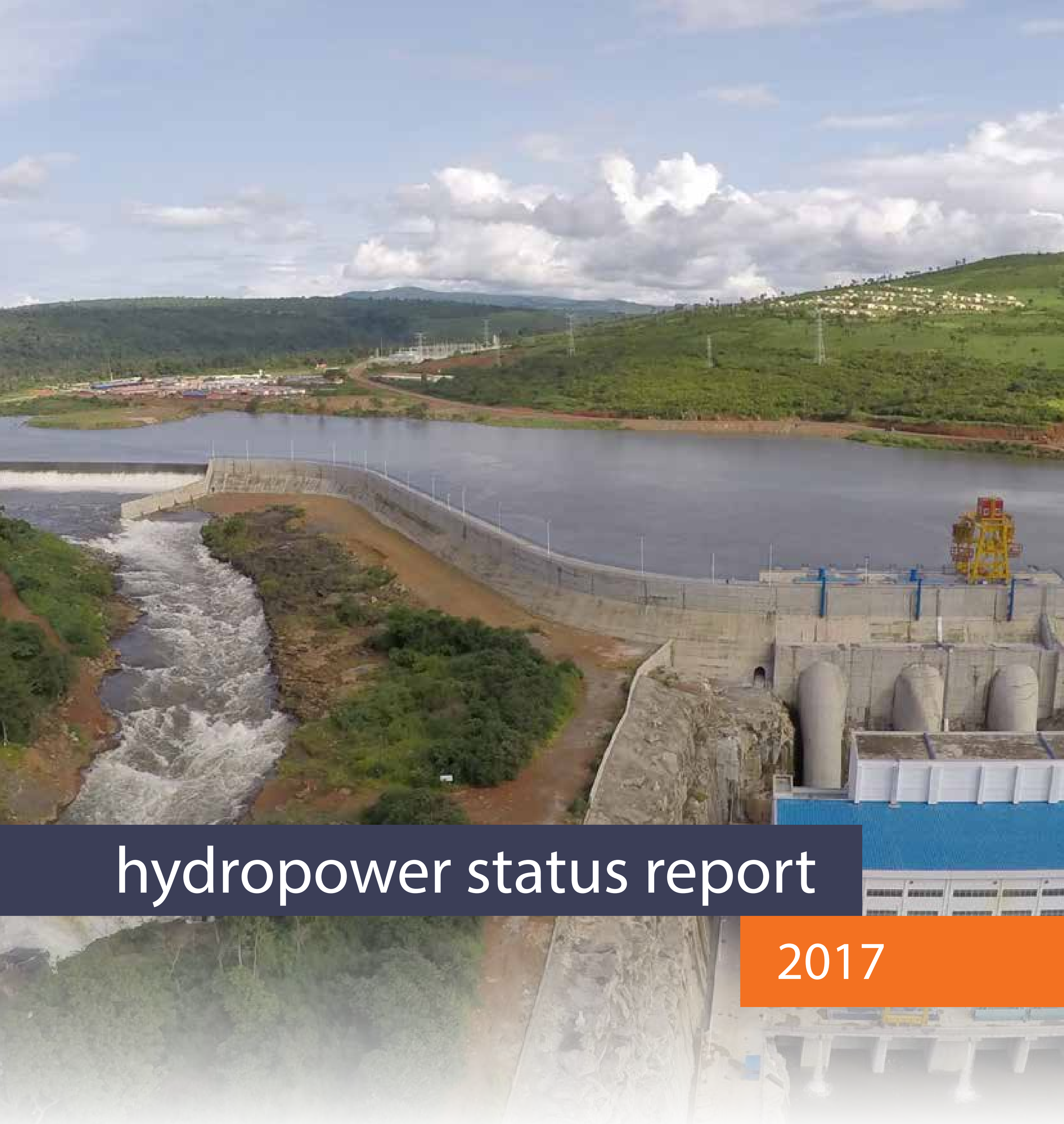

hydropower status report

2017

international hydropower association

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Printed using vegetable-based inks on FSC-certified paper.

In memory of Lorna Charles, our friend and colleague.

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Methodology

Statistics are compiled by IHA using data from published sources, IHA members, government representatives, industry sources and media monitoring. The data is regularly 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 needed.

IHA's database houses data for all sizes of hydropower assets, in all locations and of all types.

Conversely, IHA is working to separate out hydropower generation derived by pumping, in spite of combined reporting from various sources.

For hydropower generation, statistics are a combination of official government reports and IHA estimates based on averaged capacity factors.

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FOREWORD

The *2017 Hydropower Status Report*: an insight into recent hydropower development and sector trends around the world.

It is my pleasure to introduce the *2017 Hydropower Status Report*: our flagship annual publication that shines a light on hydropower development activity around the world, and the most significant current trends in the sector.

We publish this report following a year of steady worldwide growth in hydropower development, with 31.5 GW new capacity installed. This figure includes 6.4 GW of pumped storage – nearly double the previous year – while there is a further 20 GW of pumped storage under construction globally. This is indicative of hydropower's increasingly important role in providing flexible support to renewable energy systems, as countries around the world take steps to meet the carbon reduction goals of the Paris Agreement.

A striking example of this trend can be seen in China's 13th five-year plan for energy development, launched last year and covering the period to 2020. Having implemented the necessary policy frameworks, China now aims to reach a 40 GW total pumped storage capacity by 2020 to balance the huge volume of solar and wind power coming online. Progress is well under way, with 3.7 GW of pumped storage commissioned in China in 2016 across three new projects.

In a world facing complex water and energy challenges and rapid population growth, the multiple benefits that hydropower can offer are needed more today than ever before. Furthermore, a large proportion of the world's untapped hydropower resources are located in regions where new development has the greatest potential to positively affect people's lives. However, many barriers to progress in developing countries remain, in particular at the preparation phase of projects where it is crucial to ensure they are built in a sustainable way and in the right place.

Project preparation is key to success, and it could be done in a cost- and risk-efficient way through innovative mechanisms. We are working with international financial institutions to initiate the establishment of support facilities, which could manage a revolving fund to assist in the selection of appropriate project types and locations according to the local or regional needs. The initiative could help catalyse responsible development in the regions where it is most needed by advancing projects that are built to the highest sustainability standards, and aligned with the energy and water systems to which they contribute.

We launch this report at the 2017 World Hydropower Congress, hosted in Africa for the first time at the United Nations Conference Centre in Addis Ababa. The event is unique in providing a high-level platform for dialogue among all parties interested in hydropower, and I hope this analysis can provide a stimulating backdrop for the discussions that will take place in Addis, and continue in the weeks and months to come.

The statistics that underpin this report are driven by the International Hydropower Association's global database of hydropower stations and companies, a product of our collaboration with regulators, ministries, power associations, and station owners and operators. Furthermore, our international outreach, year-round media monitoring and annual sector survey provide the basis for the in-depth topic analysis and country profiles. The report has also benefited greatly from contributions and reviews provided by our community of members and partners around the world.

We would like to thank everyone who contributed to the production of the *2017 Hydropower Status Report*, and I invite everyone reading to join the international network that is IHA.

Richard Taylor
Chief executive

31.5 GW
of new installed capacity in 2016 (including pumped storage)

1,246 GW
global hydropower capacity (including pumped storage)

4,102 GWh
estimated worldwide generation by hydropower in 2016

EXECUTIVE SUMMARY

In 2016, hydropower development continued a steady growth trend, driven by a demand for reliable, clean and affordable power as countries seek to meet the carbon reduction goals set out in the Paris Agreement.

DURING 2016

- Total hydropower generation for the year is estimated at 4,102 TWh, the greatest ever contribution from a renewable source
- An estimated 31.5 GW of hydropower capacity was put into operation, including pumped storage, bringing the world's total installed capacity to 1,246 GW
- 6.4 GW of pumped storage capacity came online, nearly twice the amount installed in 2015
- China once again led the market for new development, adding 11.7 GW of new capacity, including 3.7 GW of pumped storage
- Other countries leading in new deployments include Ecuador (2 GW), Ethiopia (1.5 GW), South Africa (1.3 GW), Vietnam (1.1 GW), Peru (1 GW) and Switzerland (1 GW).

Key trends and noteworthy developments

Initiatives are being established to manage the risk profile of hydropower

With an ever-increasing focus on ensuring that projects are built in the right way and in the right place, utilising all its multiple benefits, momentum is building for the establishment of a support facility for hydropower project preparation. Such a facility would optimise private sector engagement by managing a revolving fund to support the selection of the most appropriate project type and location according to the local or regional context.

This approach could help ensure projects are built to the highest environmental standards and are compatible with the goals of the Paris Agreement, and would allow developers access to the growing green bond market, which nearly doubled in value in 2016, reaching a record USD 81 billion in issuances.

Renewables are working together to support grid stability

Innovative projects coupling renewable technologies are providing firm, stable power to the grid, while increasing efficiencies and creating net benefits. Floating photovoltaics on reservoirs are under construction in all regions. Utilising existing infrastructure, 'floatovoltaics' also have increased efficiencies due to more stable temperature regimes.

Also, floating PV panels on hydropower reservoirs can help reduce water losses due to evaporation. Pilot projects began in Brazil, while India announced plans for 600 MW project on the Koyna reservoir. The USA began operations at the world's first geothermal–hydropower hybrid project, where a hydropower turbine was added to the injection well, resulting in reduced operational costs and well safety.

The role of pumped storage is serving global energy storage requirements

Remaining the most practical form of electricity storage available on a large scale and at a competitive cost, pumped-storage systems continue to grow, adding 6.4 GW in 2016. Pumped-storage technologies are also evolving with our changing systems. In terms of quality of supply, an innovative wind-hydro hybrid pumped-storage system began construction at the German Naturspeicher project. Vessels at the base of the wind turbines act as upper reservoirs of a pumped-storage system. Wind turbine heights are increased, harnessing stronger winds, and the pumped-storage technology regulates frequency variations from fluctuations in wind. Meanwhile, pumped-storage projects are being developed for small-grid systems in Hawaii and on the island of Gran Canaria.

Ultra-high voltage transmission is connecting hydropower to markets

The concept of 'global energy interconnection' has emerged as one the latest trends towards developing major interconnections to enable the massive growth in renewable technologies to meet global energy demand and increase reliability. Discussions are under way among major energy companies in China, Japan, Russia and South Korea on the creation of an 'Asian Super Grid', in which an ultra-high-voltage grid would interconnect the region to transmit electricity generated from an abundance of clean, renewable sources like hydro.

In other parts of the world, such as in Canada, the predominantly hydro-based systems are increasing their already strong interconnections with the neighbouring grids of the US Midwest. Utilities like Manitoba Hydro can utilise their hydropower reservoirs to balance the output of major windfarm developments to the south, while enabling bilateral trade opportunities for export and providing import capability for reliability in low-water conditions.

New priorities are emerging on smart modernisation and digitisation of assets

Asset management is becoming more challenging across the sector as a growing number of assets are reaching the end of their expected life. By 2050, it is estimated that roughly half of the entire fleet of existing hydropower equipment will have undergone modernisation.

The digitisation of hydropower plants, control systems and surrounding networks is an emerging industry trend that promises to optimise asset management and performance. For example, the digitisation of hydropower systems is increasingly being implemented to allow hydro to work together with other renewable resources to provide increased flexibility and enhanced control for ancillary services (frequency control, balancing services, etc). Other digital innovations include cybersecurity, plant and fleet optimisation, outage management, condition monitoring equipment and energy forecasting. Together, these innovations are providing hydropower asset owners with actionable insights from data to increase the value of hydropower assets.

Reporting mechanisms for hydro's carbon footprint are advancing

An international research initiative has developed a framework for calculating the net greenhouse gas (GHG) emissions of freshwater reservoirs. To accurately account for hydropower's carbon footprint, pre-impoundment emissions specific to each reservoir will now be considered, as well as the multiple services provided by the reservoir. As investors and lenders are currently seeking to further refine guidelines on eligibility criteria for hydropower, there is an increasing obligation for the sector to report on its carbon footprint.

The new conceptual approach has led to the development of the *G-res* tool which will provide estimates of net GHG emissions from planned and existing reservoirs, contributing a much more consistent estimate of hydropower's GHG footprint, while establishing hydropower projects on a level playing field with other renewable energy resources for access to premium markets and green investments.

Tools for reporting on sustainability performance are diversifying

The Hydropower Sustainability Assessment Protocol has become broadly recognised as the primary tool for evaluating sustainability performance, having been implemented worldwide. The range in the tool's application has grown, from full assessments through to guided internal assessments that are playing a strong role in building internal capacity. New initiatives such as green and climate bonds are increasingly recognising the protocol.

For example, the Barclays MSCI Green Bond Index lists a published protocol assessment meeting 'basic good practice' in its eligibility criteria, while the Climate Bonds Initiative is working with multiple stakeholders to develop its own eligibility criteria. This evolution in protocol use has indicated the need to develop complementary derivatives to enable practical application while protecting the strong quality control elements of the tool. Two priorities are an environmental and social derivative, and *International Industry Good Practice Guidelines*.

Financing institutions are placing greater emphasis on climate resilience

Financing institutions are seeking to address climate-related risk by ensuring projects are planned and operated to be resilient to climate change. Resilience and adaptation measures must be communicated clearly to investors. The World Bank has launched a study to develop guidelines for designing resilient projects, where possible enabling them to take advantage of opportunities arising from climate change. These would ensure projects are safe and reliable, and can provide adaptation services to incentivise policy and investment. The World Bank recently convened sector experts to outline a vision for these guidelines, where it was agreed they should cover practical risk assessment and mitigation, and be recognised by investors and multilateral organisations. One of the Climate Bonds Initiative's eligibility criteria for financing hydro projects now requires consideration of measure relating to climate resilience. Guidelines are set to become increasingly important in the sector.

REGIONAL TRENDS IN BRIEF

North and Central America

- 1,051 MW added in 2016.
- Transmission projects under development include a 1,000 MW line from the Canadian border to New York City, expected to be in service by 2021, and an 833 MW line linking Manitoba and Minnesota.
- Canada commissioned several projects, while Romaine 3 (395 MW) in Quebec is expected to come online in 2017.
- Costa Rica commissioned the 306 MW Reventazón hydropower plant, one of the largest public infrastructure projects in Central America.

Read more on pages 36–41

South America

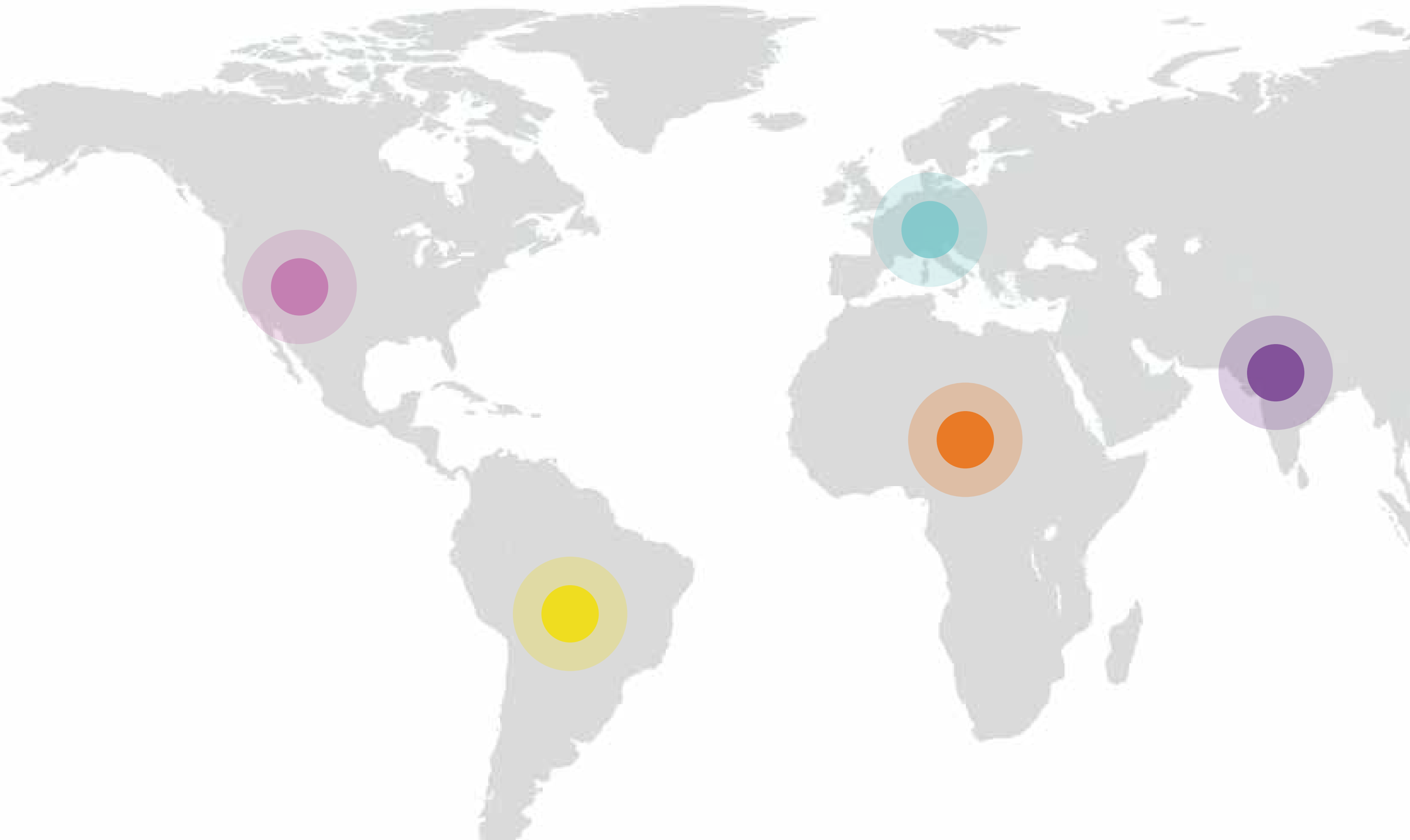
- 9,738 MW added in 2016, including 6,365 MW in Brazil.
- Brazil completed the commissioning of the 3,750 MW Jirau project on the Madeira River.
- Ecuador's 1,500 MW Coca Coda Sinclair plant went into full operation in November 2016.
- Peru commissioned the Cerro de Águila (510 MW) and Chaglla (456 MW) projects.
- Chile launched an online platform to publish information from the study of hydro potential of several river basins.

Read more on pages 42–49

Africa

- 3,413 MW added in 2016.
- Ethiopia commissioned the final eight turbines of the 1,870 MW Gibe III project.
- In South Africa, the 1,332 MW Ingula pumped storage project came online.
- The Cameroon Government confirmed EDF and IFC's support for the 420 MW Nachtigal hydro plant on the Sanaga River, due for completion in 2021.
- As part of the Eastern African Power Pool, Rwanda is scheduled to begin importing 400 MW of power from Ethiopia and 30 MW from Kenya by the end of 2017.

Read more on pages 50–57



Europe

- 1,810 MW added in 2016, including Switzerland's 1,000 MW Linthal pumped storage project.
- An estimated 2,500 MW of pumped storage capacity is planned or under construction, mostly concentrated in France and Spain.
- The European Union commissioned a regional hydropower master-plan for the Western Balkans.
- The UK's Swansea Bay Tidal Lagoon (320 MW) is advancing and could come online in 2021.

Read more on pages 58–63

South and Central Asia

- 1,315 MW added in 2016.
- The Indian Government began discussions to extend the scope of renewable energy to include hydro stations with capacities over 25 MW.
- In Tajikistan, construction is under way at the 3,600 MW Rogun dam, set to be one of the world's tallest at 335 m.
- Russia commissioned the 30.6 MW Zaragizhskaya and 140 MW Zelenchukskaya hydropower plants.
- The World Bank has provided funds to repair the Mosul dam in Iraq, which is facing some potentially devastating structural problems.

Read more on pages 64–69

East Asia and Pacific

- 14,154 MW added in 2016, 83 per cent of which was in China, bringing the country's total installed hydropower capacity to an estimated 331,110 MW.
- China published its 13th five-year plan on energy development, covering the period to 2020, with a strong emphasis on developing pumped storage.
- In Laos, the first phase of the 1,272 MW Nam Ou cascade project, including dams 2, 5 and 6 totalling 540 MW in capacity, was completed.
- The final two 400 MW turbines were commissioned at the 1,200 MW Lau Châu plant in Vietnam.
- Japan is set to have its first commercial-scale tidal power plant in its waters in 2018.

Read more on pages 70–77

In the last year we have seen markets for pumped storage continue to grow. Over 6 GW was installed in 2016, almost double the previous year, signifying its vital role in supporting and enabling renewable energy in future clean energy systems.

CLIMATE RESILIENCE GUIDELINES FOR HYDROPOWER

The International Hydropower Association (IHA) carried out a survey of more than 50 organisations involved in the hydropower sector to give feedback on perceptions of climate risk and resilience and to share their insight on the actions their companies are taking to address those risks. Almost all of the respondents (98 per cent) agreed that impacts of climate change are already being felt by their organisation or will be felt within the next 30 years, while 82 per cent pointed out that sector guidelines on this topic would be useful.

Respondents also pointed out that climate change can bring opportunities for their organisation. For example, in watersheds fed largely by glacial melt, climate change is expected to increase seasonal inflows, whereas in watersheds fed by glaciers that have already lost significant mass, flow rates may change in quantity and intensity.

Landsvirkjun, the National Power Company of Iceland, has become a pioneer in adapting to climate change by modifying not only the management of its hydropower plants, but also the design of its assets. Together with other power companies, universities and meteorological services across Scandinavia, Landsvirkjun has produced data on river flows that incorporates climate trends. Every five years the company will issue new revised flows and use the data to adjust its reservoir management plans. Landsvirkjun also uses the long-term perspective provided by climate modelling to design and adjust existing and proposed new projects to take advantage of anticipated increases in flow rates.

To address the risks to the hydropower sector, associated with climate change, the World Bank has launched an initiative to produce a set of climate resilience guidelines which aim to ensure that both existing and future hydropower projects are resilient to climate change. While hydropower has a long tradition of dealing with climate variability, project developers and financial institutions currently lack guidance on appropriate methods for incorporating climate resilience measures into project design and appraisal, to ensure hydropower projects are resilient in the face of the uncertainty of future climate change and natural disasters.

There is a need to communicate climate resilience and adaptation measures to investors in a simple and clear manner. The World Bank has identified this need, and is working together with IHA and other key stakeholders to develop a set of guidelines that will ensure projects are resilient and, where possible, designed to take best advantage of any opportunities created by the direct impacts of climate change.

The World Bank and its key stakeholders met in both 2016 and 2017 to develop collaboratively the scope and schedule of delivery for these guidelines. A broad cross-section of international stakeholders, including representatives from the hydropower sector, project developers and international financial institutions, reiterated the importance and urgency of this work. They established a goal of creating a set of guidelines that the industry supports as a whole and that can provide a framework for reporting on climate resilience. As an example of the urgent need for these guidelines, one element of the eligibility criteria for the Climate Bonds Initiative for financing hydropower projects will require a measure of climate resilience for candidate projects.

