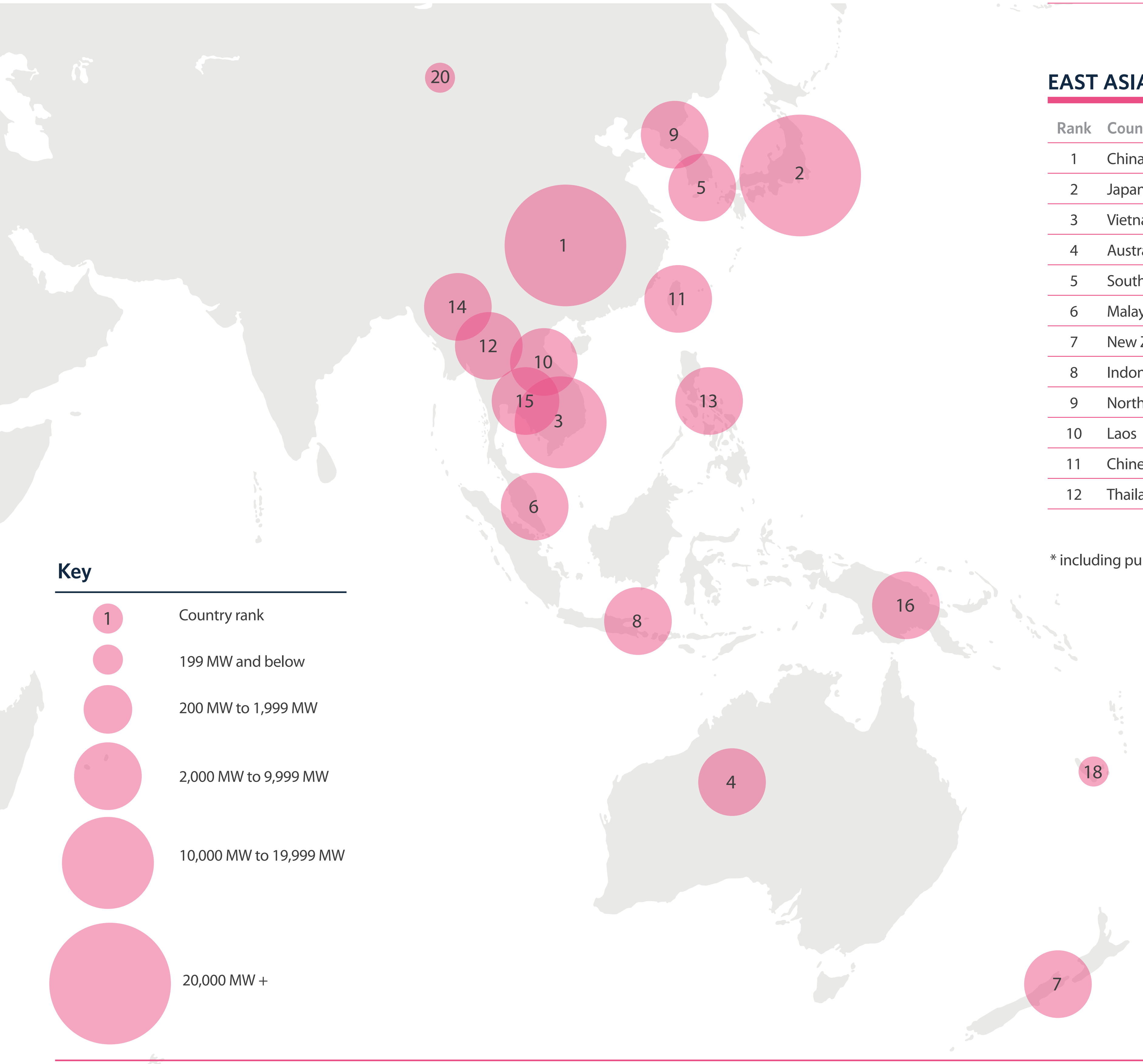
42.5%
HYDROPOWER SHARE OF ELECTRIC POWER INSTALLED CAPACITY

EAST ASIA AND PACIFIC



Baihetan hydropower project under construction. Credit: China Three Gorges

EAST ASIA AND PACIFIC INSTALLED CAPACITY



TOP SIX COUNTRIES BY INSTALLED HYDROPOWER CAPACITY (MW*)