Objectives

The objective of this initiative is to develop a tool that provides practical guidelines on the goals, objectives, analyses and recommendations needed to achieve climate resilience in the planning, design, construction and operation of hydro projects. This will also include the assessment of operational performance, rehabilitation and upgrades of existing assets. The guidelines will provide a roadmap connecting upstream analytical climate change work and downstream resilience engineering work.

Building on the work the World Bank has done in developing the 'decision tree framework' for identifying and managing climate risks, the guidelines will follow an iterative and sequential approach as described here:

- A first phase 'project screening' pre-feasibility study will be carried out, investigating if a proposed project is climate sensitive, and leading to an obligation to provide evidence proving the case.

- During the second phase, a feasibility study will be carried out measuring if climate is a dominant factor for the project. In this stage, non-climatic factors will also be considered.
- In the third phase a 'climate stress analysis' will examine plausible climate risks and, where applicable, more detailed hydrological and climate system modelling can be undertaken.
- In the final phase, 'climate risk management', the project will be evaluated to determine if it is robust and can cope with the potential changes in the system.

The path forward

Further consultation and testing with Mott MacDonald, the lead consultant for the project led by the World Bank, is ongoing with a goal of producing an initial draft of the guidelines by May 2017, concurrent with a workshop at the 2017 World Hydropower Congress in Addis Ababa, Ethiopia. Thereafter, final dissemination of the guidelines will take place at the ICOLD 2017 Annual Meeting in Prague in July.

IHA will play a coordination role by connecting the lead consultant with a community of users from the developing world, who can contribute in testing the initial version of the guidelines. In parallel, IHA will assist in engagement with leading practitioners and operators who have experience in climate resilience design for their projects, and will provide useful case stories for the initiative.

The Búrfell hydropower plant in Iceland, owned and operated by Landsvirkjun, is being expanded to cope with expected increases in flow rates

NEW REPORTING MECHANISM FOR HYDROPOWER'S CARBON FOOTPRINT

Mitigating climate change is one of the most important goals for strategic sustainable development. The reduction of greenhouse gas (GHG) emissions is the focus of a number of international targets and agreements such as the recently ratified Paris Agreement, which seeks significant emissions reductions in order to limit global average temperature increases to well below 2 °C.

GHG emissions since the industrial revolution have largely been driven by economic and population growth. As a result, the atmospheric and ocean temperatures have risen. Climate change impacts, such as the increased frequency and intensity of extreme weather events, can pose significant and irreversible adverse effects to human and environmental health.

There is therefore a clear and pressing need to quantify the GHG footprint of human activities. The footprint of hydro, especially emissions due to the development of storage reservoirs, has long been questioned in both scientific and policy spheres.

There has, however, been a lack of scientific consensus on how to quantify hydropower's GHG footprint, and this uncertainty has proven to be a significant obstacle for policy and decision makers, especially regarding the potential financing of projects and the designation of 'sustainable' or 'climate-friendly' labels to certain projects.

A consortium of researchers from around the world is introducing new conceptual thinking around the assessment of the GHG footprint of reservoirs. In essence, this new approach seeks to account for only landscape changes that result in a net change, either positive or negative, in GHG emissions. The approach has also led to the development of a new model and online tool that allows users to estimate GHG emissions from reservoir formation. This is the outcome of the multi-year UNESCO and IHA joint research project, which began in 2008.

Until only recently, estimates of the GHG footprint of reservoirs have typically been assessed by applying average numbers, which reflect a subset of empirical measurements which are then extrapolated to other reservoir types deemed comparable. These methodologies often considered all surface GHG emissions, and made no distinction between pre-existing and new emissions pathways to the atmosphere.

The new conceptual approach takes a net approach, and even goes further to look at the changing dynamic biochemical structures and pathways that reservoir impoundment creates. The approach thus takes into account:

- the GHG footprint of the affected landscape prior to impoundment. This includes a new reservoir's upstream catchment area, the reservoir itself as well as the downstream area;
- the specific and particular environmental conditions of each reservoir. Environmental conditions include the reservoir's climate and geographic characteristics, as well as particular soil and water conditions and quality;
- the temporal evolution of GHG emissions over the entire lifetime of the reservoir;
- emissions that would have occurred elsewhere in the natural system regardless of the presence of the reservoir; and
- emissions that are the result of nutrients and organic matter released by human activity to the water bodies upstream of or within the reservoir itself. This is termed 'unrelated anthropogenic emissions', and encompasses wastewater from settlements, industry, agriculture or fish farming.

In summary, this new approach indicates that on average, 75 per cent of carbon dioxide emissions observed on reservoir surfaces should be considered natural, i.e. they would have occurred even if the reservoir did not exist. On the other hand, the majority of net GHG emissions to the atmosphere are the result of an increase in methane emissions, a gas with a much higher greenhouse effect than carbon dioxide. Methane emissions are tightly linked to the environmental characteristics of the reservoir.

The development of the *G-res* tool builds upon this new conceptual framework. In order to comprehensively estimate the GHG footprint of reservoir formation, the *G-res* tool also includes an estimation of the emissions due to the construction of the reservoir, mainly from dam building. Thus, the net GHG emission from reservoir formation can be expressed as:

Net GHG emissions =
[Post-impoundment GHG balance]
– [Pre-impoundment GHG balance]
– [Emissions from the reservoir due to unrelated anthropogenic sources]
+ [GHG due to construction]

Greenhouse gas measurements being undertaken on a reservoir in Quebec, Canada

Finally, the *G-res* tool allocates emissions to the various purposes of the reservoir. Many reservoirs serve multiple purposes, including water supply, irrigation, hydropower, flood control, environmental management and pollution control. Reservoirs facilitate other activities such as navigation, fisheries and recreation, and also provide surface areas for other forms of energy generation such as floating solar PV.

Even in reservoirs that include hydropower as a purpose, a reservoir can provide baseload power or provide grid support through peaking storage or other ancillary services. The *G-res* tool allocates GHG emissions to the various uses of the reservoir. This highlights why recognising the importance of reservoirs for both sustainable energy and sustainable water systems is crucial. By recognising the different services offered by reservoir creation, the tool allows for improved GHG accounting of the related human activities.

The *G-res* tool could have a significant impact on the decision-making process around new freshwater reservoirs. Until recently, inland waters were considered a negligible component of the global carbon cycle, but recent research has identified that rivers and streams are hotspots in the carbon cycle for GHG emissions. Inland waters have a GHG flux to the atmosphere similar in magnitude to that absorbed by oceans or terrestrial land. Given the global importance of natural systems, it can be expected that man-made inland waters will come under increased scrutiny.

The *G-res* tool seeks to address this by enabling the estimation of the global GHG footprint of reservoirs and for hydropower. Its development coincides with the revision of GHG reporting criteria by the IPCC, which will be published in 2019.

In addition, new sustainability and environmental criteria are currently being developed for the provision of green bonds and other forms of climate finance. Using the new conceptual approach, a more accurate GHG profile of reservoir formation can be included. As a result, GHG reporting on existing assets, or for decision-making on site selection for new projects, can put hydropower projects on a level playing field with other renewable energy resources for access to premium markets and 'green' investments.

GREEN BONDS FOR HYDROPOWER FINANCING

The Paris Agreement reached in December 2015 was hailed by many as a turning point in the fight against climate change. The agreement sets the target of limiting global warming to well below 2 ˚C compared to pre-industrial levels. The challenge now is to turn the rhetoric into operational reality. It will require the mobilisation and alignment of the world's financial markets to drive the significant investment needed in low-carbon and climate-resilient infrastructure.

This presents new and innovative funding sources for hydropower project financing; however, such opportunities will only be grasped with continued sector engagement shaping their development.

An emerging success story is the rapid growth of green bonds. These are fixed-income loans created to specifically finance projects that help address and reduce environmental and/or climate risks. Over USD 80 billion of labelled green bonds were issued in 2016, nearly doubling the previous year, but the market is still in its infancy.

According to the investor-focused not-for-profit Climate Bonds Initiative (CBI), the green bond market will need to reach USD 1 trillion of investment per year by 2020 to be compatible with the Paris Agreement. While initially led by multilateral development banks and the corporate sector, Poland became the first country to issue a green sovereign bond in late 2016, raising USD 750 million. This was followed by France in January 2017, raising USD 7.5 billion. Other countries including Sweden, Nigeria and Kenya are expected to quickly follow suit.

Challenges for the hydropower sector

As a mature renewable technology, hydropower has already benefited from a third of the USD 130 billion energy-related unlabelled green bonds issued to date, as compiled by the CBI, led by large issuances from the likes of Hydro-Québec. This figure only gives part of the picture though, as it excludes bond issuances involving large hydropower plants (deemed as greater than 20 MW) located in tropical zones. This is due to concerns over methane emissions, which has brought into question their green credentials.

Such concerns have unfortunately contributed to a binary approach of 'small hydro is good, large hydro is bad'. This, however, fails to recognise that hydropower projects, unlike most other forms of energy sources, are unique, with site-specific characteristics. It also excludes the wider benefits that multipurpose reservoirs provide, such as using their storage capabilities to contribute to even higher levels of mitigation through the provision of firming capacity for other forms of renewable energy. Furthermore, hydropower projects offer the ability to strengthen resilience and adaptation services through appropriate water management.

We are already seeing negative outcomes play out, with a number of green bond issuances excluding all large hydropower investment. Among these is Poland's green sovereign bond, which excludes projects greater than 20 MW, presenting these alongside coal, natural gas and palm oil.

This poses a significant challenge for hydropower's future involvement in the market, and highlights the importance of the sector being heavily engaged with those organisations seeking to assess and develop criteria that certify its climate compatibility. In an effort to prevent 'greenwashing' as the market develops, these standards will become more harmonised and integrated into how green bond issuances are structured and promoted.

In June 2016, the CBI launched the Hydropower Technical Working Group to begin the process of developing the criteria for the screening of climate-compatible hydropower.

Developing criteria for hydropower

Bringing together a host of experts from NGOs, government and academia, the working group is taking a robust science-based approach to developing the criteria. The working group is drawing on the substantial work that the Hydropower Sustainability Assessment Protocol has undertaken in developing international good practice guidelines for the sector in promoting sustainable hydropower projects. Reliably estimating reservoir emissions allocated to hydropower is another complex task, which is being guided by the *G-res* tool. The tool was developed by UNESCO in conjunction with IHA and several research institutes worldwide.

The working group is looking to establish a simple and transparent climate mitigation screening process that could first apply a power density threshold (W/m^2 reservoir surface area) for prospective projects. If required, projects would then have to comply with an emissions threshold (gCO_2/kWh) using the *G-res* tool, which would take into account the multiple uses of many reservoirs. In certain circumstances further site-specific testing could be undertaken when projects do not meet these criteria.

In addition, the CBI's criteria will address climate resilience through a set of measures to be incorporated into the development of hydropower projects. This is being informed by work the World Bank is undertaking to develop guidelines for designing resilient projects that are safe, reliable and can also provide adaptation services. Finally, by incorporating aspects of the protocol, the group is developing criteria to ensure that projects demonstrate a strong appreciation of key non-climate-related environmental and social impacts.

The draft eligibility criteria are expected to be released in mid-2017 for public consultation. The working group will revisit the criteria following feedback from industry and other stakeholders. The Climate Bond Standards Board will then review the criteria before they can be used by the market.

Hydropower has a significant role to play in achieving the goals of the Paris Agreement. Supporting the growth of the green bonds market is an important step towards aligning emission reduction targets with appropriate market signals and incentives.

Climate finance was a key topic of discussion at COP22, the United Nations clmate change conference in Marrakech, Morocco, November 2016

ELECTRICITY STORAGE: A CHANGING LANDSCAPE

The rapid growth of variable renewable energies (VRE) such as wind power and solar PV in recent years is increasing the need for rapid-response energy storage technologies. The landscape for grid-scale energy storage is evolving from being almost exclusively supplied by pumped-hydropower storage to include a number of new technologies. Of these, battery storage is evolving and growing at a rapid pace, even as pumped hydropower storage continues to supply over 95 per cent of energy storage requirements worldwide.

It is widely recognised that the transition towards cleaner and more sustainable energy systems will require a significant increase in power system flexibility. Flexibility in this context refers to the ability of a power system to maintain a reliable and continuous service when faced with potentially rapid changes in supply or demand. Augmenting power system flexibility can be achieved by a variety of options, including: supply-side improvements, demand-side management, increased transmission networks, increasing system efficiencies and the provision of added energy storage. This article focuses on energy storage and explores the different but potentially complementary roles of emerging utility-scale battery storage systems (BSS) and more established pumped hydropower storage systems (PHS).

In the traditionally fossil-fuel dominated power systems, flexibility has been almost solely controlled by the supply side. The existing fleet of power stations is operated to react to variations in demand. Baseload power is typically supplied by run-of-river hydro, coal and nuclear, which are encouraged by virtue of their technical and economic nature to have continuous operation. Rapidly-responding generation such as hydropower with storage capacity and gas- or oil-fired power plants are capable of meeting load variations at sub-hourly, hourly, daily and seasonal scales. Some capacity is kept in reserve in case a power station or transmission line unexpectedly goes offline. Thus, non-baseload stations require quick responses, which is often provided by plants that are online but working below their full potential. This allows for a quick response, but decreases the efficiency of the entire system, which inevitably increases the overall system cost of operation.

Increasing the proportion of VREs inherently reduces the flexibility of a power system. High penetration of VREs into an existing energy system will in effect will introduce more variability on the supply side, while also displacing existing flexible technologies. Electricity storage technologies act as both supply and demand in the system, adding flexibility, and so have the potential to increase the system's overall efficiency and reduce overall costs.

Currently, PHS remains the primary technology used to provide energy storage services on the grid scale. PHS first saw commercial use in the early 20th century and experienced a surge in new capacity beginning in the 1970s and 1980s as a reaction to energy security concerns, and to balance baseload power produced from nuclear and coal-fired power plants. At that time, PHS allowed for the constant and efficient baseload generation, typically absorbing excess power at night and feeding it back to the grid during peak daytime hours.

However, as growth in nuclear has stagnated, and more and more variable renewables are connected to power grids, the shifts in supply and demand are becoming more dynamic in magnitude and time. Solar power available during daytime can vary subject to cloud cover and rainfall, while fluctuations in wind speeds throughout the day can create more supply-side fluctuations. While traditional pumped storage systems were used to 'time-shift' electricity production to optimise power production, i.e. charging (pumping) at night when excess low-cost electricity was available and generating during the peak hours, storage systems may now be required to cycle multiple times in a day, or remain offline for long periods, depending on weather conditions.

Thus, the landscape for energy storage is changing with each added megawatt of solar and wind, allowing alternatives to pumped storage to enter the market. According to the Global Energy Storage Database, traditional PHS-dominated storage systems have mainly been used for time-shifting (arbitrage) of electric energy (85.2 per cent), to take advantage of pricing differentials between on-peak and off-peak periods. As variable renewables reduce opportunities for arbitrage, new technologies are fast emerging, offering an increased range of flexibility applications aimed at integrating variable renewables into the system.

PHS systems are evolving to provide additional operating flexibility to balance fluctuations in the system. In traditional PHS, power regulation is only available when generating, however, variable-speed PHS systems are being implemented to increase plant efficiency and flexibility by allowing for power regulation in both pumping and turbine mode. Ternary systems, consisting of a motor-generator and separate pump and turbine set, can allow for simultaneous pumping and generating, which allows for even finer frequency control.

Battery storage systems (BSS) are currently one of the fastest-growing electricity storage technologies, and are now capable of providing both off-grid and grid-scale storage. The proportion of total installed battery capacity at nearly 2 GW at the end of 2016 is still far less than the total pumped storage capacity, currently at around 150 GW.

From a technological perspective, batteries are a mature technology; however, significant cost barriers continue to impede the full integration of BSS into the power sector. BSS and PHS systems essentially operate in the same manner. BSS, however, have faster response times, but typically cannot sustain that power output for extended periods of time.

This means that BSS are well suited to managing power quality. In addition, BSS do not have the same site-specific requirements as PHS, allowing them, for example, to couple with variable renewable technologies at source and mitigate fluctuations before power is sent to the grid.

Hybrid systems have been developed in many locations where PHS facilities are operated jointly with VRE systems to balance the intermittency of the variable generation source directly though the operation of the PHS plant. For grids with very weak interconnections, or isolated grids, such as island systems, such fluctuations could be much more damaging. This service is particularly suited to batteries given the need for rapid, quick charging and discharging.

BSS are emerging as an increasingly important large-scale storage option and have grown exponentially over the past ten years. One of the key drivers of this growth has been its rapidly decreasing costs and favourable policy settings, potentially mimicking the rapid growth seen in the solar PV industry. According to the International Renewable Energy Agency (IRENA), it is estimated that prices will continue to fall rapidly until 2030, with cost declines of 50 per cent or more to be expected for most battery technologies. Most of the cost reductions are expected to be driven by rapidly growing economies of scale, and innovations that reduce costs and further increase performance. IRENA will release a report examining the market and cost outlook for battery storage technologies to 2030 later in 2017 exploring these issues in detail.

At the same time, the growing use of electric vehicles represents a potential additional source of flexibility with the right market arrangements, as their on-board batteries could be used by the grid. Although not their primary role, the scale of their deployment means they could become an importance source of flexibility. The global electric vehicle fleet reached a total size of 1.2 million vehicles (including both battery electric vehicles and plug-in hybrid vehicles), with an estimated total battery capacity of 20–40 GWh, and a total electricity demand of 2.5 TWh in 2015.

There is little doubt that both pumped hydropower storage and battery storage will play a fundamental role in future energy systems. As more battery technologies are developed and variable-speed PHS technology becomes more advanced and affordable, both forms of energy storage can be utilised optimally to meet the ever-growing need for energy storage. The changing characteristics of power systems, brought about by growing VREs, provides new opportunities for electricity storage technologies, which by their own part can also play a significant role in restructuring current energy systems. In its *Roadmap for a Renewable Energy Future*, IRENA estimates that 150 GW of battery storage and 325 GW PHS is required to double the share of renewable power generation by 2030.

HYDROPOWER DRIVING MULTIPURPOSE RESERVOIRS

Access to energy is crucial to achieving sustainable human development. Without it, most of the United Nations Sustainable Development Goals (SDG) such as food security, healthcare coverage and access to water and sanitation will not be fulfilled. The first target of the seventh SDG is to ensure access to affordable, reliable, sustainable and modern energy for all. The second target focuses on the increase of renewable energy in the global energy mix.

Climate change poses a challenge to achieving the SDGs, and therefore the aim of SDG #13 is to take urgent action to combat climate change and its impacts. Its effects will exacerbate the increasing competition among water uses to provide food, water and energy to the rapidly increasing population. The increased frequency and intensity of extreme weather events will affect the most vulnerable countries, particularly those with the least developed infrastructures. For this reason, it becomes urgent to cooperate and find integrated solutions for managing water resources to mitigate and adapt to climate change and achieve sustainable development.

Hydropower's contribution

Hydropower plants associated with a reservoir can be a powerful tool in helping to counter the impacts of climate change and achieve SDG #13 and in turn play their part in achieving many of the SDGs, starting with SDG #7. It provides affordable, reliable, flexible and renewable energy. Besides providing firm power and reducing the fragility of the electricity grid, hydropower's role in renewable energy systems is becoming increasingly important, especially in supporting wind and solar energy.

Multipurpose reservoirs

Dams are at the core of the water and energy nexus. According to the International Commission on Large Dams World Register of Dams, of the 39,188 dams listed on their database with at least one purpose, only about a quarter are multipurpose reservoirs. Approximately half of the dams have irrigation as one of their purposes. Only 9,756 dams (25 per cent) have hydropower as one of their purposes, and about 40 per cent of those are associated with multipurpose reservoirs. Since hydropower will continue to grow, it can be the driver to increase the share of multipurpose reservoirs and thus improve the nexus efficiency.

In addition to the benefits for hydropower, multipurpose reservoirs offer storage capacity to manage floods, provide long-term energy storage during extended droughts, and supply water for irrigation and domestic uses. Reservoir regulation can also provide better environmental management by trapping excess fertiliser runoff from agricultural lands, and pollution attenuation, particularly in dams where wetlands can be developed. Around the reservoir, commercial activities can prosper to enhance the livelihood of the local population such as trade from navigation, fisheries and recreational activities.

Innovative hybrid solutions, such as floating photovoltaic solar panels, have been developed utilising the storage reservoirs to increase the energy generation. Floating PV on the reservoir surface is the most novel example of the multiple services that a reservoir can provide, by producing clean, renewable energy with a higher efficiency than conventional land-based solar PV, while reducing evaporation from the reservoir surface. Additionally, this hybrid solution can be achieved without competition for land acquisition.

Dams have contributed in an important way to human development and their benefits have been considerable. However, the negative social and ecological impacts have tarnished the positive effects, as it was pointed out by the World Commission on Dams in 2000. Optimising and sharing the multiple benefits will not be achieved unless the decision-making process incorporates all stakeholders from the earliest planning stage and reflects a comprehensive and sustainable approach that integrates the social, environmental and economic dimensions. Through cooperation, multipurpose reservoirs can be a solution to competing uses over water, land, and energy.

Methods for allocating multiple uses

The Intergovernmental Panel on Climate Change (IPCC) Special Report on Renewable Energy in 2012 reported a water consumption value of 209 m^3/MWh for hydropower due to evaporation. This estimation has been shown to be skewed by a small number of outliers, and the lack of allocation to multiple reservoir services. This revealed the need for procedures that allocate water consumption proportionately to the multiple uses in the case of multipurpose reservoirs. Certainly, hydropower is dependent on water availability, which

The Victoria reservoir in Kandy, Sri Lanka, which provides 210 MW of installed power capacity and irrigation water for the surrounding land

can in some cases result in competition over regional water uses. However, in this context, hydropower reservoirs also offer a sustainable water supply when water is scarce. Thus, in the research arena, some methodologies like water consumption by volume allocation and water stress indices have been proposed.

Following the World Commission on Dams recommendations, a multi-stakeholder forum developed the Hydropower Sustainability Assessment Protocol, a tool that promotes and guides more sustainable hydropower projects. It covers a wide range of topics including climate change along with environmental, social and economic dimensions.

The World Water Council together with EDF presented the SHARE Concept, a framework based on the principles of shared responsibilities, shared risks and rights, and shared costs and benefits in order to achieve the successful implementation of multipurpose hydropower reservoirs. It is clear that appraisal of the benefits becomes necessary in order to optimise the reservoir operation in a more efficient and sustainable way.

The way forward is better guidance on how to allocate water, land and energy among multiple stakeholders solving competing uses. If built in the right place and with the right equity share, such multipurpose reservoirs can contribute to achieving the SDGs.

LONG-DISTANCE TRANSMISSION ENABLING HYDROPOWER DEVELOPMENT

Long-distance transmission infrastructure is fundamental to the delivery of hydropower generation to load centres while providing access to regional markets for the export of surplus electricity. Transmission interconnections to countries with abundant hydropower resources provide access to low-cost, renewable electricity supply, and for developing countries, linking resources to major energy users can help to facilitate much-needed investment in the development or expansion of hydropower. When properly planned, that investment can also benefit the local population by providing vital access to energy, driving local economic development and creating jobs.

Regional interconnections can also result in lower energy costs for trading partners, by providing access to clean, renewable generation. In certain markets, it can be more advantageous to import excess hydropower than it is to build local power plants. Interconnections also facilitate access to energy storage, balancing variable generation sources like wind power and solar PV in neighbouring countries.

In many countries, vast quantities of hydropower potential can be economically developed to serve regional demand for clean, reliable, low-cost electricity. However, development of these resources often relies on long-distance transmission facilities, connecting the hydropower resource to major load centres. This can be challenging, particularly where the load centre is located a significant distance from the generation source.

Global energy interconnections

The concept of 'global energy interconnection' is one of the latest trends towards the development of ultra-high-voltage (UHV), long-distance interconnections, at regional and intercontinental scales to enable the growth in renewable energy technologies required to meet global energy demand. The Global Energy Interconnection Development and Cooperation Organization (GEIDCO) sets out a roadmap in its white paper on global energy interconnection development strategy, divided into three phases:

- **Domestic:** Up to 2020, countries will focus on their own clean energy development and grid interconnection projects.
- **Intracontinental:** By 2030, large-scale energy bases and cross-border grid interconnections will be promoted within each continent.
- **Intercontinental:** By 2050, energy bases of the Arctic and equatorial regions and intercontinental interconnection will be set up. Global energy interconnection will basically come into being.

Discussions are already under way among major energy companies in China, Japan, Russia and South Korea around the creation of an 'Asian Super Grid', in which a UHV grid would link electric grids across regions, countries and continents to transmit electricity generated with an abundance of clean, renewable sources like hydropower.

The following sections describe examples of long-distance UHV transmission either in service today or in planning that will form the backbone of GEIDCO's concept of a globally interconnected world.

China

China has roughly 331 GW of hydropower installed, with the potential to develop an additional 200 GW. However, this potential can only be realised with the support of interconnections and UHV electricity lines in operation.

The Asian Super Grid is a concept contingent on UHV power transmission lines, over long distances, operating at more than 1,000 kV AC / 800 kV DC, connecting China, South Korea, Russia and Japan. Since 2009 China has built nearly 16,000 km of UHV power lines and is aiming to increase the total length of its high-voltage transmission lines to 1.01 million km by the end of 2020. The State Grid Corporation of China, the largest electric utility company in the world, has stated that it will invest roughly USD 88 billion into UHV transmission development between now and 2020.

Canada: Manitoba–Minnesota interconnection

In Canada, the predominantly hydro-based provinces of Manitoba, British Columbia and Quebec are increasing their already strong interconnections with the neighbouring grids of USA. Utilities like Manitoba Hydro can utilise their hydropower reservoirs to balance the output of major windfarm developments to the south, while enabling bilateral trade opportunities for export and providing import capability for reliability in low-water conditions.

To take advantage of future export and import opportunities, Manitoba Hydro and Minnesota Power are co-operating on building a new 500 kV interconnection between Canada and the United States. The line is anticipated to enter service in 2020, coincident with the in-service date of the new hydro station at Keeyask (695 MW).

The existing interconnections to the USA have a capability of 2,000 MW. Building the new interconnection will increase that capacity to almost 3,000 MW, giving Manitoba Hydro the ability to concentrate the delivery of surplus energy during the on-peak hours rather than in the off-peak hours.

South and Central Asia: CASA-1000
Kyrgyzstan and Tajikistan are two countries in Central Asia endowed with some of the world's most abundant hydropower resources with run-off from the mountain ranges filling the rivers in the summer. Both of these countries have a surplus of electricity during this summer season.

Nearby in South Asia, Afghanistan and Pakistan suffer from chronic electricity supply shortages while trying to keep pace with a fast-growing demand for it. Pakistan cannot meet its citizens' electricity needs, especially during the summer months, leading to frequent power outages, with a significant impact on the economy. Meanwhile, millions of people still live without electricity altogether.

CASA-1000, a new electricity transmission system to connect all four countries, would help make the most efficient use of the hydropower resources in the Central Asian countries by enabling them to transfer and sell their electricity surplus during the summer months to the deficient countries in South Asia. The CASA-1000 project would also complement the countries' efforts to improve electricity access, integrate and expand markets to increase trade, and find sustainable solutions to water resources management.

Eastern African Power Pool (EAPP)
In East Africa, more than 200 million people are without electricity, accounting for around 80 per cent of its population. Ethiopia, Kenya and Uganda are among the most populous countries in the region, and have the largest populations both with and without access to electricity.

East Africa, much like the rest of Africa, exhibits a diverse range of economic and energy sector development. Regional interconnections can enable hydropower development in East Africa, and in order to meet the rapidly growing electricity demand, African governments have collectively recognised the need for effective and integrated regional planning and interconnections.

While bilateral agreements exist between some neighbouring jurisdictions in the EAPP, power exchange over existing regional interconnections has not been optimised, and often marred by failed contractual obligations due to local system deficits.

A master-plan for the EAPP was derived using existing national power development strategies. The original master-plan published in 2011 estimated that with a USD 4.5 billion investment in interconnections, USD 25 billion in net revenue could potentially be generated through increased opportunities for power trading, as compared to individual national development programmes. By optimising generation investments away from fossil fuels and towards hydropower supply, the net benefit increased to USD 32 billion.

Cross-border interconnections between the countries of the EAPP reduces fuel costs, while improving the security of energy supply in the system, allowing countries to optimise domestic energy sources and compensate for potential seasonal variability or fuel shortages.

To incentivise the development of regional interconnections in East Africa, there are a number of issues that must be addressed:

- Removing the up-front risk to investment by ensuring that projects are configured for optimal system and national benefit, and that the selected projects have the best strategic fit.
- Fostering greater regional cooperation between local and national governments.
- Implementing better policy for incentivising regional development, cross-border energy sharing and reduced regulatory risk.

OPERATION AND MAINTENANCE CHALLENGES FOR THE HYDROPOWER SECTOR

Conventional hydropower plants are among the lowest-cost electricity energy resources, due to their long life and relatively low operating and maintenance costs. Nonetheless, the operation and maintenance (O&M) of hydropower facilities is becoming increasingly complex in many regions of the world.

The civil infrastructure of hydropower facilities can last for a century or more, whereas mechanical and electrical components may require replacement in less than 40 years, depending on the operating role of the hydropower plant. Baseload plants with minimal daily load variation can operate over a longer time frame than plants operated to meet peak load requirements and frequency control operations, where significant start-stop operations may be required.

The operation and maintenance of hydropower facilities is particularly challenging when the owners of aging facilities are faced with strategic asset replacement and/or refurbishment decisions. For example, in North America, a significant proportion of the existing fleet of hydropower mechanical and electrical equipment is reaching its life expectancy. For this reason, project owners are often facing difficult economic decisions between overhaul and replacement.

In developed countries with significant hydropower assets such as Canada, the United States, Norway and Iceland, basic O&M practices such as regular inspections for cavitation damage on turbine blades, stator and rotor windings, bearings and excitation systems, are based on well-established guidelines and are generally carried out under a scheduled work programme. The key challenge facing project owners and operators is developing an optimised asset management strategy that targets safety and maximises unit availability; with a fleet of aging assets reaching the end of their useable life, compounded by an aging workforce to complete this work on time and on budget.

Common strategies employed in developed countries include implementing remote operation at older facilities, installing real-time asset monitoring systems, maintaining key spare components on-site to reduce outage time and other solutions to minimize O&M costs. Asset managers are increasingly turning to digitisation for implementing sophisticated risk-based decision-making tools to optimise their near-term and long-term O&M asset management plans for maintaining, overhauling or replacing the most critical components of their fleet.

In less developed areas of the world including many countries in Africa, South Asia and South America, a unique set of challenges for operating and maintaining hydropower assets exist. Often, developing nations face institutional challenges such as a lack of training to operate and maintain facilities, lack of dam safety enforcement and compliance, limited access to spare parts and lack of financial support.

Beyond these challenges, other regional issues can add an additional level of complexity to their O&M challenges, including climate extremes (droughts and floods) and sedimentation problems which can compromise conventional O&M practices.

Challenges for hydropower O&M in Africa

At a recent workshop hosted by World Bank Group and SECO (Swiss State Secretariat for Economic Affairs) in Martigny, Switzerland, stakeholders from a broad cross-section of the hydropower community gathered to discuss O&M challenges, with a specific focus on developing a better understanding of the main O&M challenges in several countries in Africa including Cameroon, Uganda, Rwanda and São Tomé.

A number of common O&M issues were observed consistently across all of these African countries. In all cases, there was a preponderance of insufficient training on best practices in O&M and a lack of knowledge-sharing across the hydropower sector. In most of these African utilities, there was no formal maintenance optimisation programme in place to prioritise maintenance around available budgets and staff resources, to target the most critical components requiring maintenance, often resulting in extended forced outages and lost revenue.

Many African countries are dealing with inadequate financial resources to procure spare parts for critical components requiring replacement, often lacking the appropriate tools to put forward a business case for mitigating these preventable forced outages by purchasing spare parts to keep on site. Insufficient financial support is also a barrier to countries having the capacity to undertake any major rehabilitation or refurbishment.

Another common theme among African utilities is a loss of production revenue associated with sub-optimal operating strategies, resulting in lost revenue from inefficient unit operation and spilled energy, ultimately impacting funds available for ongoing maintenance. For example, in a case study of the Sanaga River complex in Cameroon, operational issues such as inconsistent, poorly defined operating rules and a lack of basin management strategies have resulted in increasing sedimentation of the reservoir.

In specific cases, political interference and cross-border disputes have severely restricted the utility's capability to carry out optimal O&M practices. In Rwanda, the different legal status of two existing hydropower plants (Ruzizi I and Ruzizi II) and the recent creation of a new authority for water management of the Kivu Lake and the Ruzizi River have resulted in separate power dispatching between Ruzizi I and Ruzizi II.

In many countries in Africa, there is an absence of a regulatory framework to monitor safety of hydro infrastructure and in particular a lack of enforcement around dam safety guidelines.

In order for African countries to progress in terms of building the capacity and knowledge to implement successful O&M practices into their respective hydropower facilities, good practice guidelines need to be developed with the assistance of hydropower operators from developed countries, to ensure that the following O&M practices can be adopted:

- Hydropower stations should be operated within the context of the management of the entire watershed (considering both upstream and downstream impacts) when developing long-term O&M plans, to optimise efficient management of water supply, minimise erosion and reduce sediment problems.
- Implementing a long-term strategy for O&M is essential, including (where possible) the inclusion of long-term O&M contracts, and a well-planned O&M programme to motivate staff and methodologies in place to invoke capacity building.
- Better communication between the asset owner and stakeholders responsible for corporate social responsibility and emergency preparedness is necessary to understand the financial and economic attractiveness of a good O&M programme.
- A policy that addresses the need for standardisation of equipment is also needed.

The Ruzizi I hydropower plant on the Ruzizi River, bordering Rwanda and DR Congo

ADVANCEMENTS IN SEDIMENT MANAGEMENT BEST PRACTICES

Hydro dams have traditionally been designed around the life-of-reservoir concept, providing storage to offset 50 to 100 years of sedimentation. However, original designs often fail to address what happens to the reservoir after losing capacity due to sediment deposition. While decommissioning is an option, it is not only costly but most owners want to sustain benefits from their existing infrastructure.

Sustainable sediment management, according to the World Bank definition, “seeks to maintain long-term reservoir capacity, retarding the rate of storage loss and eventually bringing sediment inflow and discharge into balance while maximising usable storage capacity, hydropower production, or other benefits”.

Sediment issues

In the hydropower sector, sedimentation can result in loss of power supply reliability, intake obstruction and the entrainment of coarse sediment which abrades hydro-mechanical equipment. For ecosystems in the downstream river, dam construction dramatically reduces the flow of sediment over the period that the reservoir accumulates sediment.

However, managing a reservoir to achieve a sediment balance often implies reloading the downstream river with sediment, following many decades of sediment-starved clear water releases. This can lead to a variety of sediment management issues and impacts downstream. However, without proper sediment management, once the reservoir has lost its capacity, the sediment inflow and outflow will again come into balance, inevitably reloading the channel below the dam with sediment.

From this perspective, sediment management may be seen as an attempt to reestablish natural sediment flows along the river, while preserving storage capacity.

Sediment sources

Sediment deposited into reservoirs is derived from upstream erosion of soil and river banks. While erosion is a natural process, it can be accelerated as much as a hundredfold by human activities that disturb the soil, such as deforestation, agriculture, mining and urban development. Climate change is generally expected to increase sediment yield due to greater frequency of extreme events responsible for most erosion and sediment transport. In glaciated catchments, the retreat of ice uncovers highly erodible sediments at elevations too high to be stabilised by vegetation.

Sediment management strategies

The application of different sediment management strategies is driven by a wide range of factors, including: hydrology, land use, vegetative cover, and the variation in sediment yield over time and space within the catchment; reservoir size, geometry, operating rules and types of beneficial use; configuration of outlets at the dam; environmental constraints and downstream users that may be impacted by sediment release; and financial considerations.

Available sediment management strategies can be classified into four main groups: reducing sediment inflow; routing sediment through or around the reservoir; sediment removal; and strategies to adapt to sedimentation.

Reducing sediment inflow

Sediment inflow can be reduced through watershed management, which reduces erosion. There is typically a wide range in soil erodibility within watersheds, and the most effective management will normally focus on those areas producing the most sediment per unit of land area, and where management can be most effective.

Revegetation is typically the most important and sustainable element of watershed management. For example, the Water and Land Resource Centre’s watershed management strategies in Ethiopia, including gully rehabilitation and vegetated graded soil bunds, have been successful in reducing surface runoff and soil loss.

This not only reduces reservoir siltation, but also delivers additional benefits, such as reduced flooding. Sediment inflow can also be reduced by constructing upstream dams, but this will only be effective for as long as upstream reservoirs have capacity remaining to store sediment.

Sediment routing

Techniques that sustain sediment in motion, minimising deposition within the reservoir, are classified as ‘routing’. Routing strategies are considered environmentally friendly because they seek to maintain the natural rate and timing of sediment transport along the river.

These techniques include reservoir drawdown during periods of high sediment flow (e.g. monsoon), in order to pass sediment-laden flows through the reservoir at high velocity and minimise deposition. It can also involve bypassing sediment-laden flood events around the storage pool, either by placing the storage pool off-channel or using a bypass tunnel.

For example, Alpine reservoirs, like Solis in Switzerland, receive much of their sediment load during short-duration flood events. The Electric Power

Company of Zurich (EWZ), which operates the Solis dam, constructed a 170 m^3/s sediment bypass tunnel to redirect sediment-laden flood flows around the storage pool to minimise sediment accumulation.

Sediment removal

Dredging and flushing are the most common approaches to removing reservoir sediment deposits. Dredging is technically feasible in any reservoir, although it can be very costly and is therefore often not financially feasible. Flushing, on the other hand, is primarily applicable to smaller and relatively narrow reservoirs, where the narrow channel scoured out by flushing constitutes a significant part of the reservoir volume.

As a first approximation, the bottom width of a flushing channel will be similar to the width of the pre-impoundment river channel. In the high-rainfall mountain area of Costa Rica, the 100 MW Cachí reservoir is subjected to empty flushing most years, scouring and releasing sediment through a low-level outlet, thereby preserving capacity and maintaining the power intake free of sediment.

At the 150 MW Patrind hydropower project in Pakistan, sediment routing and removal strategies have been designed to operate in a complementary manner. Coarser particles will be redirected through a sediment bypass tunnel during flood events to minimise accumulation, and flushing through low-level outlets will be used to remove the remaining sediment that becomes trapped upstream of the dam.

Adaptive strategies

There are also many adaptive strategies that do not directly handle sediment but that help adapt to the sediment. In hydropower reservoirs, intake modification and use of abrasion-resistant turbine runner coatings to combat increasing abrasion are two examples being employed with increasing frequency.

Sediment management in hydrologically large storage reservoirs, especially reservoirs with a storage volume greater than mean annual inflow (capacity: inflow ratio >1), present a particular problem. These sites typically trap virtually all inflowing water and sediment, leaving little excess water for sediment release.

In these cases, strategies may focus on reduction of sediment inflow, optimisation of the operating rule to maximise the benefit from available storage volume, or heightening the dam to increase storage, thus extending reservoir life. Density current venting is a routing technique that may be successfully applied in large reservoirs where conditions allow. Also, as large reservoirs lose capacity through sedimentation, they eventually become 'small' reservoirs, at which point management techniques appropriate for hydrologically smaller reservoirs may become viable.

In summary, there are a wide range of strategies that can be used, either alone or in combination, to transition from non-sustainable to sustainable use of dams and reservoirs. A common need at all sites is for adequate monitoring data, which enables dam owners and their consultants to better understand the dynamics of sediment generation and transport in their specific case, and use this to identify and implement the most appropriate sediment management strategies.

Case study guidance

IHA is assisting the project *Analysis of the Impact of Sedimentation on Dams and Reservoirs: Case Studies*, funded by the World Bank. This study will contribute to identifying and documenting case studies that demonstrate a variety of sediment management practices across different geographies and methodologies.

The project seeks to gather information on 'things that worked' as well as 'things that didn't work'. Because each strategy has its limitations, it is particularly important to understand the situations in which specific strategies were considered either successful or unsuccessful, so that the entire dam and hydropower community can better understand their respective strengths and limitations, and employ them with ever greater levels of confidence and predictability.

Because multiple strategies are often used, an individual site may have experienced different degrees of success with each of the strategies implemented. These case studies will be featured at www.hydropower.org.

FUTURE TOOLS FOR SUSTAINABILITY ASSESSMENT

The Hydropower Sustainability Assessment Protocol has become broadly recognised as the primary tool for evaluating sustainability performance, having been implemented worldwide. IHA and partners have begun work to develop tools to support more widespread use of the protocol by developing templates for more specific environmental and social performance assessment of a project, and guidelines on international good practice.

The protocol provides a methodology for a sustainability assessment of hydropower projects across more than 20 sustainability topics, encompassing environmental, social, technical, financial and economic aspects. It rests on a multi-stakeholder-agreed definition of basic good practice and proven best practice for each of the topics, and provides accompanying definitions and guidance (in the 'assessment guidance' sections in each topic, and in other parts of the protocol, such as its glossary).

Since its launch at the World Hydropower Congress in Iguaçu, Brazil, in 2011, the protocol has been applied across developed and developing regions of the world, and is increasingly used in a variety of ways, for capacity-building purposes in developing countries, and as an internal reference guideline.

Stakeholders recognise demands for focused assessment

However, feedback from a number of sources indicates that the cost of a full official assessment using the protocol may be inhibiting its uptake. There are demands from sources such as the Climate Bonds Initiative (CBI) for a more focused, lower-cost assessment. As such, a tool to assess the environmental and social sustainability of hydropower offers the opportunity to harness bonds finance for the underpinning of sustainability standards in the industry.

The option of developing and endorsing a lower-cost option for an official assessment was discussed at meetings of the protocol's multi-stakeholder governing body in December 2016 and February 2017. IHA was asked to develop the proposals further.

In addition, although the protocol provides a definition of 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. There is no widely recognised document providing a guideline on international industry good practice. IHA's Sustainability Guidelines, launched in February 2004, have been considerably superseded by the protocol and global industry practice.

The use of guidelines on good practice is widespread in other industries: for example, World Bank environmental, health and safety (EHS) guidelines for a wide range of sectors refer to 'good international industry practice' (GIIP). The World Bank Group has not published an EHS sector guideline for hydropower.

Tools to drive further uptake

IHA is now developing an initial template for an assessment using the preparation stage tool of the protocol. It will focus on basic good practice, and environmental and social topics only. The intent is that such an assessment could be completed within 20 to 30 days.

The draft template and options around it will be discussed by the protocol's multi-stakeholder governing body. Further templates may then be developed for the implementation and operation stage tools of the protocol. The new templates would then be available for discussion at the biannual meeting of the Hydropower Sustainability Assessment Council, which meets alongside the World Hydropower Congress in Addis Ababa in May 2017.

International industry good practice guidelines

The templates would be complemented by a guideline document on basic good practice. (This in turn would be complemented by a series of case studies of proven best practice as part of the 'better hydro' initiative, which IHA is developing with World Bank financing.)

The guideline will be based on the definitions of basic good practice in the protocol, the accompanying definitions of terms and guidance, additional guidance developed for capacity-building purposes by IHA in recent years, and the practice observed through numerous protocol assessments to date.

It would build on the experience developed by accredited assessors in official protocol assessments to date, and make this experience publicly available. The intention is that the guideline would become internationally recognised across the industry and its stakeholders as the key statement of good practice in hydropower.

The guideline would be a document of 30 to 40 pages, structured in chapters that correspond to the topics of the protocol. Each chapter would jointly address the preparation, implementation and operation stages, but would refer to the stages clearly within each topic section.

It would be written in a concise style, to minimise the extent to which they may be open to interpretation. This will also ensure it can be easily understood by non-English speakers, and translated reliably.

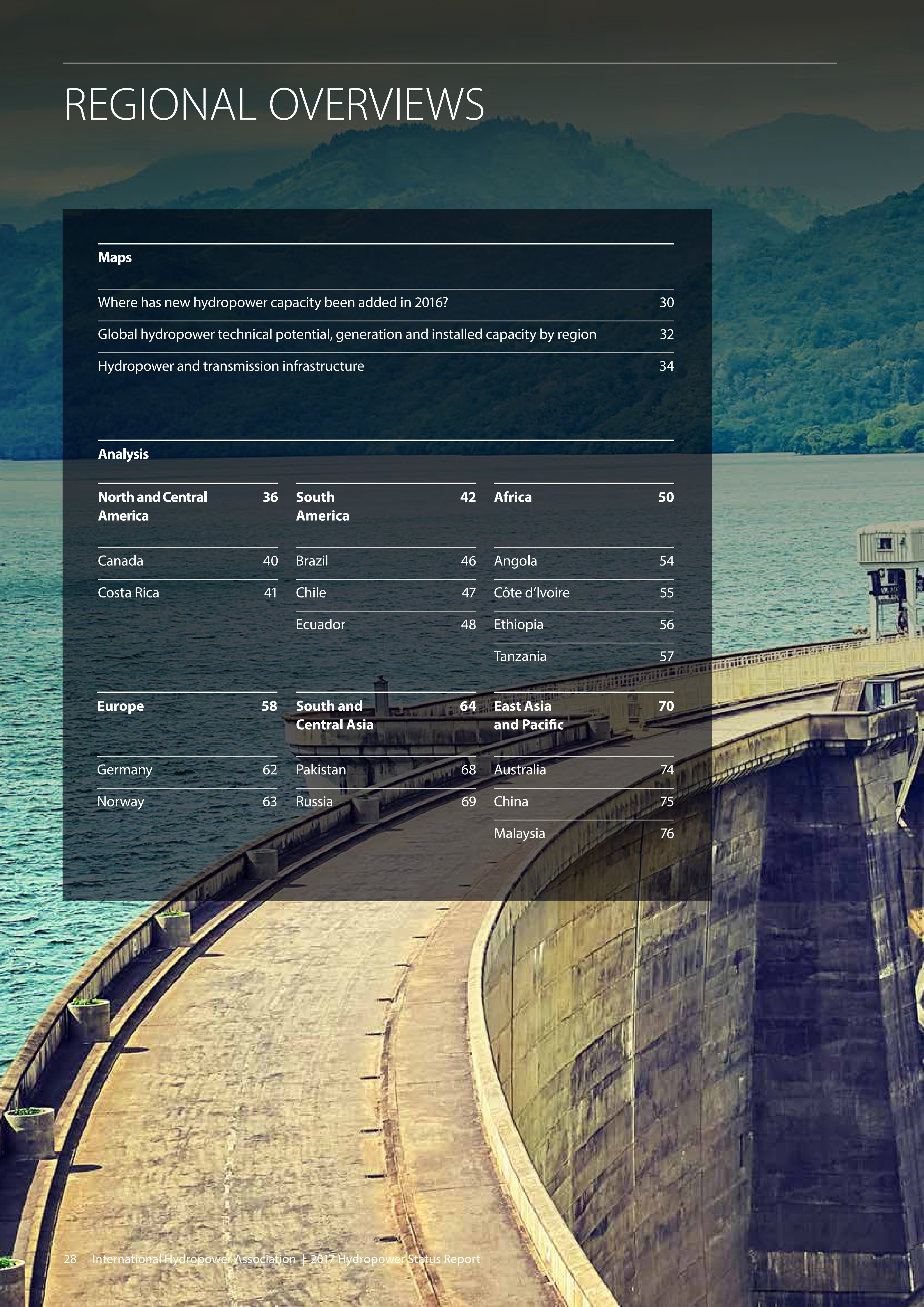
Objectives of a tool focused on environmental and social performance

- To provide report templates for the assessment of a hydropower project using selected protocol criteria, focused on basic good practice only.
- To allow more expedient lower-cost assessment, using consistent templates.
- To maintain consistency in the quality and content of assessments.
- To focus on topics, and criteria within them, of most relevance to environmental and social risks.
- To maintain the distinct value of a full official assessment using all topics.