1	2	3	4	5	6
China	Japan	Vietnam	Australia	South Korea	Malaysia
341,190	49,905	16,679	8,790	6,489	6,094

EAST ASIA AND PACIFIC CAPACITY BY COUNTRY*

Rank	Country	Total installed capacity	Rank	Country	Total installed capacity
1	China	341,190	13	Philippines	4,312
2	Japan	49,905	14	Myanmar	3,140
3	Vietnam	16,679	15	Cambodia	1,367
4	Australia	8,790	16	Papua New Guinea	234
5	South Korea	6,489	17	Fiji	125
6	Malaysia	6,094	18	New Caledonia	78
7	New Zealand	5,346	19	French Polynesia	47
8	Indonesia	5,314	20	Mongolia	23
9	North Korea	5,000	21	Samoa	12
10	Laos	4,984			
11	Chinese Taipei	4,691			
12	Thailand	4,510			

* including pumped storage

OVERVIEW

Once again led by China, East Asia and Pacific recorded the largest share of added capacity of all six regions in 2017 with 9.78 GW. China alone accounts for nearly half of the world's added capacity with 9.12 GW, including 1.8 GW of pumped storage. Excluding China, over 650 MW was added in the region.

The Greater Mekong region recorded much of the growth in hydropower outside China. This growth was led by Vietnam, with its 260 MW Trung Son project becoming fully operational in 2017; the USD 412 million project in Quan Hoa district was largely financed by the World Bank, making it the first hydropower plant in the country to have received financing from the institution.In addition, the expanded Thac Mo plant connected to the grid having increased its capacity from 150 MW to 225 MW, while the 38 MW Thuan Hoa project was commissioned on the Mien River along the Vietnam-China border.

In Cambodia, two units of the 400 MW Lower Sesan II project were put into operation representing 100 MW of capacity. The project will be Cambodia's largest ever hydropower project when completed. Being developed by a joint venture between Chinese, Cambodian and Vietnamese companies, the final six units are expected to be completed in 2018.

Laos continues to expand its generating capacity with an increased emphasis on regional cooperation and sustainability. Over 50 hydropower projects are under development across the country, representing 8,000 MW of added capacity. Several projects totalling 166 MW were commissioned in 2017 and the government is looking to further invest in transmission lines to support its goal of becoming the major energy exporter of Southeast Asia. Laos already exports electricity to China, Vietnam and Thailand and is in negotiations with Cambodia and Myanmar.

The Indonesian government remains committed to its ambition of quadrupling its hydropower capacity to 20 GW by 2025 with the first Indonesian project being assessed under the Hydropower Sustainability Assessment Protocol in December last year. The Protocol was applied to the proposed Pelosika project in southeast Sulawesi and was accompanied by capacity building training to support the development of future projects across the country.

Further projects currently under development include Upper Cioskan (1,040 MW), Matenggeng (900 MW), Asahan III (174 MW) and Pembangkin (150 MW).

In North Korea, as much as 70 per cent of electricity is generated by hydropower. China is helping to increase generating capacity by building two joint-venture projects on the Yalu River, which acts as a common border between the two countries. The China-Korea Hydropower Company is responsible for the development of the projects, Wangjianglou and Chanchuan, which are expected to be operational in 2019.

Xiluodu hydropower project.
Credit: China Three Gorges

Australia saw a flurry of hydropower sector activity in 2017 with the government announcing plans to expand the 4,100 MW Snowy Mountains Scheme. Known as Snowy 2.0, the pumped storage project involves linking two large dams and would act as a giant 2 GW battery. The state-owned Snowy Hydro Limited is seeking financing for the project in 2018 and they hope it will be generating electricity in 2024. With the support of the Australian Renewable Energy Agency, Hydro Tasmania's 'Battery of the Nation' initiative is also advancing with preliminary studies identifying over 4 GW of potential pumped storage across the state. Further pumped storage projects are also being developed in Queensland and South Australia.

Elsewhere in the Pacific, the proposed 20 MW Tina River project in the Solomon Islands received a boost with the Green Climate Fund announcing it would provide USD 86 million towards its development in the form of a low-interest loan and grant contribution.

The project would greatly reduce the country's dependence on imported diesel fuel which has meant it suffers from one of the highest electricity tariffs in the world.

Finally, the Asian Development Bank (ADB) and the Potsdam Institute for Climate Impact Research released a report in 2017 titled 'A Region at Risk: The Human Dimensions of Climate Change in Asia and the Pacific'. The report highlighted the potential impacts of climate change for agriculture, fisheries, security and health, among other sectors. It argued for the rapid decarbonisation of the Asian economy combined with appropriate adaptation measures as the ADB pledged to scale up climate financing to USD 6 billion by 2020 – up from USD 4.5 billion in 2017.

CHINA

As China pivots to renewable energy to reduce its greenhouse emissions and position itself as a major energy exporter, hydropower continues to be the foundation of their energy transition. In 2017, the country added 9.12 GW of installed capacity bringing its total to 341 GW, having also contributed to nearly 20 per cent of the total electricity generated, far outstripping wind (5 per cent) and solar (2 per cent).

Since the turn of the century, China's development of its hydropower resources has been nothing short of remarkable. The country has more than quadrupled its installed capacity and accounted for over half of global hydropower growth, with much of the growth taking place in the country's southwest.

While development has slowed since its most recent peak in 2014 when over 30 GW was commissioned, average annual growth in installed capacity is expected to remain steady at between 3.5 and 4 per cent to 2020 in order to achieve the government's 13th Five-Year Plan target of 380 GW. Notable projects commissioned in 2017 included Changheba (2,600 MW), Houziyan (1,700 MW) and Miaowei (700 MW).

China Three Gorges Corporation (CTG) announced in August 2017 that the 16 GW Baihetan plant commenced construction. Situated on the lower reaches of the Jinsha River along the border between the Sichuan and Yunnan provinces, once complete in 2023 Baihetan will be the second largest in the world in terms of installed capacity behind CTG's 22.5 GW Three Gorges plant.

Pumped hydropower storage is playing an increasingly important role in China's electricity market. It is seen as a key priority of the government in order to support the increasing penetration of both intermittent wind and solar. Installed capacity is set to reach at least 40 GW by 2020 from its current 28.49 GW, and with 60 GW either under construction or in the planning stages, the National Energy Administration expects pumped hydropower capacity to total 90 GW by 2025.

In 2017, 1.8 GW of pumped storage was commissioned including Liyang (1,500 MW) and Shenzhen (300 MW, first unit), while the State Grid Corporation of China announced construction of a further six pumped storage projects. Spread throughout the country, these projects have a combined installed capacity of 8.4 GW and are expected to be fully operational in 2026.

In December 2017, the government announced that the first phase of its long awaited emissions trading scheme (ETS) would focus on the power sector, covering roughly 3.5 billion tonnes of CO_2 – almost double the size of the European Union ETS. The scheme is expected to be up and running in 2019 but, as the government is yet to publish the scheme's targets, it remains unclear what price signal it will send to the sector and how it will impact hydropower as a low-carbon source of electricity.

China is emerging as a leader in green finance as a means to reach its ambitious climate and energy goals. With green bond issuances over USD 37 billion in 2017, this market is expected to be a major source of finance for hydropower into the future, particularly as internationally recognised eligibility standards for green bonds are developed and gain acceptance.

1.4 BILLION
POPULATION

341,190 MW
INSTALLED HYDROPOWER CAPACITY

1,194,500 GWh
HYDROPOWER GENERATION

19.2%
HYDROPOWER SHARE OF ELECTRIC POWER INSTALLED CAPACITY

PAPUA NEW GUINEA

Due to its mountainous terrain and high rainfall in many parts of the country, Papua New Guinea has abundant, although largely untapped, hydropower resources. No detailed studies of hydropower potential have ever been completed although an estimate commonly cited is a technical potential of 15,000 MW.

Given the relatively small population size, low access to electricity, commercial and technical challenges of hydropower, Papua New Guinea today has an installed capacity of less than 250 MW. However this is likely to increase over the coming decade with several projects under development.