Objectives of developing international industry good practice guidelines

- To develop a document providing a hydropower international industry good practice guideline, as a 'normative' statement of good practice.
- To propose the guidelines at the World Hydropower Congress in Addis Ababa in May 2017.
- To establish the guidelines as a widely recognised manual of international good practice.

The site of the Kabeli A hydropower project in Nepal, which undertook a protocol assessment in September 2014



REGIONAL OVERVIEWS

Maps

Analysis

WHERE HAS NEW HYDROPOWER CAPACITY BEEN ADDED IN 2016?

NEW INSTALLED CAPACITY BY COUNTRY*

Rank	Country	Capacity added (MW)
1	China	11,740
2	Brazil	6,365
3	Ecuador	1,987
4	Ethiopia	1,502
5	South Africa	1,332
6	Vietnam	1,095
7	Peru	1,040
8	Switzerland	1,022

Rank	Country	Capacity added (MW)
9	Laos	650
10	Malaysia	622
11	India	481
12	Angola	400
13	Portugal	391
14	United States	379
15	Turkey	363
16	Costa Rica	323

Rank	Country	Capacity added (MW)
17	Norway	254
18	Chile	239
19	Russia	171
20	Guatemala	163
21	Canada	122
22	Zambia	120
23	Nepal	115
24	Colombia	106

WHERE HAS NEW HYDROPOWER CAPACITY BEEN ADDED IN 2016?

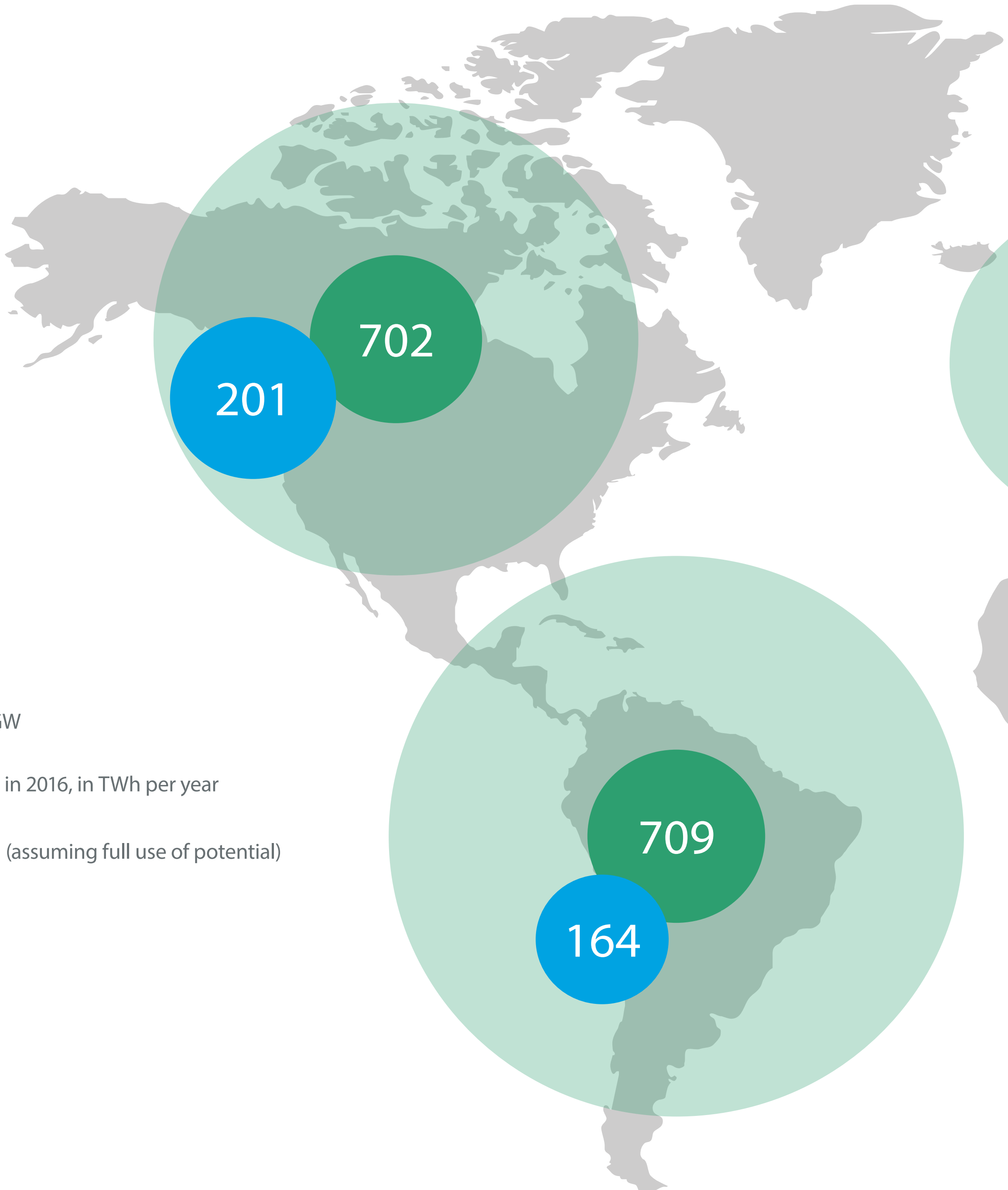
Rank	Country	Capacity added (MW)
25	Albania	81
26	Mexico	64
27	Pakistan	56
28	Indonesia	47
29	Afghanistan	42
30	Belarus	40

Rank	Country	Capacity added (MW)
31	Kazakhstan	22
32	Liberia	22
33	DR Congo	14
34	Cameroon	10
35	France	8
36	United Kingdom	7

Rank	Country	Capacity added (MW)
37	Sri Lanka	5
38	Sierra Leone	5
39	Italy	4
40	Rwanda	4
41	Zimbabwe	4
42	Azerbaijan	2

*including pumped storage

GLOBAL HYDROPOWER TECHNICAL POTENTIAL, GENERATION AND INSTALLED CAPACITY BY REGION

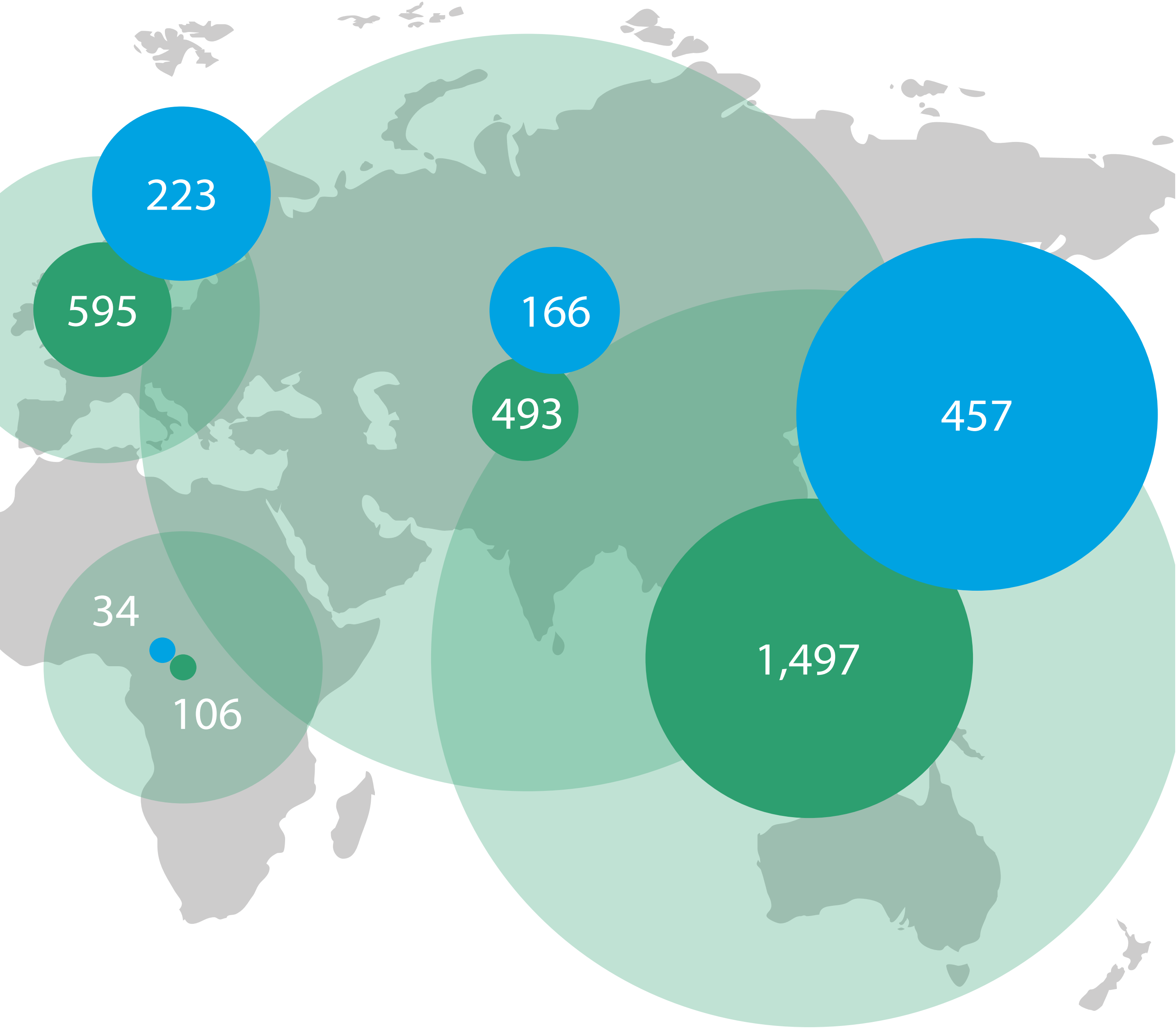


Installed capacity in GW

Estimated generation in 2016, in TWh per year

Maximum generation (assuming full use of potential)

GLOBAL HYDROPOWER TECHNICAL POTENTIAL, GENERATION AND INSTALLED CAPACITY BY REGION



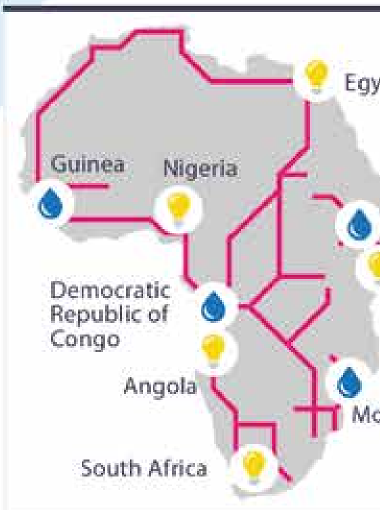
HYDROPOWER AND TRANSMISSION INFRASTRUCTURE

Manitoba–Minnesota

The Great Northern Transmission Line (500 kV) will deliver electricity generated by hydropower across the Canada–USA border to the Iron Range 500 kV substation near Grand Rapids, Minnesota. The new transmission line will meet Minnesota's growing energy demands and increase system reliability and electricity security for the region.

Brazil

Carrying 800 kV over 2,500 km, the country's longest transmission line will link the world's third largest hydropower station, Belo Monte (11.2 GW), in the north of Brazil, to the south-east of the country where the largest demand markets are situated. Led by the State Grid Corporation of China, the project is expected to be finalised by the end of 2019.



Hydropower generation

Demand

Long-distance transmission line

China

With significant amounts of China's energy sources located in the west of the country, high-voltage transmission projects from rural regions will deliver electricity to meet demand in the east where most of the population resides. State Grid Corporation of China aims to invest USD 88 billion on UHVDC lines between 2009 and 2020.

Europe North Sea Link

The North Sea Link (NSL) will connect the national grids of the UK and Norway via high-voltage subsea cables spanning approximately 720 km. By linking the two energy markets, the countries aim to increase security of electricity supplies and enable a two-way flow of renewable energy – most notably, the exchange of hydropower and wind power.

India

India is also making critical investments in transmission projects in order to strengthen the power supply to the growing energy demand in the country's largest cities and surrounding regions. Most recently the Raigarh–Pugalur (800 kV) UHVDC transmission line will span 1,830 km, linking hydropower and other energy sources from central India to demand cities in the south such as Bangalore.

Africa Clean Energy Corridor

The Clean Energy Corridor will facilitate accelerated deployment of hydropower and other renewable energy sources, as well as increasing regional integration and electricity access. Participating networks will greatly benefit from sharing reserve capacity, diversified markets and wider generation mix. This will have far-reaching implications in securing the energy future for Africa.

NORTH AND CENTRAL AMERICA
REGION MAP

TOP SIX COUNTRIES BY INSTALLED HYDROPOWER CAPACITY (MW)* **OTHERS:** 2,019 | **TOTAL: 200,922**

1	2	3	4	5	6
UNITED STATES 102,485	CANADA 79,323	MEXICO 12,092	COSTA RICA 2,123	PANAMA 1,726	GUATEMALA 1,154

NORTH AND CENTRAL AMERICA
CAPACITY BY COUNTRY

Rank	Country	Installed hydropower capacity (MW)*
1	**United States**	102,485
2	**Canada**	79,323
3	**Mexico**	12,092
4	**Costa Rica**	2,123
5	**Panama**	1,726
6	**Guatemala**	1,154
7	**Honduras**	558
8	**Dominican Republic**	543
9	**El Salvador**	472
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

* includes pumped storage

NORTH AND CENTRAL AMERICA **OVERVIEW**

Hydropower remains a critical energy resource for North and Central American countries, as well as in the Caribbean islands. The United States and Canada continue to be among the world's leading countries in terms of installed hydropower capacity, with 102.5 GW and 79.3 GW respectively (including pumped storage) at the end of 2016. 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, several projects came online in 2016, including Big Silver Creek (40.6 MW) and Jimmie Creek (62 MW), among others. Romaine 3 (395 MW) is expected to begin operations in 2017, with several other projects also in the pipeline.

The US Department of Energy announced its flagship programme for advancing hydropower development under the banner of a report called *Hydropower Vision: A New Chapter for America's 1st Renewable Electricity Source*. The report outlines plans to increase hydropower capacity in the US from its current 102 GW of combined generating and storage capacity to nearly 150 GW by 2050, with more than 50 per cent of this growth realised by 2030. The target comprises 13 GW of new hydropower generation capacity from upgrades to existing plants, adding power at existing dams and canals, and the addition of 36 GW of new pumped-storage capacity.

The electricity grids and markets of the USA and Canada are already well integrated, and Canada is a net exporter of electricity to the USA, currently exporting nearly 60 TWh per annum. Several new cross-border transmission interconnections are in the approval process to increase the export of Canadian hydropower into the USA. Transmission projects currently under development include the Champlain Hudson Power Express, a 1,000 MW line from the Canadian border to New York City, which is expected to be complete by 2017, and the Great Northern Transmission Line, an 833 MW line linking Manitoba and Minnesota.

Mexico currently has approximately 12,092 MW of installed hydropower capacity. The economically feasible hydropower potential of the country is estimated to be approximately 27,000 MW. There is also an increasing potential future role of IPPs in hydropower development since reforms to the energy market in 2015 lifted restrictions of private ownership of hydropower stations. Chicoasen 2 (240 MW), which is expected to produce 591 GWh of electricity annually, is due to come online in 2019.

In Haiti, the Artibonite 4C (32 MW) hydropower plant was initiated by the Brazilian Government, which funded the preliminary studies. Construction of the project will be executed by the Chinese construction firm Sinohydro, and the project will be situated in the country's agricultural region, the Central Plateau. The project is expected to provide more physical infrastructure necessary for further economic and social development across the island.

In Jamaica, the Maggotty hydropower plant, which is the largest on the island and is critical to the country's grid, recently upgraded the automation system to a newer digital control platform. Viewed as the most cost-effective option, upgrading the automation system will extend the life of the plant by reducing downtime, improving operations and reducing required maintenance, while simultaneously achieving unit-to-unit integration with the other running units.

The main investor of the 65.8 MW El Chaparral hydropower project in El Salvador, CEL (Executive Hydroelectric Commission of Lempa River), will progress with construction of the plant with the support of Costa Rican service provider ICE (Costa Rican Electricity Institute). With both El Salvador and Costa Rica members of the Central American Electrical Interconnection System (SIEPAC), collaboration in the El Chaparral project is further progress towards integration of the region's electricity system.

In Dominica, hydropower stations and the Clarke's River System, which were severely damaged during Tropical Storm

Erika, have been mainly all restored by the end of 2016. After significant damage, infrastructural repairs were time-consuming, and temporary support systems were established in order to maintain hydro generation on the island.

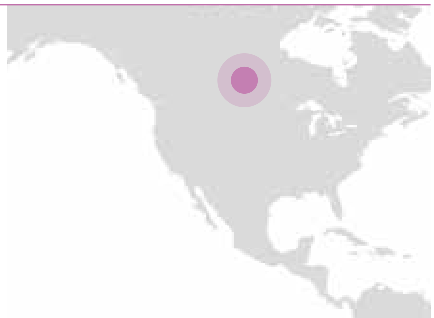
In Cuba, the Kuwait Fund for Arab Economic Development (KFAED) will provide USD 30 million in financing for the construction of 34 small hydropower projects. The projects, which will be constructed on existing infrastructure, as well as the construction of 75 km of transmission line, will aim to stimulate agricultural production in rural parts of the island. Access to electricity through small hydropower projects will continue to grow throughout Cuba as the island will also benefit from an International Renewable Energy Agency (IRENA) collaboration with the Abu Dhabi Fund for Development (ADFD).

In Guatemala, a number of new hydropower projects came online including La Libertad (9.6 MW) and El Recreo 2 (24.3 MW). The Renace Hydroelectric Complex on the Cahabón River is still under construction. Once in full operation, it will be the largest hydro facility in the country with a total installed capacity of approximately 300 MW.

HYDROPOWER TARGETS

Country	Target
Canada	Reduce greenhouse gas emissions by 30 per cent below 2005 levels by 2030
Honduras	Increase exploitation of hydropower resources from 5 per cent of technical potential to 25 per cent by 2034

NORTH AND CENTRAL AMERICA
CANADA



Canada ranks fourth in the world for hydropower development, with over 79 GW of installed capacity, including pumped storage. Total annual generation from all hydropower facilities in Canada reached an estimated 380 TWh in 2016, with only China and Brazil exceeding this figure. Hydropower currently accounts for 62 per cent of the country's power mix.

During 2016, work progressed on four major Canadian hydropower projects under development. Ongoing projects that are in the construction phase will add over 3,000 MW of installed capacity.

BC Hydro is continuing to develop Site C on the Peace River in northern British Columbia. The project is entering the third year of construction, and upon completion will see six 183 MW units go into production for a total installed capacity of 1,100 MW by 2024. Manitoba Hydro is constructing the Keeyask generating station on the Nelson River in northern Manitoba, which began construction in 2015 and will add 695 MW of new capacity by 2021. Following the completion of the Romaine-2 power plant (640 MW) in 2014 and Romaine-1 (270 MW) in 2015, Hydro-Québec is completing, Romaine-3 (395 MW), which is expected to be in service in 2017, while the fourth component, Romaine-4 (245 MW) is scheduled for completion by 2020.

In Labrador, Nalcor is constructing Muskrat Falls, an 824 MW hydroelectric generating facility on the lower Churchill River, which upon completion in 2019 will be the second-largest hydroelectric facility in the province.

Major rehabilitation and modernisation of aging hydropower assets continues in Canada. In British Columbia, the 70-year-old John Hart generating station is being modernised, and upon completion in 2021, the original 126 MW six-unit powerhouse will be replaced by a new 132 MW three-unit powerhouse. Hydro-Québec continues with a programme of life-extension projects on a number of older generating stations, including Beauharnois (1,903 MW), Manic 5 (1,596 MW) and Rapide-2 (67 MW) and Rapide-7 (67 MW).

Canada commissioned a number of smaller projects in 2016, including the 18.9 MW Gitchi Animki hydropower complex in northern Ontario. The project, which includes two separate generation sites at 10 MW and 8.9 MW, was developed as a joint venture with the Pic Mobert First Nation, on whose land the project lies. The partnership between the Pic Mobert First Nation and Regional Power Inc., includes 50–50 ownership of the project, and training and employment opportunities for local residents.

Other projects completed in 2016 include the Big Silver Creek (40.6 MW) and Jimmie Creek (62 MW) run-of-river projects in British Columbia. The Jimmie Creek project lies adjacent to the existing east Toba (123 MW) and Montrose Creek (123 MW) facilities, and takes advantage of existing transmission lines in place.

Major transmission interconnections linking Canada's vast hydropower resources with the US are a vital part of the energy trade relationships between the two countries. Manitoba Hydro and Hydro-Québec are currently two of the largest exporters of hydroelectricity, and are continuing to expand their interconnections. Manitoba Hydro is planning a new 500 kV Interconnection between Manitoba and Minnesota that will increase export capacity and enhance reliability by doubling the utility's ability to import electricity from the United States. Two new interconnections between Quebec and the United States are also planned. The first involves the construction of a 320 kV direct-current transmission line, connecting Des Cantons substation in Val-Joli to Franklin substation in southern New Hampshire. The second is a 320 kV DC underground line between the Hertel substation and the border with the state of New York.

POPULATION
35,851,774

GDP
USD 1,551 BN

INSTALLED HYDROPOWER CAPACITY
79,323 MW
INCL. 177 MW PUMPED STORAGE

HYDROPOWER GENERATION
379,627 GWh

NORTH AND CENTRAL AMERICA
COSTA RICA

At the end of 2016, Costa Rica reached a total installed hydropower capacity of 2.12 GW. The country dominated the headlines for the second consecutive year, achieving 100 per cent renewable electricity production for a total of 271 days.

This high percentage of steady renewable energy penetration throughout the country was facilitated by the critical role of baseload energy from hydropower generation. Representing roughly 75 per cent of the total electricity profile, hydropower is the largest source of energy in the country and can be utilised to support the increased penetration of more variable renewable energy sources both within the country and region.

The country has set a target to reach 100 per cent renewables power share by 2030, which will not be possible without hydro.

Costa Rica has a notable geographic advantage in that its concentration per capita of rivers, dams and volcanoes allow for high levels of renewable energy production. This abundance of natural resources and favourable rainfall levels are beneficial for great amounts of hydropower generation.

2016 saw new stations come online, such as Bijagua (17 MW) in Upala, Alajuela province. The Reventazón facility (305.5 MW) also came online in 2016. This USD 1.4 billion project is the largest hydropower project in Central America after the Panama Canal, and one of the largest public infrastructure projects in the region in the modern era. Furthermore, due to its environmental features, such as migration corridors for jaguars and many other species, the project is a model of good practice for other future hydroelectric power plants.

The proposed El Diquís hydroelectric project (631 MW), which has the potential to be the biggest hydropower facility in Central America, is currently suffering significant delays under the domestic supreme court and UN legal framework.

With regards to regional integration of affordable, reliable electricity, the Central American Electrical Interconnection System (SIEPAC) is an ongoing initiative involving Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua and Panama. When completed, the SIEPAC line will consist of 15 substations and 28 access bays across 1,800 km. As Costa Rica has the largest installed capacity and is the largest producer in the region, the planned transmission segment length in Costa Rica dominates at 489 km. With such a substantial percentage of Costa Rican electricity generated from hydropower, the energy source will have a significantly positive and extensive impact on the entire region. Energy systems in central America will have the opportunity to support increasing levels of intermittent renewable energy sources due to the ancillary and grid balancing services provided by hydropower.

As well as the abundance of natural resources enabling increased production of renewable energy, Costa Rica also holds strong commitment to environmentalism, and is one of the world's leaders in nature conservation. The extent of nature conservation in Costa Rica has spurred policymakers to pledge to become the world's first carbon-neutral economy by 2021. The country also declared certain rivers to be "pristine" and have enacted a law to keep them as such. Costa Rica sets a prime example of how to successfully harness vast amounts of hydropower to provide electricity for the entire country and potentially the extended region in the future, while equally protecting a diverse and rich natural environment.

Overall, the level of access to electricity in Costa Rica is the highest in Central America and currently stands at 99.5 per cent. Meanwhile, the consumption of fossil fuels has increased, caused by a significant growth in the number of motor vehicles. Costa Rica's largest challenge will be to decrease emissions in this sector in order to achieve the national carbon neutrality goal. The country currently plans to increase the use of electric and hybrid vehicles, which will be powered by renewable energy.

POPULATION
4,807,850

GDP
USD 54 BN

INSTALLED HYDROPOWER CAPACITY
2,123 MW

HYDROPOWER GENERATION
7,253 GWh

SOUTH AMERICA
REGION MAP

TOP SIX COUNTRIES BY INSTALLED HYDROPOWER CAPACITY (MW)* **OTHERS:** 12,021 | **TOTAL:** 164,071

1	2	3	4	5	6
BRAZIL 98,015	VENEZUELA 15,393	COLOMBIA 11,606	ARGENTINA 11,170	PARAGUAY 8,810	CHILE 7,055

SOUTH AMERICA
CAPACITY BY COUNTRY

Rank	Country	Installed hydropower capacity (MW)*
1	**Brazil**	98,015
2	**Venezuela**	15,393
3	**Colombia**	11,606
4	**Argentina**	11,170
5	**Paraguay**	8,810
6	**Chile**	7,055
7	**Peru**	5,271
8	**Ecuador**	4,409
9	**Uruguay**	1,538
10	**Bolivia**	494
11	**Suriname**	189
12	**French Guiana**	119
13	**Guyana**	1

*includes pumped storage

SOUTH AMERICA
OVERVIEW

South America was strongly affected by the El Niño Southern Oscillation (ENSO) in 2016, with less precipitation in the north in Colombia and Venezuela, where reservoirs could not be filled to optimal storage capacity, and increased precipitation in the south in the Peruvian Amazon, Ecuador and Bolivia.

With more than 9.7 GW of new hydropower installed in 2016, South America has incremented more than triple the capacity commissioned in 2015. Approximately 65 per cent of the new capacity corresponds to projects in north-west Brazil, while Peru and Ecuador brought a significant number of projects into operation.

Hydropower is key to South America's development, and thus it is at the core of the national energy strategies of countries like Bolivia, Ecuador, Paraguay, Chile and Brazil.

Colombia reached a total capacity of 11,606 MW, which represents 70 per cent of the national electricity grid, after the commissioning of the 820 MW Hidrosogamoso hydroelectric project, and the 10 MW Bajo Tuluá in 2015 and 20 MW Tunjita stations in 2016.

The ENSO effects and the suspension at the beginning of 2016 of the 400 MW El Quimbo project due to non-compliance with the environmental oxygen level for Magdalena River increased the risk of a power outage. To address this risk, in April 2016 the government introduced a six-week programme to encourage households to save energy. With this measure, Colombia saved 1,200 GWh – about a 6 per cent saving daily. In addition, the 560 MW Guatapé power plant began its operation also in April after the fire that shut it down in February 2016.

Colombia plans to further develop its hydropower potential and expand transmission lines. The company Celsia received the environmental license to construct and operate the 352 MW Porvenir II after six years of feasibility studies and environmental impact assessments. Isagen has four projects totalling 2,841 MW undergoing feasibility studies, and EPM is building the 2,400 MW Ituango hydroelectric project, expected to enter into operation in 2018.

The Venezuelan hydropower sector is facing a lack of adaptation measures to deal with the effects of climate change to weather patterns. The Guri reservoir regulates the flow that supplies the cascade hydropower complex in the Caroní river that represents 70 per cent of the national power supply. This is one of the largest hydropower generating complexes in the world, formed by the 10,235 MW Simón Bolívar, the 2,160 MW Francisco de Miranda (Caruachi), the 3,150 MW Antonio José Sucre (Macagua), and the 2,160 MW Manuel Carlos Piar (Tocoma) hydropower station, which is currently under construction.

Peru's growing electricity demand due to the new mining projects is driving an increase of installed power capacity. In 2016, the 456 MW Chaglla plant by Odebrecht, and the 510 MW run-of-the-river Cerro del Águila plant by IC Power, started commercial operations, as well as smaller hydropower plants such as Chancay (19 MW), the Rucuy (20 MW) and the Carpapata III (13 MW).

In 2016, the ministry of energy and mining of Peru finalised a detailed study to determine the wind and hydropower potential to foster the private investments in the energy sector. Among the future projects, Tractebel has been awarded a contract to upgrade Peru's largest generating asset, the 1,000 MW Mantaro hydropower plant. Smaller-scale projects include the construction of six hydropower plants in the Áncash region with a total installed capacity of 56 MW, including Renovandes H1 (20 MW) and the Potrero (20 MW).

In Bolivia, the state-owned Empresa Nacional de Electricidad (ENDE) manages the generation, distribution and transmission of energy in the country, and supports the change in the energy mix towards more renewable energy sources and the extension of the national electric interconnected system. In 2015, hydropower only represented 30 per cent of Bolivia's electricity mix: the country aims to increase this to 70 per cent by 2025.

Currently, Bolivia has three hydropower project under construction: Miguillas (203 MW), San Jose (124 MW) and Misicuni (120 MW); and over 20 projects undergoing feasibility studies, such as Rositas (400 MW), Carrizal (347 MW) and Margarita (150 MW). The National Electric Plan – 2025 also envisions large projects such as the 990 MW Cachuela Esperanza and the 1,680 MW Bala stations in the Beni River, and the Río Grande hydroelectric complex with a total capacity of 2,882 MW.

Uruguay has already developed all its viable hydropower potential, which during the last decade has represented 50–80 per cent of the energy mix. This variation is due to the annual volume variation strongly associated to the precipitation regime. The National Water Plan, published in August 2016, envisions a potential 10 per cent hydropower generation increase by upgrading existing plants and developing multipurpose plants. In order to increase resilience and diversify the energy mix, Uruguay is fostering the development of wind power. Since 2006, the wind farms for large-scale generation have 1,227 MW of installed capacity, increasing to 95 per cent the electricity provided from clean energy.

In 2016, Yacyretá, shared between Argentina and Paraguay, exceeded

21,000 GWh annual generation, and upgrading works to produce 5 per cent more electricity by 2023 have begun. After the filling, the Punta Negra station started test operation in May 2016.

After a government decision to downsize the planned Néstor Kirchner and Jorge Cepernic hydropower projects in Patagonia from a cumulative capacity of 1,740 MW to 1290 MW, the projects have stalled while they undergo additional environmental impact assessments. The decision to reduce the capacities was due to cost considerations and savings up to USD 1.3 billion. These projects are framed in the China–Argentina cooperation agreement, and also include the 75 MW El Tambolar in San Juan River, and the multipurpose 637 MW Chihuido I in the Neuquén River.

Argentina is fostering the development of hydropower projects in the Mendoza province, with El Baqueano (190 MW), Cordon del Plata (1,100 MW), Los Blancos (464 MW) and Portezuelo del Viento (216 MW) undergoing feasibility studies.

HYDROPOWER TARGETS

Country	Target
Brazil	Increase installed hydro capacity to 116,700 MW by 2019
Ecuador	86 per cent of electricity demand to be covered by hydropower by 2020
Venezuela	613 MW renewable energy to be provided to isolated and rural communities by 2019, including through hydropower

SOUTH AMERICA
BRAZIL

Brazil has the largest hydro resources in South America, with an estimated technical potential of 3,040 TWh/yr. However, less than a third, about 818 TWh/yr, is considered economically exploitable, of which Brazil has already exploited over half. On top of that, plants with a capacity of less than 30 MW are estimated to have an economically exploitable capacity of 11.2 TWh/yr.

During 2016, 9,526 MW was added to the national electricity grid, the highest value in the historical records since 1998. The hydropower sector represents 55 per cent of this total. However, the recent recession experienced by Brazil's economy caused a slowdown in electricity demand growth. The demand in 2015 and 2016 remained practically unchanged compared to that of 2014, mainly driven by the fall in industry consumption. In 2017, Brazil expects to increase installed hydropower capacity by about 4,000 MW.

In December 2016, the 3,750 MW Jirau hydropower project, located on the Madeira River in the state of Rondônia, close to the border with Bolivia, was inaugurated. The plant is operated by Energia Sustentável do Brasil, where Engie is the largest shareholder. The project is certified by the Clean Development Mechanism of the United Nations for the commercialisation of carbon credits.

Jirau is part of a hydroelectric complex on the Madeira River. The Santo Antônio run-of-river plant is located downstream of the Jirau plant with a total capacity of 3,568 MW. The third project, Guayaramerín, will be located on the border between Brazil and Bolivia, and the fourth, Cachuela Esperanza, will be located further upstream in Bolivia. The complex is framed on the Initiative for the Integration of the Regional Infrastructure of South America (IIRSA), an initiative to build an infrastructure network by South American national governments, to satisfy both increasing energy demands and navigational interests.

During 2016, other highlights of hydroelectric generation are the increase of commercial operation from the existing plants: 652 MW entered into operation in Santo Antônio, 1,092 MW in Teles Pires, and 518.8 MW in Maranhão III.

Belo Monte, the second largest hydropower development in Brazil, activated its first turbines in April 2016 and by December 2016, Belo Monte already had 1,989 MW in commercial operation. Located on the Xingu River in the state of Pará, it represents the largest 100-per-cent national development, with a total installed capacity of 11,233 MW, with 24 turbines divided into two powerhouses.

Small hydropower plants, defined in Brazil as lower than 30 MW, comprised 203 MW added capacity in 2016.

Hydropower provides services to support the intermittency of increasing wind and solar power installations in Brazil. The state-owned Energy Research Company identified new potential hydroelectric projects that could add 50.7 GW of energy storage to the national interconnected system to reduce the fragility of the grid to climatic variations. In addition, Brazil is investigating new technology to increase the resilience of the energy system, and has invested in floating solar pilot projects at the Balbina and Sobradinho reservoirs.

In 2016, ANEEL granted new operating licences for 29 existing hydropower plants with a total installed capacity of 6,000 MW. China Three Gorges Corporation's Brazilian subsidiary, CTG Brasil, successfully bid for the highest lot formed by Jupiá and Ilha Solteira in the river Paraná (1,551 MW and 3,444 MW respectively) for about USD 746 million. CTG paid USD 2.81 billion to the Brazilian Government for that concession right. At the end of the year, CTG Brasil completed the acquisition of Duke Energy assets in Brazil with 2,274 MW, increasing its installed capacity in the country to 8.27 GW.

POPULATION
207,847,528

GDP
USD 1,775 BN

INSTALLED HYDROPOWER CAPACITY
98,015 MW
INCL. 30 MW PUMPED STORAGE

HYDROPOWER GENERATION
410,237 GWh

SOUTH AMERICA
CHILE

Chile has been one of Latin American's fastest-growing economies over the past decade. As it continues to grow, it is expected that Chile's energy demand will increase from roughly 75 TWh today, to over 100 TWh by 2020. The country will have to add over 8 GW of new generation capacity by 2020 in order to meet the expected expansion in demand.

Chile has struggled to exploit its abundant supply of natural resources or encourage adequate development of the power sector in order to satisfy the rate of economic growth. This is predominantly due to the lack of connection between the power system grids and lack of critical investments. As a result, the country is facing high energy prices as well as an absence of energy supply and security.

The country has an abundance of natural resources ideal for harnessing renewable energy sources, including vast deserts for solar power, forests and rivers in the south for biomass and hydropower, and winds across the country for potential wind generation. The country also has 6,400 km of coastline where tidal and wave power could potentially be harnessed. In 2014, the Chilean Government facilitated the establishment of MERIC (Chile's Marine Energy Research and Innovation Centre) for further research and development of marine projects off the Chilean coast.

There is currently a total of 7,055 MW of installed hydropower capacity in Chile. The majority is concentrated in the Maule and Bío Bío regions, where the plants export production to Santiago. The National Energy Strategy (ENE) has targets for 45-48 per cent of electricity generation to be sourced from hydropower by 2024. The strategy also estimates that Chile's hydro energy potential could easily exceed 12.5 GW.

Chile also aims to promote the sustainable development of hydropower including through new environmental legislation and land-use planning in river basins. In 2016, the ministry of energy launched an online platform, "Hidroelectricidad Sustentable", to publish information from the study of hydropower potential of several river basins in central-southern Chile. Overall, in order to further encourage the deployment of renewable energy sources in Chile, substantial investments are required in the transmission system.

Chile's electricity transmission system is divided into four sections. The SING (Sistema Interconectado del Norte Grande) is the northern grid, and accounts for roughly 20 per cent of national generation. The SIC (Sistema Interconectado Central) is the central region's grid, which accounts for 68.5 per cent of national generation and serves 93 per cent of Chile's population. The remaining two systems in southern Chile – the Aysén grid and the Magallanes grid – contribute 0.3 and 0.8 per cent respectively. In efforts to connect the grids together, and with isolated renewable energy projects, an interconnection between the SING and SIC lines will be finalised in 2017, providing a larger market for the high concentration of solar energy in the north to the most populated central regions around Santiago.

The Chilean Government has implemented the 100 Mini Hydro Plan in order to develop 100 additional small-scale hydropower plants each with a total installed capacity of under 20 MW by 2018. The projects will be predominantly distributed between Metropolitana and Aysén in order to meet energy demand in areas outside of the country's main transmission networks. As mini-hydro developers must often build their own transmission lines, lack of sufficient transmission infrastructure remains a significant challenge in Chile.

New projects commissioned in 2016 include the 60 MW El Paso run-of-river facility in the Colchagua province, which will provide electricity to the central SIC grid. Another notable project in planning is the 300 MW Espejo de Tarapacá pumped storage plant. The hybrid project proposes to combine hydropower and solar power. The pumped storage system will use the Pacific Ocean as a lower reservoir, and the natural depressions in the overlying plateaus as an upper storage reservoir. The project is still in the process of reaching financial close.

POPULATION
17,948,141

GDP
USD 241 BN

INSTALLED HYDROPOWER CAPACITY
7,055 MW

HYDROPOWER GENERATION
20,799 GWh

SOUTH AMERICA
ECUADOR

A decade ago, Ecuador was highly dependent on fossil fuel production for power generation, with thermopower plants accounting for about half of energy production. Fossil fuels also represented almost the half of the exportations from the country. About 40 per cent of the population had a subsistence livelihood, and rural and indigenous populations faced a lack of access to electricity. In 2006, hydropower represented 44 per cent of energy production with 1,640 MW installed capacity.

Ecuador took the decision to exploit its hydropower potential, estimated at more than 20,000 MW, to reduce the country's reliance on fossil fuel and foster economy growth. Hydropower is crucial in the government's strategy to change the energy mix, increase energy security and reduce energy cost.

Framed in the National Plan for Good Living 2009–2013, the most important milestone was the decision to begin the simultaneous construction of eight hydropower projects that will increase the total capacity by 2,832 MW. Ecuador aims to have one of the cleanest energy mixes in the world by generating 90 per cent of its energy from hydropower once all the plants are in full operation in 2017.

With these eight hydroelectric projects, Ecuador will be able to satisfy the national domestic energy demand and export surplus energy to Colombia and Peru. The government estimates this will save millions of USD by not importing fossil fuels to operate thermopower plants, and will also reduce CO_2 emissions.

Within the framework to eradicate poverty, promote sustainable development and equitable redistribution of resources, Ecuador now leads in promoting energy security in the region.

The grid has also been strengthened by more than 2,000 km of transmission lines and an increase of transformative capacity by 74 per cent in one decade. In order to connect the new hydropower plants to the national electricity grid, 600 km of high-voltage 500 kV transmission lines are under construction. They connect four substations: one in the north-east, close to the 1,500 MW hydropower plant Coca Codo Sinclair; two in the centre close to Quito and Tisaleo; and one in the south-west in Guayaquil, increasing the supply reliability to the country's major demand centres. Power generation, distribution and commercialisation are managed by the state-owned company CELEC (Electric Corporation of Ecuador).

Ecuador's most emblematic hydropower project, the 1,500 MW Coca Coda Sinclair plant, went into full operation in November 2016. The first four Pelton units started to generate electricity in April just three days before the 7.8 magnitude earthquake. The plant did not suffer any damage and continues to supply power to the national grid. The USD 2.25 billion project was 70 per cent financed by the Chinese Exim Bank and built by the Sinohydro Corporation. It is the largest hydroelectric project in Ecuador, and the largest built by China overseas, meeting 30 per cent of total domestic electricity demand with a mean annual generation of 8,734 GWh.

The Sopladora hydropower project, the third largest in Ecuador, was completed in August 2016. At a cost of USD 755 million, the project was 85 per cent financed by the Chinese Exim Bank and built by a Chinese consortium. The station is part of the Hydropaute cascade scheme in the Paute River, located in the south-east. Sopladora relies on the water discharged by the upstream 1,075 MW hydroelectric plant Molino. Three Francis turbines with a power of 487 MW will supply an average annual generation of 2,770 GWh to the national grid, meeting about 13 per cent of energy demand.

Five other hydropower projects from the government's strategic plan are in an advanced stage of construction. They are spread across the country, and CELEC plans to start their operation in 2017. These include Minas San Francisco (275 MW), Toachi-Pilatón (254 MW), Delsitanisagua (180 MW), Quijos (50 MW), and Mazar-Dudas (21 MW).

POPULATION
16,144,363

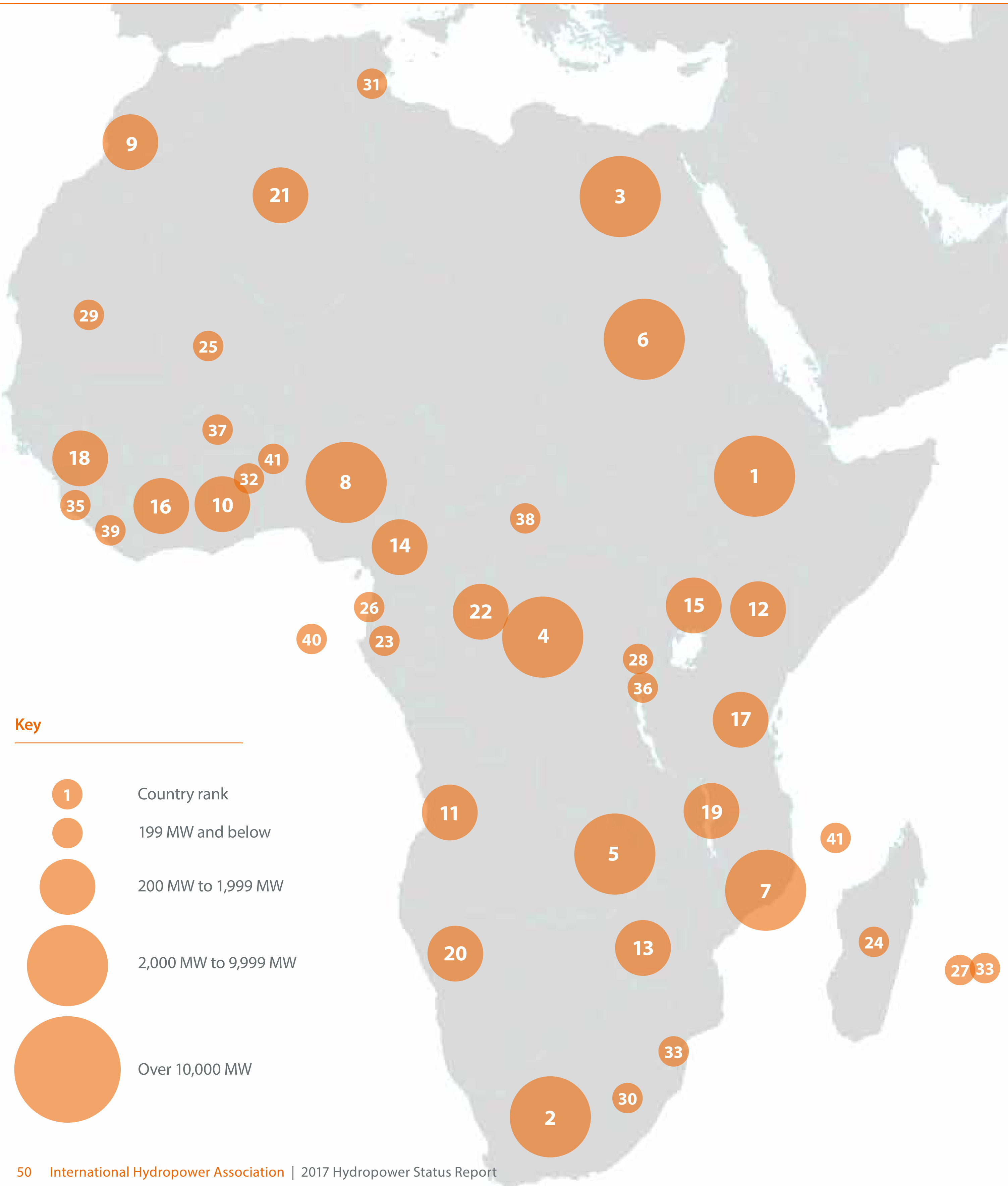
GDP
USD 100 BN

INSTALLED HYDROPOWER CAPACITY
4,409 MW

HYDROPOWER GENERATION
15,590 GWh

The 1,500 MW Coca Codo Sinclair hydropower plant, Ecuador

AFRICA
REGION MAP



TOP SIX COUNTRIES BY INSTALLED HYDROPOWER CAPACITY (MW)* **OTHERS:** 16,036 | **TOTAL:** 33,624

1	2	3	4	5	6
ETHIOPIA	S. AFRICA	EGYPT	DR CONGO	ZAMBIA	SUDAN
4,054	3,583	2,800	2,509	2,392	2,250

AFRICA
COUNTRY RANKINGS

Rank	Country	Installed hydropower capacity (MW)*
1	**Ethiopia**	4,054
2	**South Africa**	3,583
3	**Egypt**	2,800
4	**DR Congo**	2,509
5	**Zambia**	2,392
6	**Sudan**	2,250
7	**Mozambique**	2,187
8	**Nigeria**	2,040
9	**Morocco**	1,770
10	**Ghana**	1,584
11	**Angola**	1,267
12	**Kenya**	818
13	**Zimbabwe**	769
14	**Cameroon**	751
15	**Uganda**	706
16	**Côte d'Ivoire**	604
17	**Tanzania**	562
18	**Guinea**	368
19	**Malawi**	364
20	**Namibia**	341
21	**Algeria**	228
22	**Congo**	209
23	**Gabon**	170
24	**Madagascar**	164
25	**Mali**	157
26	**Equatorial Guinea**	127
27	**Réunion**	121
28	**Rwanda**	103
29	**Mauritania**	97
30	**Lesotho**	80

Rank	Country	Installed hydropower capacity (MW)*
31	**Tunisia**	66
32	**Togo**	65
33	**Mauritius**	60
33	**Swaziland**	60
35	**Sierra Leone**	59
36	**Burundi**	54
37	**Burkina Faso**	32
38	**Central African Republic**	25
39	**Liberia**	22
40	**São Tomé and Príncipe**	4
41	**Benin**	1
41	**Comoros**	1

*includes pumped storage

AFRICA
OVERVIEW

A lack of power infrastructure, especially in sub-Saharan Africa, is hindering the region's economic and social development. Over 30 African countries are currently experiencing power shortages, resulting in outages and over-reliance on expensive and often environmentally unfriendly temporary solutions. There are encouraging signs though, with greater involvement from the private sector through various policies and programmes injecting substantial capital into local power industries.