Despite many years of economic growth, less than 20 per cent of the country's population is connected to the power grid, which is owned and operated by the national utility company, PNG Power Ltd. The government is working closely with the private sector and international partners to scale up household access having set a goal of 70 per cent by 2030. Hydropower development will be critical to not only improving household electricity access, affordability and grid reliability but also in achieving the government's 2050 vision of a decarbonised power supply.

Hydropower accounts for approximately 40 per cent of Papua New Guinea's installed capacity, with plants operating in each of the country's three main power grids: Port Moresby, Ramu and the Gazelle Peninsula. The remainder is supplied by a mixture of natural gas, geothermal and diesel-fired plants, many of which serve rural communities.

The largest hydropower projects under active development include Naoro-Brown (80 MW), Ramu 2 (240 MW) and Edevu (50 MW). Detailed preparatory work is underway on Naoro-Brown, located northeast of the capital. PNG Power appointed transaction advisers Multiconsult and King & Spalding in 2016 with financial support from the World Bank. Given the size of the project and the need for connecting infrastructure, multiple government agencies were involved in the transaction structuring process which is now complete. The full environmental and social impact study is due in late 2018 after which PNG Power will tender the project to private investors and engineering, procurement and construction partners.

Ramu 2 is slated to be developed under a Public-Private Partnership model with Chinese firms, Shenzen Energy and Sinohydro, but construction has been delayed due to question marks over demand as much of the power was intended to be consumed by a new mine yet to secure necessary investment.

The Edevu project was launched in February 2017 by PNG Power and is being constructed by the Chinese company PNG Hydro Development Ltd, with commissioning expected in 2020. PNG Hydro Development Ltd will also construct the Edevu-Moitaka 132 kV transmission line to transport electricity from the Edevu plant, and eventually from the Naoro-Brown plant to the Central Province.

There are also several rehabilitation works being supported by the Asian Development Bank (ADB). These include the Rouna I (2.5 MW) and Sirinumu plants (1.6 MW) which are part of the Port Moresby Power Grid Development Project. Further rehabilitation works under the Town Electrification Investment Programme will see both the Yonki Toe dam (18 MW) and the Warangoi (10 MW) plants increase their generation and extend their operating life by up to 25 years.

In addition, the ADB is aiding the development of two 3 MW run-of-river projects (Divune and Ramazon) with the aim of both significantly increasing electrification rates and supplanting diesel generation in small rural centres.

Finally, to support the sustainable development of the hydropower sector and given the unique cultural and ecological diversity of Papua New Guinea, the World Bank is funding a study to assess how best to enable the long-term sharing of benefits from hydropower projects among impacted communities.

7.4 MILLION
POPULATION

234 MW
INSTALLED HYDROPOWER CAPACITY

799 GWh
HYDROPOWER GENERATION

40%
HYDROPOWER SHARE OF ELECTRIC POWER INSTALLED CAPACITY

PHILIPPINES

As one of the world's fastest growing economies, having recorded GDP growth of 7 per cent in 2017, the Philippines is seeking to rapidly expand its power generating capacity while minimising costs to consumers, particularly its rising manufacturing industry.

The country's hydropower sector has experienced limited capacity growth in recent years but still accounts for 18 per cent of total installed capacity, and there are significant projects under development.

The Philippine government is juggling with the energy trilemma of balancing energy security, affordability and sustainability. Over the past fifteen years it has introduced several initiatives including Feed-in Tariffs (FiTs) to support the growth of renewables, but its electricity mix is still dominated by fossil fuels namely coal (35% of installed capacity), oil (18%) and gas (15%). Coal is expected to remain the largest single source for the foreseeable future with 500 MW added to the grid last year, as it is still considered to be the cheapest option in many provinces.

The development and trajectory of the country's power sector to 2040 is guided by the 'Philippine Energy Plan' which was published in 2017. The plan outlines that the country's installed capacity will need to increase by some 40 GW to over 60 GW to meet increasing demand.

The share of renewables on the grid is likely to remain more or less constant to 2040 (30-35 per cent) as the plan includes an ambition to expand the installed capacity of renewables to at least 20,000 MW from its current 7,079 MW. Hydropower is expected to make up the lion's share of this growth in renewables with the Department of Energy having most recently approved and awarded over 450 projects totalling 13.5 GW.