While the traditional approach has been to increase generation capacity, countries are tending to cooperate more to improve energy access. Greater regional integration through transmission interconnectors and shared power pools is enabling countries to maximise the benefits of abundant, yet unevenly distributed, natural resources. Greater transmission can help alleviate temporary shortfalls in production and further monetise surpluses.

The African region added over 3 GW of new hydropower capacity in 2016, including commissioning the 1,332 MW Ingula pumped storage project in South Africa. Ethiopia completed the commissioning of the final eight turbines of its transformative Gibe III project.

In 2016, Cameroon commissioned the final two 5 MW turbines at the Mekin project, which began producing electricity in 2015. The country reached further important milestones in 2016. The government was able to confirm EDF and IFC's cooperation and financial commitment on the 420 MW Nachtigal hydropower plant on the Sanaga River, which upon completion in 2021 should increase Cameroon's total installed capacity by more than 30 per cent. This will help relieve chronic power shortages and meet the country's goal of 3,000 MW total installed capacity by 2020, up from the current 1,400 MW, over half of which is hydropower.

Cameroon looks to be on track, with Sinohydro expected to commission the 211 MW Memve'ele project in summer 2017. The China International Water and Electric Corporation began impounding water at the 30 MW Lom Pangar project in 2015, attracting new fishing settlements in 2016. Commissioning of electromechanical equipment is scheduled for 2018.

Morocco approved its first three hydropower projects by an independent power producer in late 2016. This follows a 2015 policy to promote private sector engagement in developing renewable energies. Tillouguit Aval (30 MW) and Tillouguit Amont (8 MW) are located on the Ahancal River, while Boutferda (18 MW) is on the Laabid River in the Middle Atlas mountain range.

Zimbabwe completed the third and final hydro project along the Pungwe River in 2016. The 3.75 MW Pungwe C project was commissioned in March 2016, harnessing the power of the Chiteme river, a tributary of the Pungwe river. The two other projects, Pungwe A (2.7 MW) and Pungwe B (15 MW), were commissioned in 2010 and 2015 respectively.

The Tokwe Mukorsi dam in Masvingo was completed after 15 years of work, and construction began on the 15 MW hydropower station. The station will bring further benefits to the dam, which now has the capacity to irrigate 26,000 hectares of land as well as delivering other economic advantages. Other projects in the pipeline include the 30 MW Gairezi project, for which an EPC contract was signed in 2016, and the proposed 2,400 MW Batoka Gorge, shared with Zambia. Both are currently seeking funding. The first stage of the extension of the Kariba hydropower station should add a further 150 MW to the southern power station by the end of 2017, while a further 150 MW is expected in 2018.

Generation began in early 2016 at Zambia's 120 MW Itezhi-Tezhi hydropower project on the Kafue River. The project installed two 60 MW turbines at the existing dam, which regulates water for the 900 MW Kafue Gorge power stations some 200 km downstream. The project is supplying Zambia's capital Lusaka through a newly constructed 280 km transmission line. The line also connects the power station to the Southern African Power Pool, reducing electricity prices and the region's reliance on fossil fuels. The project was the first public–private partnership in the Zambian power sector, between Zesco, the Zambian power utility, and India's Tata Power.

Three hydropower projects were completed in Sierra Leone in 2016, totalling 5 MW. Bankasoca (2.2 MW), Charlotte (2.2 MW) and Makali (0.64 MW) were delivered in cooperation with the Chinese Hunan Construction Engineering Group as part of the government's push to boost decentralised power production to improve energy access in rural communities. While the projects have been completed, considerable work remains to be done to improve the transmission and distribution system.

Liberia reached an important milestone with the reconstruction of the 88 MW Mount Coffee hydropower project after the first 22 MW turbine was commissioned in late 2016. The project was originally commissioned in 1973 but was destroyed during the civil war in the 1990s.

The Rwanda Mountain Tea company completed its second hydropower station in as many years, finalising work on the 4 MW Giciye II project on the Giciye River. This project falls within the government's policy to increase private sector engagement in renewable energy development. The Rwandan Government supported the project by constructing access roads and building transmission lines to connect the power station to the grid. Giciye II was able to take advantage of the infrastructure built around its 4 MW sister Giciye I plant, and there are plans for a third hydropower station. As part of the East African Power Pool (EAPP), Rwanda is scheduled to begin importing 400 MW of power from Ethiopia and 30 MW from Kenya by the end of 2017.

DR Congo announced that the first of three 50 MW turbines would begin generation at the 150 MW Zongo 2 project in summer 2017. Meanwhile, work was completed on the Mwadingusha project, the first of three hydro plants undergoing upgrading and modernisation. It will supply an additional 11 MW to the national grid, bringing total installed capacity to 71 MW. Modernisation work will now begin on the Koni (36 MW) and Nzilo 1 (100 MW) projects. The 9.3 MW Kakobola project in Kwilu province was also commissioned after three years of construction.

Construction has resumed on Gabon's FE2-Mitzic (36 MW) and Empress Ngounié Falls (84 MW) projects. This is part of the country's target to increase its national power installed capacity from 374 MW to 1,200 MW by 2020, with the goal of achieving universal access to electricity. China Gezhouba Group has stepped in to take over construction work after the previous development company's contract was terminated.

The 128 MW Sambangalou project currently under construction in Senegal is set to be connected to the recently completed 402 MW Kaleta project in Guinea. This follows an agreement between members of the Gambia River Basin Organisation (OMVG). The 1,677 km of transmission lines will improve the quality of electricity supply for OMVG countries and create a more stable and reliable shared power system.

Uganda, a member of the EAPP, is currently looking to double power generation by harnessing its hydropower resources. The Isimba Power Station (183 MW) is expected to be complete in 2018, while the 600 MW Karuma project is scheduled for 2019. This would increase the country's total installed hydropower capacity to greater than 1,500 MW.

Uganda plans to export a portion of this hydropower to the other countries of the EAPP, which is currently constructing over 2,000 km of transmission lines and cross-border interconnections. These are expected to be completed in various stages between 2018 and 2020.

Eastern Africa suffered from a drought in 2016 which reduced hydropower generation in the region. Ugandan hydropower reservoirs were able to adjust to this shortfall by obtaining permission to release some 10 per cent more water for power generation, reducing the need to replace power deficits with expensive diesel-fired generation.

HYDROPOWER TARGETS

Country	Target
Angola	9,000 MW total installed capacity by 2025
Ethiopia	22,000 MW total installed capacity by 2030
Kenya	Hydropower to represent 5 per cent of total installed capacity by 2031
Morocco	2,000 MW increase in hydropower installed capacity by 2020
Mozambique	5,400 MW total installed capacity by 2025
Nigeria	2,000 MW increase in small-scale hydropower installed capacity by 2025

AFRICA

ANGOLA

A country blessed with many rivers, Angola's hydropower potential is among the highest in Africa, estimated at 18,200 MW. This, coupled with increasing demand for electricity following years of strong economic growth and urbanisation, has placed hydropower development as a central element of the Angolan Government's long-term vision for its power sector. The government's stated aim is to substantially grow its hydropower generation capacity from its current levels of around 1,200 MW to 9,000 MW by 2025.

Angola's hydropower development has been mainly located on the Kwanza River, the country's largest river, and includes the Capanda plant (520 MW) and the Cambambe plant, which in 2016 increased its capacity from 260 MW to 610 MW following the completion of two of the four 175 MW turbines being constructed at a second power station. Once fully completed, the Cambambe plant will have an installed capacity of 960 MW.

The Kwanza River is also home to several other hydropower projects either under construction or in the planning stages, including Laúca (2,070 MW) and Caculo Cabaça (2,170 MW). The Laúca project, which commenced construction in 2012, is expected to begin operations in 2017 and is the largest civil engineering project being undertaken in Angola. Once Laúca is fully operational, installed hydropower capacity in the country is expected to reach close to 4,000 MW, representing roughly 70 per cent of the total installed power capacity.

In late 2016, the Industrial and Commercial Bank of China signed an agreement with the Angolan Government to grant a loan to finance the construction of the Caculo Cabaça hydropower project. Located in the Middle Kwanza, the project is expected to take over six years to build and will contribute to the power supply security of the domestic market, and that of neighbouring countries that form the Southern African Power Pool (SAPP).

On the Cunene River, in the south of the country near the Namibian border, decades after the initial studies were conducted, the proposed Baynes hydropower project (600 MW) may commence construction in 2017. A joint Angolan and Namibian initiative, the project would be supported by a proposed new power transmission line being coordinated by the SAPP, which would further improve the region's connectivity.

Other hydropower plants located on the Cunene River include Matala (40 MW), which in 2016 underwent a rehabilitation to ensure its structural safety and to increase its production capacity, Gove (62 MW), Mabubas (27 MW), Biopio (14 MW) and Calueque (20 MW). Projects in the pipeline include Jamba ia Oma (65 MW) and Jamba ia Mina (180 MW).

Further hydropower projects along the Keve River in central Angola have also been identified by the government, and include Capunda (330 MW), Dala (440 MW) and Cafula (520 MW).

Finally, the 65 MW Lomaum hydropower plant in Cubal, located in Benguela province, reopened in 2016 after lying idle since 1984 due to being heavily damaged in the country's civil war that ended in 2002.

POPULATION
25,021,974

GDP
USD 103 BN

INSTALLED HYDROPOWER CAPACITY
1,267 MW

HYDROPOWER GENERATION
4,954 GWh

AFRICA
CÔTE D'IVOIRE

Hydropower currently accounts for approximately 32 per cent of total installed capacity in Côte d'Ivoire, and is responsible for 16 per cent of total electricity generated in the country. The country still has a vast amount of untapped resources, specifically concerning hydropower and solar generation. A study by Électricité de France in 1980 put the theoretical potential of hydropower at 46 TWh/year, with an economically exploitable potential of approximately 12.4 TWh.

Côte d'Ivoire's growing economy is putting the power supply network under pressure, and the government is targeting an increase in overall generating capacity from 2,000 MW to 4,000 MW by 2020. This growth is expected to be reached by using a mix of gas-fired generation and hydroelectric power, and the expansion will be mostly driven by the private sector.

As part of the enhancing private sector engagement, foreign investment has been a feature of the Ivorian electricity market for a quarter of a century. This dates back to the privatisation that created the Compagnie Ivoirienne d'Electricité (CIE), the power supplier and distributor at the heart of the sector. Eranove, the company that now owns a majority stake in CIE, also owns Ciprel, one of the country's independent power producers. Overall, Côte d'Ivoire has developed and maintained a vigorous regulatory framework for the power sector that has encouraged investor confidence. In order to sustain investments, the energy ministry has approved higher tariffs, enabling flat costs for poorer domestic users while raising prices up to 10 per cent for the largest industrial users.

Developing sustainable energy through renewable and other new sources is one of the focus areas of the government's 2011–30 Strategic Development Plan. The government has set targets to reach 34 per cent of renewable energy by 2020 and to increase energy efficiency in industry by 25 per cent by 2030.

In its strategic plan for the development of the electricity sector by 2030, the Côte d'Ivoire Government identified 66 projects that will require significant private-sector investment, including through public–private partnerships with independent power producers. Overall, the country aims to expand generation capacity and modernise the nationwide transmission and distribution of electricity.

Côte d'Ivoire's largest hydropower facilities include projects such as the Buyo Dam (165 MW), Kossou Dam (174 MW) and Taabo Dam (210 MW), and several others. There are also plans to build additional dams in Louaga (283 MW), Boutoubré (156 MW) and Tiboto (220 MW). The country is currently constructing its biggest hydropower facility – the Soubré hydropower dam (275 MW), which is located upstream around the natural falls of the Sassandra River, and has been predominantly supported by Chinese funding. The project is expected to come online in 2017, a year earlier than anticipated. Singrobo (44 MW), which is being primarily funded by the African Finance Corporation (AFC), is due to come online in 2020. The Gribo Popoli (112 MW) project is due to come online in 2021.

Regionally, Côte d'Ivoire considers itself as one of the most significant players in the pan-regional West African Power Pool, with further plans for interconnections to Liberia, Sierra Leone and Guinea currently under consideration. Electricity in Côte d'Ivoire is currently exported to Benin, Burkina Faso, Ghana, Liberia, Mali and Togo.

POPULATION
22,701,556

GDP
USD 32 BN

INSTALLED HYDROPOWER CAPACITY
604 MW

HYDROPOWER GENERATION
1,799 GWh

AFRICA
ETHIOPIA

For the past decade, Ethiopia's economy has been one of the fastest-growing in the world, averaging an 11 per cent increase in GDP each year. Record GDP growth, coupled with a population growth rate of 2.3 per cent, has led to a staggering 14 per cent increase in energy demand. The country is making significant efforts to satisfy demand, maintain growth and supply a population where currently only 25 per cent have power connectivity.

Ethiopia is fast becoming a centre of industry and new infrastructure, with the aspiration to achieve middle-income status by 2025. Since 2011, Ethiopia has implemented the Climate-Resilient Green Economy (CRGE) strategy, which substitutes conventional development by means of harnessing clean energy sources like hydropower, wind, geothermal, solar and biomass, and implementing energy-efficient technologies in the transport and industrial sectors.

With its 2010 Growth and Transformation Plan I (GTP-I), Ethiopia aimed to quadruple installed capacity by prioritising large hydro developments and achieving total power installed capacity of 10,000 MW by 2015. The government published the GTP-II for 2016–20, with the objective of reaching total installed capacity over 17,208 MW. Hydropower is set to make up about 90 per cent of the power supply.

Ethiopia has some of the richest water resources in Africa, distributed across eight major basins with an exploitable hydropower potential of 45,000 MW. Over half of this potential is located in the Abbay and Omo river basins, where the nearly-completed 6,000 MW Grand Ethiopian Renaissance Dam (GERD) and the recently-completed 1,870 MW Gibe III project, are located.

Gibe III, the tallest roller-compacted concrete (RCC) dam in the world, with 246 m dam height and 630 m crest length, was inaugurated in December 2016. The USD 1.8 billion construction was financed 40 per cent by the Ethiopian Government, and 60 per cent by the China Exim Bank. While all turbines have been installed and commissioned, not all are yet online, as reservoir filling is still in progress.

GERD's construction is progressing according to the timeframe, with more than half already complete. Sudan, Egypt and Ethiopia agreed a new declaration for cooperation in March 2016 that alters the 1929 treaty, where Egypt had a veto over any upstream projects in the Nile River. In addition to GERD's construction, the 254 MW Genale Dawa hydropower plant is near completion.

Salini Impregilo, the constructor of Gibe III and GERD, signed a USD 2.8 billion contract with EEP in March 2016 to build the 2,160 MW Koysha hydro project. The project is financed between EEP and the Italian Export Credit Agency.

Downstream from Gibe III, this is the fourth plant in the Omo River cascade scheme, which envisions a fifth dam further downstream. Other hydropower projects in the bidding phase are Tams (1,700 MW), Chemoga Yeda (280 MW), and the Geba complex (385 MW).

PowerChina Huadong Engineering Corporation completed the rehabilitation – at a cost of USD 14 million – of Ethiopia's oldest hydropower plant, the 6.6 MW Aba Samuel, which dates back to 1941.

The GTP-II also envisions exploiting alternative sources such as wind, solar, geothermal and biogas resources. The exploitable capacity from other sources is estimated at 1.3 million MW (wind) and 7,000 MW (geothermal). The 1,000 MW Corbetti geothermal power project, with a cost of USD 4 billion, is expected to be commissioned in 2018. Currently, the 300 MW Aysha, 100 MW Debreberhan and 150 MW Itaya wind farms are under development, with others like the 100 MW Assela under study.

Ethiopia is also rapidly expanding its transmission and distribution network in order to light up the country. Existing cross-border interconnections include 100 MW to Sudan and 50 MW to Djibouti, while the 1,000 km Eastern Electricity Highway Project (500 kV) will be capable of exporting 2,000 MW to Kenya upon completion in 2018. The country has ambitions of becoming the 'energy hub' within the Eastern Africa Power Pool.

POPULATION
103,205,224

GDP
USD 62 BN

INSTALLED HYDROPOWER CAPACITY
3,813 MW

HYDROPOWER GENERATION
9,674 GWh

AFRICA
TANZANIA

Tanzania has abundant energy sources, most of which remain unexploited. Hydro has traditionally played a significant role: with an installed capacity of 562 MW, it accounts for roughly one-third of total installed power capacity. With a hydro potential of 4.7 GW, the country plans further development, but views weak transmission infrastructure as a significant short-term barrier.

Only 41 per cent of the population has access to electricity. Low population density and expensive transmission costs have led to the government adopting targeted policies to develop off-grid schemes in order to increase the current levels of rural electricity access.

In 2016, the Tanzania Rural Electrification Expansion Project was approved by the World Bank, with USD 200 million in funding from the International Development Association. The programme will scale up the supply of renewable energy in rural areas while strengthening sector institutional capacity. Overall, the Tanzanian power system master-plan aims to achieve 75 per cent access by 2035, compared to 41 per cent today. This will require a seven-fold increase on the current rate of installed capacity in order to satisfy demand.

The Tanzanian Government's Big Results Now (BRN) initiative seeks to phase out high-cost emergency power plants, increase total generation capacity from 1,300 MW to 2,780 MW, reform operations at the public utility (TANESCO) and meet increasing demand through low-cost solutions.

In recent years, the ministry for energy and minerals has established a framework for developing small power projects using the country's abundant renewable energy resources. This aims to accelerate access to electricity and promote the development and operation of small power projects among local and foreign private investors. Eligible projects are those with a capacity ranging from 100 kW to 10 MW, which use a renewable energy source, and which intend to supply commercial electricity to the national grid or isolated grid in the country.

One of the first projects implemented under this initiative, the Tulila hydroelectric plant on the Ruvuma River in southern Tanzania has since 2015 been delivering 5 MW (with provision to expand to 7.5 MW) of renewable electricity to a TANESCO-operated mini-grid, which supplies the remote Ruvuma region. The region was previously dependent on diesel-generated power. The project, developed by the African Benedictine Sisters convent, reliably produces and sells excess electricity to the state-owned energy supplier. This in turn generates long-term income for the convent's charitable work, including a kindergarten, schools with roughly 1,400 schoolchildren and an orphanage.

Agriculture is the basis of the Tanzanian economy, representing almost 30 per cent of the national GDP. It is therefore critical that the country has sufficient infrastructure for irrigation in order to support agricultural industry during periods of drought. Hydropower facilities could be used to store water specifically so that it can be released during periods of drought.

Recent notable hydropower projects in Tanzania include Rusumo Falls (80 MW), which was agreed by energy ministers of Burundi, Rwanda and Tanzania in 2014. In 2016, contracts were awarded for the electromechanical equipment and dam facilities, with operation scheduled to begin in 2019. Supported by the World Bank and the African Development Bank, the project is located on the Kagera River along the Rwanda–Tanzania border, and will share its output with, and connect the grids of, Rwanda, Tanzania and Burundi.

The Kikonge project, currently in the planning process, will store water to be released during periods of drought. The project comprises a dam across the Ruhuhu River, forming a reservoir of 6 billion m^3, capable of generating 300 MW. The pre-feasability study is partially funded by the African Development Bank. A high-voltage transmission line, an irrigation scheme and an agro-business development are also planned as part of the project.