In 2017, the 8.5 MW run-of-river Maris Canal plant was commissioned, which was developed by SN Aboitiz Power-Magat Inc (SNAP-Magat), a joint venture of the locally based AboitizPower and the Norwegian SN Power AS. Located in Ambatali village within the province of Isabella, the USD 47 million project took two years to complete and in addition to bolstering the grid, will improve irrigation facilities for the surrounding communities. Maris is SNAP-Magat's first completed project since its acquisition of the 380 MW Magot project back in 2007.

AboitizPower, through its wholly owned subsidiary Hedcor Bukidnon, is also set to commence operations on the 69 MW Manolo Fortich cascade project in 2018. Located in Bukidnon province, it includes two run-of-river plants: 43.4 MW Manolo Fortich 1 and 25.4 MW Manolo Fortich 2.

While much of the hydropower developed over the past decade has been relatively small-scale run-of-river projects aided by FiTs, there are a number of large projects under development including SNAP's 350 MW Alimit project. Situated in Ifugao province, it comprises three plants including a 240 MW pumped storage facility, with a final investment decision expected to be announced in the first half of 2018.

A further large project under development is the 500 MW Wawa pumped storage project in Rizal province. In July last year, the Philippine developer Olympia Violago Water & Power signed an agreement with PowerChina for design, procurement and construction. Expected to cost USD 1 billion, it will greatly contribute to the country's renewable energy ambitions with commissioning planned for 2022.

The government is seeking Official Development Assistance (ODA) finance from China for the rehabilitation of the state-owned 983 MW Agus-Pulangi cascade project which is currently operating at only 60 per cent of its capacity due to ageing infrastructure. The works would cost up to USD 1 billion and once completed would extend its service life by an additional 30 years while also increasing total capacity by an average of 10 per cent for each of the six powerhouses. The government has also expressed a desire to privatise the project once the rehabilitation is completed.

103.5 MILLION
POPULATION

4,312 MW
INSTALLED HYDROPOWER CAPACITY

10,199 GWh
HYDROPOWER GENERATION

18%
HYDROPOWER SHARE OF ELECTRIC POWER INSTALLED CAPACITY

With a 2,400 MW capacity, the Guangzhou pumped storage plant in China is one of the largest in the world. Credit: Voith.

Advancing sustainable hydropower

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

Established in 1995 under the auspices of UNESCO, IHA's membership today includes more than 100 organisations as well individual members.

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.

Sustainability

IHA is a champion of international good practices and continuous improvement. We support project sustainability assessments and training as the management body for the Hydropower Sustainability Assessment Protocol, an internationally recognised framework for assessing performance against environmental, social, technical and economic criteria.

Knowledge building

IHA's knowledge building 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 technical issues covering operations and maintenance, modernisation and sediment management, and have developed tools for dealing with new challenges such as assessing reservoir carbon emissions and building climate resilience.

Recognising that investment in hydropower is essential if the world is to meet global climate targets, we are also working with partners to agree eligibility criteria for green bond financing, and promoting a new preparation facility model to support sustainable hydropower development.

Find out more:

www.hydropower.org

The 78 MW Banja hydropower plant, part of the Devoll project in Albania which will have a total installed capacity of 278 MW when completed in 2019.

Credit: IHA member Statkraft

Download our 2017-18 Activity and Strategy Report:

hydropower.org/activity2018

INSTALLED CAPACITY AND GENERATION 2017

AFRICA

Country	Total installed capacity including pumped storage (MW)	Pumped storage (MW)	Generation (TWh)
Algeria	269	-	0.31
Angola	2,415	-	6.35
Benin	33	-	0.13
Botswana	-	-	-
Burkina Faso	32	-	0.10
Burundi	55	-	0.10
Cote dIvoire	879	-	2.62
Cameroon	761	-	4.60
Cape Verde	-	-	-
Central African Republic	19	-	0.15
Chad	-	-	-
Comoros	-	-	-
Congo	233	-	1.06
Democratic Republic of the Congo	2,593	-	8.63
Djibouti	-	-	-
Egypt	2,844	-	13.41
Equatorial Guinea	128	-	0.12
Eritrea	-	-	-
Ethiopia	3,822	-	8.37
Gabon	331	-	1.54
Gambia	-	-	-
Ghana	1,584	-	8.88
Guinea	368	-	1.36
Guinea-bissau	-	-	-
Kenya	824	-	2.87
Lesotho	72	-	0.49
Liberia	93	-	0.49
Libya	-	-	-
Madagascar	164	-	0.69
Malawi	364	-	1.84
Maldives	-	-	-
Mali	181	-	0.90
Mauritania	49	-	0.24
Mauritius	60	-	0.09
Morocco	1,770	464	3.69
Mozambique	2,191	-	13.70
Namibia	341	-	1.44
Niger	-	-	-
Nigeria	2,062	-	7.31
Reunion	134	-	0.50
Rwanda	105	-	0.37
Sao Tome And Principe	2	-	0.01
Senegal	150	-	0.60
Seychelles	-	-	-
Sierra Leone	64	-	0.15
Somalia	-	-	-
South Africa	3,595	2,912	5.67
South Sudan	-	-	-
Sudan	1,923	-	6.74
Swaziland	60	-	0.26
Tanzania	572	-	2.26
Togo	49	-	0.19
Tunisia	66	-	0.07
Uganda	743	-	3.33
Western Sahara	-	-	-
Yemen	-	-	-
Zambia	2,397	-	13.65
Zimbabwe	941	-	5.77
TOTAL	35,339	3,376	131

SOUTH AND CENTRAL ASIA

Country	Total installed capacity including pumped storage (MW)	Pumped storage (MW)	Generation (TWh)
Afghanistan	461	-	1.37
Armenia	1,249	-	2.30
Azerbaijan	1,122	-	1.87
Bahrain	-	-	-
Bangladesh	230	-	1.07
Bhutan	1,615	-	7.78
Georgia	3,161	-	9.21
India	49,382	4,786	135.54
Iran	11,811	1,040	16.44
Iraq	2,753	240	4.58
Israel	7	-	0.03
Jordan	12	-	0.06
Kazakhstan	2,554	-	11.20
Kuwait	-	-	-
Kyrgyzstan	3,091	-	13.46
Lebanon	221	-	0.58
Nepal	968	-	3.14
Oman	-	-	-
Pakistan	7,477	-	34.06
Qatar	-	-	-
Russia	48,450	1,385	178.90
Saudi Arabia	0.000	-	-
Sri Lanka	1,719	-	2.79
Syria	1,505	-	3.03
Tajikistan	5,190	-	16.37
Turkmenistan	1	-	0.00
United Arab Emirates	-	-	-
Uzbekistan	1,731	-	11.98
TOTAL	144,710	7,451	456

EAST ASIA AND PACIFIC

Country	Total installed capacity including pumped storage (MW)	Pumped storage (MW)	Generation (TWh)
American Samoa	-	-	-
Australia	8,790	1,340	13.65
Brunei	-	-	-
Cambodia	1,367	-	2.40
China	341,190	28,490	1,194.50
Chinese Taipei	4,691	2,602	6.04
Cook Islands	-	-	-
Fiji	125	-	0.47
French Polynesia	47	-	0.22
Guam	-	-	-
Hong Kong	-	-	-
Indonesia	5,314	-	17.28
Japan	49,905	27,637	92.55
Kiribati	-	-	-
Laos	4,984	-	22.70
Macau	-	-	-
Malaysia	6,094	-	17.62
Marshall Islands	-	-	-
Micronesia, Federated States Of	-	-	-
Mongolia	23	-	0.05
Myanmar	3,140	-	9.35
Nauru	-	-	-
New Caledonia	78	-	0.32
New Zealand	5,346	-	24.97
Niue	-	-	-
North Korea	5,000	-	11.83
Papua New Guinea	234	-	0.80
Philippines	4,312	685	10.20
Samoa	12	-	0.03
Singapore	-	-	-
Solomon Islands	-	-	-
South Korea	6,489	4,700	6.99
Thailand	4,510	1,000	8.69
Timor-leste	-	-	-
Tonga	-	-	-
Tuvalu	-	-	-
Vanuatu	-	-	-
Vietnam	16,679	-	59.90
TOTAL	468,331	66,454	1,501