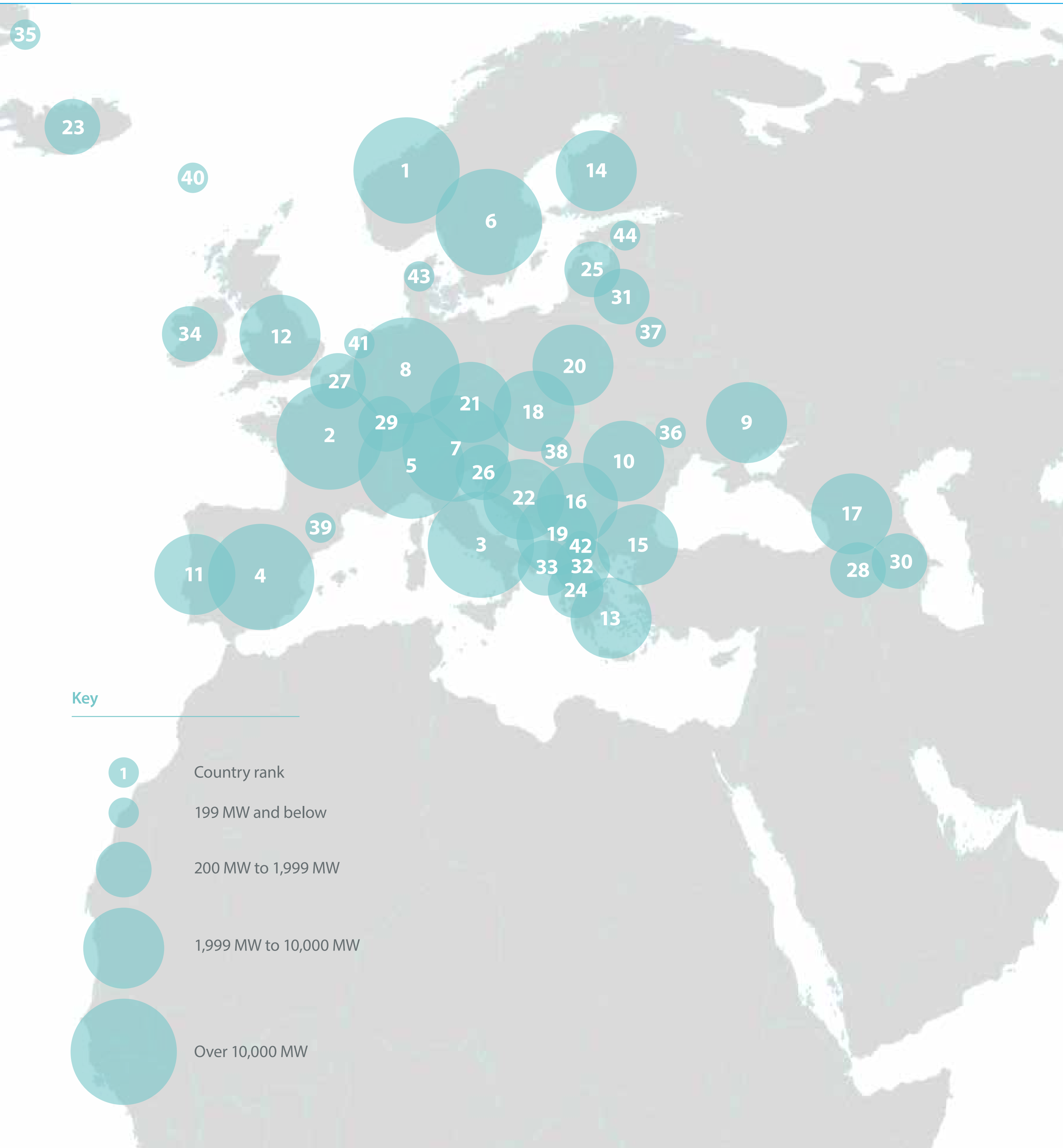
POPULATION
53,470,420

GDP
USD 46 BN

INSTALLED HYDROPOWER CAPACITY
562 MW

HYDROPOWER GENERATION
1,916 GWh

EUROPE
REGION MAP



TOP SIX COUNTRIES BY INSTALLED HYDROPOWER CAPACITY (MW)*					OTHERS: 90,663 | TOTAL: 223,008
1	2	3	4	5	6
NORWAY	FRANCE	ITALY	SPAIN	SWITZERLAND	SWEDEN
31,626	25,405	21,884	20,354	16,657	16,419

EUROPE
CAPACITY BY COUNTRY

Rank	Country	Installed hydropower capacity (MW)*
1	**Norway**	31,626
2	**France**	25,405
3	**Italy**	21,884
4	**Spain**	20,354
5	**Switzerland**	16,657
6	**Sweden**	16,419
7	**Austria**	13,177
8	**Germany**	11,258
9	**Ukraine**	6,785
10	**Romania**	6,705
11	**Portugal**	6,293
12	**United Kingdom**	4,450
13	**Greece**	3,396
14	**Finland**	3,198
15	**Bulgaria**	3,129
16	**Serbia**	2,835
17	**Georgia**	2,727
18	**Slovakia**	2,522
19	**Bosnia and Herzegovina**	2,504
20	**Poland**	2,351
21	**Czech Republic**	2,212
22	**Croatia**	2,141
23	**Iceland**	1,986
24	**Albania**	1,608
25	**Latvia**	1,576
26	**Slovenia**	1,479
27	**Belgium**	1,427
28	**Armenia**	1,249
29	**Luxembourg**	1,134
30	**Azerbaijan**	1,118

Rank	Country	Installed hydropower capacity (MW)
31	**Lithuania**	876
32	**Macedonia**	674
33	**Montenegro**	658
34	**Ireland**	529
35	**Greenland**	90
36	**Moldova**	76
37	**Belarus**	73
38	**Hungary**	56
39	**Andorra**	45
40	**Faroe Islands**	39
41	**Netherlands**	37
42	**Kosovo**	36
43	**Denmark**	9
44	**Estonia**	8

* includes pumped storage

EUROPE
OVERVIEW

As European countries aim to transition to a more secure, affordable and decarbonised energy system, adopting climate and energy targets for 2020, 2030 and 2050, hydropower is poised to play a central role.

In 2016, the total installed hydropower capacity in Europe amounted to 223 GW. Several countries have already put forth even more ambitious targets for the following decades, including further penetration of variable renewable sources such as wind and solar power. As a consequence, the power system will face more generation-driven fluctuations. These fluctuations will have to be dealt with through flexible generation, storage options and interconnectors.

Renewable energy represented 29.6 per cent of the European energy mix in 2016, of which 10.7 per cent came from hydropower. It is the most flexible and consistent of the renewable energy sources, offering baseload capability, storage capability and grid stabilisation by meeting peak and unexpected demand. Flexible hydropower can play a major role in European energy objectives by enabling the increased penetration of intermittent renewables into the power grid.

Furthermore, storage hydropower, including pumped storage, offers a range of ancillary services, which can further enable the increased penetration of fluctuating renewable energy sources across the region. In addition, investment in new pumped-storage technologies such as variable speed pump-turbines as well as ternary systems is growing. However, the high penetration of variable renewables is also significantly affecting peak pricing, making pumped storage systems less profitable. Certain mature markets will require market reforms to adequately compensate pumped storage services.

In 2016 an estimated 2,500 MW of pumped storage capacity was planned or under construction, mostly concentrated in France and Spain up until 2020. In eastern Europe in particular there are highly developed hydropower markets, for example in the Caucasus region. These are open to investment for modernisation and expansion of existing assets to secure more efficient and sustainable operations. In northern and western Europe, the industry is moving towards modernisation and expansion of existing assets, in an effort to secure more efficient and sustainable operations in the region. Latvian state utility Latvenergo, for example, is presently engaged in a USD 214.5 million upgrade programme of its hydropower facilities.

The Western Balkans still represent a significant portion of untapped European hydropower potential. Efforts are being made to strengthen regional cooperation between the European Union and Albania, Bosnia and Herzegovina, Kosovo, Macedonia, Montenegro and Serbia. In 2016 the European Union commissioned a regional hydropower master-plan for the Western Balkans, which will aim to define how to develop the region's hydropower potential in a way that balances energy generation, flood protection and ecological concerns.

Efforts are being made to work towards a regional market for electricity, which will also facilitate renewable energy production. By expanding and connecting the market, new interconnections could improve energy security, increase efficiency and reduce costs.

In 2016, a EUR 12 million EU grant was announced, which will support the construction of the first electricity interconnector between Albania and Macedonia, and grid efficiency improvements to the infrastructure of MEPSO, the national electricity transmission system operator. The project is part of the European Commission's initiative to establish an east–west electricity transmission corridor between Bulgaria, Macedonia, Albania, Montenegro and Italy.

Another driver for hydropower development in the Western Balkans is the services reservoir storage can offer to assist the region to adapt to climate change, for example in providing solutions for flood protection and freshwater for irrigation and municipal use. Flooding accounts for a major share of natural disasters in the region, often with catastrophic trans-boundary effects on lives, properties and economic productivity in the region – emphasising the requirement for improved coordination throughout the region.

In Portugal, the Frades variable-speed pumped-storage plant (760 MW) will bring the total installed capacity of the Venda Nova complex up to 1,058 MW, and will be used to support frequency stabilisation in the local grid. The Foz Tua station (263 MW), located on the Tua river in the northern region, will come online in 2017. In 2016, Iberdrola Generación awarded the electro-mechanical equipment and penstocks for the new PSPP Gouvães to Andritz Hydro (4 x 220 MW reversible pump turbines and motor generators). Gouvães, part of the Alto Támega hydropower scheme, is expected to be online in the early 2020s.

Plans for the Swansea Bay Tidal Lagoon (320 MW) are powering through in the UK, and if approved by the government, the project is expected to come online in 2021. It has been estimated that the tidal lagoons could supply more than 10 per cent of the nation's electricity. Major delivery partners include GE and Andritz Hydro. Several small-scale run-of-river projects came online in 2016 in Scotland, including Cia Aig (3 MW), Leacann (1 MW) and Lochy (2 MW).

The Reisseck II pumped-storage project in Austria was commissioned in summer 2016. The project, which has been under construction since 2010, is part of an extended group of power stations; Malta and Reisseck in the Reisseck/Kreuzeck mountain range has an expected peak generating capacity of 430 MW.

In Switzerland, the 1,000 MW Linthal pumped-storage plant was connected to the grid in 2016. The project is an addition to the existing 450 MW Linth–Limmern project, and consists of four variable-speed generating units enabling increased levels of flexible generation from hydropower in comparison to solar and wind.

France has already realised 95 per cent of its hydroelectricity potential, but work is ongoing to increase capacity at existing plants and develop small hydro projects. EDF began construction in 2016 on a new generator at the Coche-en-Savoie pumped-storage plant, expected to increase installed capacity by 20 per cent. A project under way at the Bathie power station will add an additional 50 MW, while modernisation work at Romanche-Gavet should add an extra 93 MW when a single plant replaces six small stations.

In Albania, the 73 MW Banja hydro plant was commissioned in 2016, and is expected to generate roughly 255 GWh. Situated near the capital, Tirana, the facility is part of the 265 MW Devoll project – which, overall, is expected to increase the country's power generation capacity by 17 per cent.

The Santa Vittoria d'Alba hydropower plant in Italy was also commissioned after some initial setbacks. The 4.1 MW plant is situated on the Tanaro River in the Piedmont Region of north-west Italy.

The 100 MW expansion of the Búrfell hydropower project began in 2016 in Iceland, with commissioning expected in May 2018. The new underground powerhouse will be located about 2 km from the existing 288 MW Búrfell power station, using the same reservoir but a separate intake structure and tailrace canal. The expansion project uses water that mostly bypasses the existing station during summer months.

HYDROPOWER TARGETS

Country	Target
Armenia	397 MW small-scale hydro installed capacity added by 2025
Romania	Increasing share of electricity from renewable sources to 38 per cent by 2020, including through hydropower development
Serbia	Increasing share of electricity from renewable sources to 27 per cent by 2020, including through hydropower development
Switzerland	37,400 GWh/year by 2035

EUROPE
GERMANY

With the highest annual electricity demand and generation, Germany has the largest power system in Europe. Furthermore, its energy system is interconnected with ten countries with a total transfer capacity of more than 20 GW. German and European energy systems are heavily intertwined, and the sheer size of the German power system has undoubtable influence on its European neighbours.

Under the German Energiewende (energy transition), the country aims to generate 35 per cent of electricity from renewables by 2020, and 80 per cent by 2050. In order to integrate the increasing amount of variable renewable energy from wind and solar, the country is now looking towards increasing capacity in north–south transmission lines as well as an intensified electricity trade with other EU countries and with better demand-side and energy storage management, interlinked with battery storage and pumped-storage hydropower.

Hydropower installations (including pumped storage) account for a share of around 6 per cent of installed capacity in Germany at roughly 11,300 MW (including 1,244 MW of shared storage hydropower with Austria), and with approximately 22,000 GWh for about 3 per cent of the net electricity generation.

Germany has a highly developed and saturated hydropower market. Investment is primarily focused on refurbishment and modernisation to increase the lifespan and efficiency of existing plants and to minimise ecological impacts. The historical influence of German hydropower technology is far-reaching, as a substantial share of hydropower plants worldwide are based on technology and expertise from Germany; from project development, to the delivery of components and complete systems right through to business management and maintenance.

Currently, several new hydropower projects totalling approximately 2,770 MW are under development, and were expected to come online by 2020. However, due to current market and policy conditions, some projects have been postponed or cancelled, such as Waldeck II (extension of 300 MW) and Atdorf (1,398 MW). Nevertheless, notable needs in modernisations and large overhauls may be performed in the next years in several other stations.

The use of pumped storage plants in Germany and in neighbouring countries, such as Vianden (1,296 MW) in Luxembourg and COO I and II (1,164 MW) in Belgium, already support the German energy transition by storing excess electricity from variable renewables sources, while providing back-up electricity for Germany. Pumped-storage hydropower provides peak load capability, storage capability, grid stabilisation and further ancillary services to a power system. It also remains the only form of electricity storage that is available on a large scale and at a competitive cost, therefore providing strong potential to play a significant role in the German energy transition. Nevertheless, improved prediction of wind power and implementation of intelligent energy management systems may reduce the need for further large-scale pumped-storage plants, ensuring relatively low feed-in tariffs.

A notable innovative project under development is the Naturstromspeicher project, a hybrid wind and pumped-storage plant consisting of a 13.6 MW wind farm and a 16 MW pumped-storage system, where the bases of the wind turbines act as the upper reservoirs. The hybrid system is designed to guarantee a firm power output and balance short-term fluctuations.

Geographically, Germany lies close to countries with large hydropower storage facilities. With interconnections to these countries, such as Norway and Sweden to the north, and Switzerland and Austria in the Alpine region to the south, this external hydropower supply provides balancing opportunities and additional flexibility to the German power system, particularly by facilitating the increased penetration of other renewable and highly volatile energy sources such as solar and wind.

POPULATION
81,299,878

GDP
USD 3,363 BN

INSTALLED HYDROPOWER CAPACITY
11,258
INCL. 6,806 MW PUMPED STORAGE

HYDROPOWER GENERATION
21,500 GWh

EUROPE
NORWAY

A country well known for its high mountain plateaus, abundant natural lakes and steep valleys and fjords, Norway's topography lends itself perfectly to hydropower development. Indeed, hydro provided the basis for the nation's industrialisation in the late 19th century, and remains the backbone of its power system.

Hydropower regularly accounts for more than 95 per cent of total Norwegian power production, with the small remainder made up by thermal and, only recently, wind. At the end of 2016, Norway's inland waters powered over 31 GW installed capacity, producing 144 TWh of clean power. It marks the highest annual hydropower generation ever recorded in Norway, which has been attributed in large part to very high rainfall throughout the year.

Despite hosting a mature and established hydropower sector, Norway plans to continue to develop its hydropower resources in the near future. The current average age of hydropower and dam infrastructure in the country is around 46 years; this is triggering refurbishments and upgrades through the country, as well as environmental improvements. The terms of operation in about 430 hydropower licences may be revised before 2022, increasing the standards for environmental impacts.

As a result of climate change, the country is currently experiencing an increase in average inflow feeding its river systems, adding a further incentive for extension projects. Some of these projects can involve including new catchment areas or increasing the size of the reservoirs and turbines to accommodate increased inflow. One such modernisation and extension project is the Nedre Rossaga station, which was completed in 2016. In addition to modernising the existing turbines, a new power station with an additional turbine unit was installed, increasing total installed capacity from 250 MW to 300 MW. This is part of Statkraft's USD 1.95 billion investment for upgrades of its domestic hydropower assets.

The introduction of renewable energy certificates in 2003, and the merging in 2012 of the Norwegian and Swedish certificate markets, has resulted in a boom of smaller-scale (in this case 10 MW or less) hydropower projects throughout Norway. Investors were able to quickly identify opportunities after the Norwegian Water Resource and Energy Directorate published country-wide mapping for potential sites in 2004. Over 350 small-scale hydropower projects have been commissioned since 2003, and the number is expected to grow up until 2020, when the certificate scheme ends.

Norway commissioned 35 new hydropower stations in 2016, totalling 154 MW. Notable projects include the 27 MW Govddesaga station, which was commissioned in the summer of 2016. There are also two notable projects currently under construction within the polar circle: Smilberg (33 MW) and Storavatn (36 MW) are scheduled for commissioning in 2019.

The Norwegian power system benefits from an integrated, open electricity market (Nord Pool) shared with the neighbouring countries Sweden, Denmark, Finland, Estonia, Lithuania and Latvia. The Nordic system is also interconnected with a number of other countries via high-voltage direct current (DC) transmission lines. DC connections exist from Sweden to Germany and Poland, as well as a recently completed interconnector to Lithuania. Norway also has a DC line to the Netherlands and Russia, while Finland is connected to Estonia and Russia. The Norwegian TSO Statnett has been granted licence to build interconnectors to Germany and the UK, each of 1,400 MW to be commissioned in 2018 (Germany) and 2020 (UK).

This extent of interconnectors provides ample export opportunities for Norwegian hydropower. In 2016, taking advantage of record-breaking hydropower production, Norway's net power exports reached 16.5 TWh, roughly 10 per cent of total domestic production. In addition, Norway and the UK recently announced plans to build the world's longest submarine high-voltage cable for the export of Norwegian hydropower to the United Kingdom, and there are plans to export Norwegian hydropower to Germany as well.

POPULATION
5,195,921

GDP
USD 387 BN

INSTALLED HYDROPOWER CAPACITY
31,626 MW
INCL. 1,392 MW PUMPED STORAGE

HYDROPOWER GENERATION
144,005 GWh

SOUTH AND CENTRAL ASIA **REGION MAP**

TOP SIX COUNTRIES BY INSTALLED HYDROPOWER CAPACITY (MW)*					**OTHERS:** 16,390 | **TOTAL:** 166,402
1	**2**	**3**	**4**	**5**	**6**
INDIA 51,975	RUSSIA 48,086	TURKEY 26,249	IRAN 11,196	PAKISTAN 7,320	TAJIKISTAN 5,190

SOUTH AND CENTRAL ASIA
CAPACITY BY COUNTRY

Rank	Country	Installed hydropower capacity (MW)*
1	**India**	51,975
2	**Russia**	48,086
3	**Turkey**	26,249
4	**Iran**	11,196
5	**Pakistan**	7,320
6	**Tajikistan**	5,190
7	**Kyrgyzstan**	3,091
8	**Iraq**	2,753
9	**Kazakhstan**	2,282
10	**Uzbekistan**	1,731
11	**Sri Lanka**	1,629
12	**Bhutan**	1,615
13	**Syria**	1,505
14	**Nepal**	867
15	**Afghanistan**	442
16	**Bangladesh**	230
17	**Lebanon**	221
18	**Jordan**	12
19	**Israel**	7
20	**Turkmenistan**	1

*includes pumped storage

SOUTH AND CENTRAL ASIA **OVERVIEW**

Hydropower capacity continues to grow in South and Central Asia. The region added a total of 1,315 MW in 2016, and announced a number of policy and infrastructure changes that could accelerate development.

The Indian Government began discussions in 2016 to extend the scope of renewable energy to include hydropower stations with capacities greater than 25 MW. At present, only hydropower plants of up to 25 MW are classified as renewable.

The change would help meet the country's renewable energy target of 175 GW by 2022. In addition, it would enable hydropower projects to attract more capital, and free up existing projects to sell power (distribution companies must purchase a certain quantity of renewables).

India commissioned several hydropower projects in 2016, with total capacity of 703 MW. These include: the final 40 MW unit of four installed at the Teesta Low Dam; 36 MW Chanju 1, a run-of-river project in the northern Himachal Pradesh state; the first 30 MW unit of four at the Pulichintala hydroelectric project; and 8 MW Pathankayam, a small run-of-river project in Kerala. The Lower Jurala project, meanwhile, added 160 MW (the final four turbines), bringing its total capacity to 240 MW.

The National Hydroelectric Power Corporation (NHPC) in India revealed plans to rehabilitate and upgrade the 180 MW Baira Siul hydropower plant. NHPC is also in the process of developing a unique project, combining floating PV with pumped hydropower storage. This will be located at the Koyna hydroelectric project in the Satara district of Maharashtra, and will have a total capacity of 600 MW. An initial feasibility study showed positive signs for the future development of tidal lagoon power in the Gulf of Khambhat.

Construction is under way in Tajikistan of the 3,600 MW Rogun dam, set to be one of the world's tallest at 335 m. The dam will connect to the CASA-1000 transmission line, which should reach 1,222 km when constructed, and deliver power to many of South Asia's electricity-deprived countries. Once completed, the power plant will become the largest in Central Asia. It is being constructed upstream of the Nurek dam, and its 13.3 km^2 reservoir will help reduce the quantity of sediment entering the Nurek reservoir.

In Afghanistan, work was completed on the 42 MW Salma dam on the Hari River (renamed Afghan-India Friendship Dam). The reservoir will provide hydropower and irrigation services, supplying 75,000 ha of land.

Pakistan added a total of 56.2 MW new hydropower to the grid in 2016, in the form of three greenfield projects. The country has also seen significant investment in hydropower projects recently, with the Asian Development Bank announcing plans to add up to 1,000 micro hydropower plants at Khyber Pakhtunkhwa. The China Three Gorges Corporation is set to develop the 1,124 MW Kohala hydropower project as part of the China Pakistan Economic Corridor (CPEC) venture. Construction also began in 2016 on the 870 MW Suki Kinari and the 84 MW Matiltan projects, while modernisation is under way at the 1,000 MW Mangla project.

The private sector added 115 MW of hydropower capacity in Nepal in 2016. This includes the 25 MW Upper Madi and the 50 MW Upper Marsyandgi A. By the end of the year, Nepal had a total generating capacity of 867 MW, with an additional 240 MW expected to come online in 2017 – a record for the country. Meanwhile, SJVN Limited signed a project development agreement with the Nepalese Government for the implementation of the 900 MW Arun III hydroelectric project.

Bangladesh and Nepal have signed an agreement to develop two pumped storage projects in Nepal: the 1,110 MW Sunkoshi II and the 536 MW Sunkoshi III. Electricity produced at these two plants will be exported to Bangladesh via India through the Bangladesh, Bhutan, India, Nepal (BBIN) initiative economic corridor. In addition, Bangladesh, India and Bhutan have signed a memorandum of understanding to construct the 1,125 MW Dorjilung plant in Bhutan.

Economic slowdown over the past couple of years in Russia has had a negative impact on hydropower development in the region. Despite this, RusHydro commissioned the 30.6 MW Zaragizhskaya and 140 MW Zelenchukskaya hydropower plants in 2016. There is also some major hydropower development expected to be completed by 2019.

In Kyrgyzstan, difficulties receiving financial obligations from Russian companies led to a multibillion-dollar plan to construct five plants being revoked by the Kyrgyz parliament. However, the Asian Development Bank approved financial support for the third and final phase of the upgrade and rehabilitation project at the 1,200 MW Toktogul hydropower plant on the Naryn River.