EUROPE

Country	Total installed capacity including pumped storage (MW)	Pumped storage (MW)	Generation (TWh)
Albania	2,020	-	4.53
Andorra	45	-	0.12
Austria	14,130	5,212	38.05
Belarus	97	-	0.30
Belgium	1,427	1,307	0.12
Bosnia and Herzegovina	2,504	420	3.40
Bulgaria	3,129	864	3.03
Croatia	2,141	293	5.43
Cyprus	-	-	-
Czech Republic	2,212	1,147	3.01
Denmark	9	-	0.02
Estonia	8	-	0.03
Faroe Islands	39	-	0.11
Finland	3,236	-	14.63
France	25,517	6,985	53.24
Germany	11,258	6,806	22.68
Gibraltar	-	-	-
Greece	3,396	699	4.04
Greenland	90	-	0.40
Hungary	56	-	0.23
Iceland	1,986	-	13.82
Ireland	529	292	0.89
Italy	21,884	7,555	37.53
Kosovo	68	-	0.18
Latvia	1,576	-	4.35
Liechtenstein	-	-	-
Lithuania	876	760	1.17
Luxembourg	1,330	1,296	1.40
Macedonia	674	-	1.09
Malta	-	-	-
Moldova	76	-	0.37
Monaco	-	-	-
Montenegro	658	-	1.03
Netherlands	37	-	0.06
Norway	31,837	1,392	143.00
Poland	2,353	1,782	2.64
Portugal	7,343	2,613	7.61
Romania	6,717	92	14.54
San Marino	-	-	-
Serbia	2,903	614	9.53
Slovakia	2,522	916	4.71
Slovenia	1,479	180	4.08
Spain	20,344	3,329	20.57
Sweden	16,466	99	63.86
Switzerland	16,922	3,057	36.67
Turkey	27,273	-	59.19
Ukraine	6,785	1,315	12.01
United Kingdom	4,611	2,744	5.17
TOTAL	248,564	51,769	599

SOUTH AMERICA

Country	Total installed capacity including pumped storage (MW)	Pumped storage (MW)	Generation (TWh)
Argentina	11,242	974	41.28
Bolivia	603	-	2.66
Brazil	100,273	30	401.06
Chile	7271	-	21.67
Colombia	11,726	-	54.92
Ecuador	4,409	-	20.09
French Guiana	119	-	0.73
Guyana	1	-	0.00
Paraguay	8,810	-	59.29
Peru	5,385	-	33.40
Suriname	189	-	1.22
Uruguay	1,538	-	7.28
Venezuela	15,393	-	72.09
TOTAL	166,959	1,004	716

NORTH 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	80,985	177	403.35
Cayman Islands	-	-	-
Costa Rica	2,123	-	8.74
Cuba	64	-	0.10
Dominica	6	-	0.03
Dominican Republic	543	-	1.33
El Salvador	472	-	1.74
Grenada	-	-	-
Guadeloupe	10	-	0.02
Guatemala	1,156	-	5.06
Haiti	61	-	0.15
Honduras	558	-	2.59
Jamaica	23	-	0.12
Martinique	-	-	-
Mexico	12,125	-	29.83
Montserrat	-	-	-
Nicaragua	123	-	0.43
Panama	1,777	-	6.52
Puerto Rico	100	-	0.04
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	102,867	22,809	322.39
Virgin Islands, British	-	-	-
Virgin Islands, U.S.	-	-	-
TOTAL	203,053	22,986	783

WORLD

	Total installed capacity including pumped storage (MW)	Pumped storage (MW)	Generation (TWh)
TOTAL	1,266,955	153,041	4,185

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With the theme of 'The Power of Water in a Sustainable, Interconnected World', the Congress will focus attention on hydropower's role in delivering on the Paris Climate Agreement and the Sustainable Development Goals.

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Latest information on the programme and speakers will be announced at hydropower.org/congress.

Contact us at congress@hydropower.org for early registration and to participate in preparatory meetings.

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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.