Turkey announced the commissioning of 101 hydroelectric projects in early 2016, with total capacity of 2,194 MW and an annual generation of 7.4 billion kWh.

In Iran, the China Gezhouba Group Co. Ltd. has finished construction of a dam at the 450 MW Rudbar Lorestan hydropower plant. The first of two 225 MW units at the project are expected to enter into service in March 2017.

The World Bank has provided funds to repair the Mosul dam in Iraq, which is facing some potentially devastating structural problems.

Dubai meanwhile is progressing with plans to build a 250 MW pumped storage hydropower project in Hatta, at the Al Hattawi Dam. The project will utilise one of the existing reservoirs at the site. Hydro turbines powered by solar energy will pump water from the lower to the upper reservoir.

HYDROPOWER TARGETS

Country	Target
Kazakhstan	170 MW new capacity by 2020
Kyrgyzstan	178 MW new capacity by 2025
Russia	159 MW new small hydropower capacity by 2019
Turkey	36 GW total capacity by 2023
Uzbekistan	938 MW new capacity by 2030; 2,091 MW by 2050

The reservoir at the 1,200 MW Toktogul hydro project on the Naryn River (Kyrgyzstan), which is currently undergoing rehabilitation and upgrade

SOUTH AND CENTRAL ASIA
PAKISTAN

Straddling the Indus Valley, Pakistan is endowed with considerable water resources. According to Pakistan's Water and Power Development Authority (WAPDA), there is 60,000 MW of hydropower potential in the country, of which only 7,320 MW has been developed. Pakistan's untapped hydropower potential largely lies in the mountainous north along the Indus River in the provinces of Gilgit-Baltistan and Khyber Pakhtunkhwa as well as the Jhelum River in the provinces of Punjab and Azad Jammu and Kashmir.

Pakistan is currently amid an energy crisis. Some 51 million Pakistanis lack access to electricity, while a further 90 million suffer from unreliable power supply and load-shedding on a daily basis, which is having a serious impact on the economy.

An over-reliance on imported fuels for thermal generation subject to price fluctuations is at the core of the energy crisis, and the government remains under significant pressure to address an annual average power deficit of 4,000 MW. Hydropower once underpinned the country's power sector, accounting for 45 per cent of power generation in 1991, but this share has dropped to around 28 per cent, as short-term planning preferred thermal power plants.

However, hydropower is poised for a resurgence and will play a significant role in addressing this power deficit, with some studies estimating the proportion of hydropower in the total electricity generation to increase to more than 40 per cent by 2030.

There is a great emphasis of the present government on the development of hitherto untapped hydropower potential, and to fulfil this ambition, the government has relied heavily on foreign investment from private investors, foreign governments and multilateral development banks.

A number of hydropower plants were completed or commissioned in 2016 including Ranolia (17 MW), Daral Khwar (37 MW) and Machai (2.6 MW), all located in the Khyber Pakhtunkhwa province. Several micro hydropower projects were also installed as part of an initiative led by the government of Khyber Pakhtunkhwa, with the support of the Asian Development Bank, to install some 1,000 micro plants. Expected to have a total installed capacity of 100 MW, these micro projects are designed to support rural, off-grid communities by providing affordable and reliable electricity.

Numerous projects are currently under planning and construction in the private sector, overseen by the Private Power & Infrastructure Board, including Karot (720 MW), Suki (870 MW) and Kohala (1,124 MW). These projects are part of the China–Pakistan Economic Corridor (CPEC) – a collection of infrastructure projects supported by the Chinese Government to strengthen Pakistan's economy and enhance the economic connectivity between both countries.

The run-of-river Patrind hydropower project is another being led by the private sector, a Korean consortium including Star Hydro Power, K-water and Daewoo Engineering & Construction Company. Scheduled for completion in 2017, the project has also received loans from the Islamic Development Bank, International Finance Corporation, Asian Development Bank and the Export-Import Bank of Korea.

The regulatory regime for private sector investors includes substantial incentives such as generous return on equity, tax concessions and hydrological risk cover.

Current public sector projects under construction and overseen by WAPDA include Golen Gol (106 MW), Neelum-Jhelum (969 MW), Dasu (4,320 MW) and the extension of the Tarbela plant.

The construction on the fourth extension of the 3,478 MW Tarbela hydropower plant located on the Indus River continues, with completion likely in 2017. The Tarbela Dam is the largest earth-filled dam in the world, and the fourth extension to the hydropower plant will lift its installed capacity to 4,888 MW. The World Bank and the Asian Infrastructure Investment Bank have also announced USD 720 million in co-financing to help fund the fifth extension to the plant, which will add a further 1,140 MW in capacity.

POPULATION
188,924,874

GDP
USD 271 BN

INSTALLED HYDROPOWER CAPACITY
7,320 MW

HYDROPOWER GENERATION
34,419 GWh

SOUTH AND CENTRAL ASIA

RUSSIA

Russia ranks second in the world in undeveloped hydropower resources, with economic potential reaching 852 TWh, and only 20 per cent of it currently utilised. With 80 per cent of population and industry located in the central and southern regions of European Russia, most unexploited potential hydropower sites are located far from major load centres. Hydropower accounts for 99 per cent of renewable energy share, with other renewables undeveloped.

The Draft Energy Strategy for the period until 2035 expects further increases in power demand, particularly in regions undergoing high economic development such as the Russian Far East, Siberia, Russian North and the Caspian, creating new opportunities for hydropower development in these areas.

Overall, Russian electricity demand is expected to increase by nearly 2 per cent per year. The Strategy for Development of Renewable Energy (published in 2009) considers the accelerated development of renewable energy sources as an important factor of the economic modernisation of the country. Currently, Russia recognises only hydropower up to 25 MW as a renewable energy source, and according to the Draft Energy Strategy its production will increase for up to 30 per cent by 2035.

The federal hydropower generation company, RusHydro, owns the majority part of the hydropower plants in Russia, with 38.9 GW of installed capacity (81 per cent of the country's total).

On 23 December 2016, PJSC RusHydro successfully commissioned the 140 MW Zelenchukskaya hydropower plant on the Kuban River in the Karachay-Cherkess Republic in the North Caucasus region, which combines run-of-river hydropower and pumped storage. In its construction the project utilised new technical solutions; it has two reversible units with capacity in pumping mode up to 160 MW. Average annual output from the facility will be 162 GWh.

On 29 December 2016, the 30.6 MW Zaragizhskaya hydropower plant was launched in the Kabardino-Balkaria region. It is the third plant on the Cherek River, and will generate 114 million kWh of electricity. The total capacity of the cascade is 156 MW, and it will provide 40 per cent of regional electricity needs. RusHydro also plans to construct a small-scale hydropower plant (10 MW) in the village of Upper Balkaria.

By the end of 2019 RusHydro plans to complete the construction of further projects: Zaramagskaya HPP-1 (342 MW) in the North Ossetia-Alania Republic; the third hydro-unit of Ust-Srednekanskaya HPP (142.5 MW) in the Magadan region; and Nizhne-Bureyskaya HPP (320 MW) in the Amur region.

Eurasian Development Bank (EDB), the International Investment Bank (IIB) and Nord Hydro – Belyi Porog have signed a trilateral cooperation agreement to construct two small hydropower plants, Beloporozhskaya HPP 1 and Beloporozhskaya HPP 2, with a total capacity of 50 MW, in the Republic of Karelia near to the Finnish border.

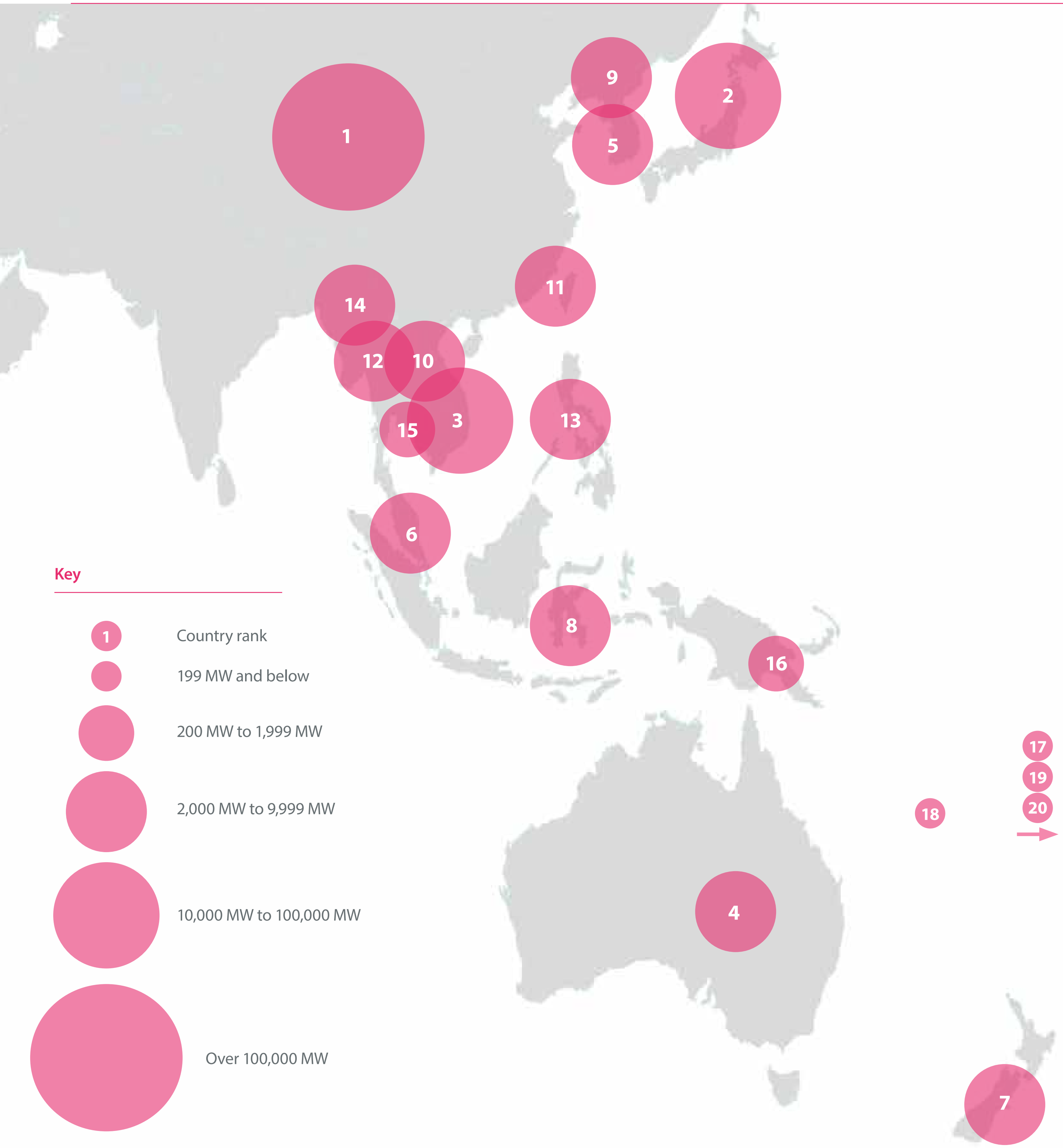
POPULATION
144,096,812

GDP
USD 1,331 BN

INSTALLED HYDROPOWER CAPACITY
48,086 MW
INCL. 1,385 MW PUMPED STORAGE

HYDROPOWER GENERATION
178,306 GWh

EAST ASIA AND PACIFIC
REGION MAP



TOP SIX COUNTRIES BY INSTALLED HYDROPOWER CAPACITY (MW)*					**OTHERS:** 38,801 | **TOTAL:** 457,476
1	**2**	**3**	**4**	**5**	**6**
CHINA	JAPAN	VIETNAM	AUSTRALIA	S. KOREA	MALAYSIA
331,110	49,905	16,306	8,790	6,471	6,094

EAST ASIA AND PACIFIC
CAPACITY BY COUNTRY

Rank	Country	Installed hydropower capacity (MW)*
1	China	331,110
2	Japan	49,905
3	Vietnam	16,306
4	Australia	8,790
5	South Korea	6,471
6	Malaysia	6,094
7	New Zealand	5,346
8	Indonesia	5,305
9	North Korea	5,000
10	Laos	4,818
11	Chinese Taipei	4,683
12	Thailand	4,510
13	Philippines	4,235
14	Myanmar	3,140
15	Cambodia	1,267
16	Papua New Guinea	234
17	Fiji	125
18	New Caledonia	78
19	French Polynesia	47
20	Samoa	12

* includes pumped storage

EAST ASIA AND PACIFIC
OVERVIEW

Led by China, the East Asia and Pacific region continues to have the largest share of global installed hydropower of all six regions. China alone accounts for almost one-third of global hydropower capacity, and added approximately 11.74 GW of new capacity in 2016, including 3.74 GW of pumped storage, taking its total installed capacity to 331 GW, including 26.7 GW of pumped storage. Excluding China, an estimated 1.6 GW was added in the region in 2016.

The Mekong region continues to witness a flurry of activity. In Laos, both the 69 MW Nam San 3A plant and the 36 MW Lamphun plant were commissioned in 2016, and the first phase of the 1,272 MW Nam Ou cascade project, including dams 2, 5 and 6 totalling 540 MW in capacity, was completed. The project is Power China's first investment in a foreign country, and is a key part of the Chinese Government's 'One Belt, One Road' initiative, designed to develop closer connections and new economic corridors. The second and final phase of the project, consisting of Nam Ou 1, 3, 4 and 7, is expected to be completed in 2020.

The Laotian Government has also indicated that construction on the proposed 912 MW run-of-river Pak Beng project may commence in 2017. Located on the upper Mekong, the project is proceeding according to the 1995 Mekong Agreement, which involves close consultation with the governments of Cambodia, Thailand and Vietnam under the auspices of the Mekong River Commission.

A further 1,095 MW of hydropower capacity was added in Vietnam in 2016. The final two 400 MW turbines were commissioned at the 1,200 MW Lai Châu plant, which will supply around 4.6 TWh of electricity to the national grid every year. The second 265 MW turbine at the 520 MW Huoi Quang plant and the 30 MW Cốc San run-of-river scheme, both located in the north-west of the country, were also commissioned.

In Myanmar, following a model adopted in Laos, the International Finance Corporation established the Hydropower Developers' Working Group to provide hydropower companies and stakeholders a forum to discuss and address the challenges the sector faces. With over 60 per cent of the population not having access to electricity, hydropower is central to achieving the government's aim of universal access to electricity by 2030.

Elsewhere in East Asia, the 47 MW Wampu hydropower plant located on the Biang River in North Sumatra, Indonesia was completed in 2016 after four years of construction. Both Wampu and the 55 MW run-of-river Semangka project on the southern tip of Sumatra (which is scheduled for completion in 2017) have been joint financed and developed by a South Korean consortium.

In the Philippines, two run-of-river plants in Manolo Fortich with a combined capacity of 69 MW are expected to be commissioned by the end of 2017, and the 25 MW Lake Mainit project, located in the north-east of Mindanao, remains under development.

Japan is set to have its first commercial-scale tidal power plant in its waters in 2018, after the Japanese ministry of the environment selected an international consortium to build the 2 MW turbine in 2016. To be situated in the Naru Strait off Nagasaki, the project will look to develop local skills and expertise in the industry, and will help determine whether further tidal power developments will be carried out across the country.

Meanwhile in the Pacific, the proposed 20 MW Tina River project located 30 km east of the Solomon Island capital, Honiara, was awarded USD 15 million in concessional loans by the International Renewable Energy Agency and the Abu Dhabi Fund for Development in January 2017. The project would significantly help to reduce power prices and deliver greater energy security for a country heavily dependent on diesel-powered generation. Further decisions on concessional finance for the project are expected from the Green Climate Fund, World Bank, Asian Development Bank and Economic Development Cooperation Fund of Korea by mid-2017.

Finally, in Papua New Guinea, the proposed 50 MW Edevu hydropower project located in the Kairuku-Hiri District was launched in February 2017. Led by a public–private partnership between PNG Power Limited and a Chinese company, PNG Hydro, the project should be completed in 2020.

TARGETS

Country	Target
China	40 GW total installed pumped storage capacity by 2020
Japan	9.6 per cent of total power generation to come from hydro by 2030
Philippines	5,394 MW new installed capacity by 2030

Floating solar PV at the Thac Ba hydropower plant, Vietnam

EAST ASIA AND PACIFIC
AUSTRALIA

Australia has over 120 operating hydroelectric power stations, with an installed capacity of nearly 8,800 MW. Despite declining generation in previous years due to low rainfall in key catchments, hydropower generation rebounded strongly in 2016, contributing to over half of the renewable electricity generated and up to 9 per cent of the total electricity generated in the National Electricity Market (NEM).

The country's hydropower resources are largely concentrated in the states of Tasmania, which is heavily reliant on hydro for its electricity generation, New South Wales (NSW) and Victoria. The Snowy Mountains Hydro-Electric Scheme, which spans both NSW and Victoria, is Australia's largest hydropower scheme, consisting of 16 major dams and nine power stations with a combined capacity of 4,100 MW.

As the driest inhabited continent on earth, water availability is a key constraint on future growth for hydroelectricity in Australia, with the majority of suitable sites having already been developed. Growth in the sector is expected to be limited to small-scale hydroelectric projects and upgrading and refurbishing existing infrastructure but pumped storage may prove to be an increasingly important component of Australia's electricity market.

The proposed Kidston pumped storage project in North Queensland is one such example and its developers are hoping to secure its financing arrangements in 2017. Using two disused mine pits, it would be the first such project in the world to be combined with a 50 MW solar farm which will have the potential to power the storage plant's water pumps.

With an optimal capacity of 250 MW of rapid and flexible power, the plant would be able to help manage the growth and increasing penetration of intermittent forms of renewable energy. Kidston would add to Australia's three main pumped storage plants, and given there are roughly 50,000 disused mines across the country, this off-river solution could be employed elsewhere.

In Tasmania, months of below-average rainfall from September 2015 and into the early months of 2016 causing record low water levels in hydro dams were compounded by an extended outage in the Basslink cable connecting the state to the NEM. In response to the severe pressure placed on the state's hydro storages, Hydro Tasmania deployed several measures including re-commissioning a gas-fired power station to protect the state's energy supply.

Hydro Tasmania's storages recovered strongly from May onwards though, as heavy rain causing flooding for some catchments meant the state ended 2016 recording its second wettest on record in what was a year of rare and extreme weather events.

On the national front, while the Australian Government has ratified the Paris Agreement, having set a 2030 target of reducing emissions by 26 to 28 per cent below 2005 levels, it remains unclear how it intends to achieve it. A review of Australia's climate change policies is set to take place in 2017 but the government has already indicated that it would not support any form of carbon tax or emissions trading scheme.

Australia's renewable energy target of sourcing 33,000 GWh of electricity from large-scale renewable sources in 2020 (equivalent to about 23.5 per cent of the expected electricity generated) remains the key driver of the country's transition to a low-carbon electricity sector. In addition, a number of state governments have separate renewable energy targets in place complemented by a suite of initiatives.

Finally, in 2016 the Snowy Mountains Hydro-Electric Scheme, the largest and most complex engineering project ever undertaken in Australia, was honoured with its inclusion on the National Heritage List. Constructed between 1949 and 1974, and built by more than 100,000 people from over 30 countries, the Snowy Mountains scheme joins other Australian icons on the list such as the Sydney Opera House and the Great Barrier Reef. Its inclusion recognises the scheme's significant contribution to the country's development following World War II.

POPULATION
23,781,169

GDP
USD 1,339 BN

INSTALLED HYDROPOWER CAPACITY
8,790 MW
INCL. 1,340 MW PUMPED STORAGE

HYDROPOWER GENERATION
17,068 GWh

EAST ASIA AND PACIFIC
CHINA

China has firmly established itself at the forefront of global hydropower development. In 2016, the country increased its total installed hydropower capacity by over 11.74 GW to 330 GW, representing more than a quarter of the world's total.

While new development of domestic hydropower has slowed down as most major sites have been identified and explored, China still commissioned more new capacity in 2016 than any other country. With the increasing development of variable renewables such as wind and solar, a strong emphasis is being placed on increasing pumped storage capacity in order to improve stability in the grid.

The most notable of China's hydropower fleet under construction is the Wudongde project on the Jinsha River in the south-west, which will provide 10.2 GW installed capacity when complete (12 x 850 MW turbines). The project began construction in 2014, with the first generator scheduled to be commissioned in 2018; it is expected to be completed in 2020, and will be the sixth-largest hydropower project in the world in terms of installed capacity.

China's 13th five-year plan on energy development, covering the period to 2020, was officially published in early January 2017. It outlines a strategy to minimise reliance on coal, and achieve a minimum share of 15 per cent non-fossil energy: specific targets include an additional 60 GW of hydropower.

The plan emphasises better and integrated planning of China's energy system in order to make it more efficient and reliable. A major east-to-west transmission expansion is a key feature of a strategy to bring hydropower from inland resource centres to load centres on the coast.

The country largely met the ambitious goals set out in its previous five-year plan, which covered the 2011–15 period; however, pumped storage capacity has not been developed at such a rapid rate as conventional hydropower.

With the required policy frameworks now in place, the new plan focuses on increasing pumped storage capacity, with its total volume representing just 1.5 per cent of China's installed electricity capacity at the beginning of 2016. In order to address this shortage, the country aims to reach 40 GW total pumped storage capacity by 2020.

Implementation is well under way. In 2016, China commissioned three pumped storage projects totalling 3.66 GW – Xianju (1,500 MW), Hongping (1,200 MW) and Qingyuan (960 MW). In addition, the first batch of units at the 1,500 MW Liyang project came online in August 2016, and the project in on schedule for completion in April 2017. Furthermore, over 30 GW of pumped storage capacity is under development in China at the end of 2016.

The new five-year plan also set outs commitments to emphasise ecological and environmental protection in the development of hydropower, to strengthen international cooperation, and to advance the alleviation of poverty.

In December 2016, China's ministry of water resources adopted 'guidelines on promoting the development of small hydropower plants'. The document outlines plans to develop and grow the small hydropower industry in China by 2030 with a respect to environmental protection, focusing on technology improvements and best practices for plant construction, operation and management.

The document calls for standards to improve small hydropower management, a system of incentives promoting small hydropower installations, and establish a number of small hydropower projects by 2020. China commissioned several new run-of-river hydropower plants in 2016, including: Tongzilin (600 MW), Lizhou (345 MW), Huangfeng (225 MW) and Qireha tal (210 MW).

POPULATION
1,371,000,000

GDP
USD 11,008 BN

INSTALLED HYDROPOWER CAPACITY
331,110 MW
INCL. 26,720 MW PUMPED STORAGE

HYDROPOWER GENERATION
1,180,700 GWh

EAST ASIA AND PACIFIC
MALAYSIA

Hydropower is poised to play an increasingly important role in meeting Malaysia's energy and climate goals. The share of hydropower in the country's electricity generation is around 11 per cent, but with less than 20 per cent of the technically feasible generation potential utilised to date, there is significant expansion already in the planning stages or under development.

Most of Malaysia's electricity generation capacity is natural gas-fired and coal, but the government is seeking to achieve a more balanced portfolio of electricity generation over the coming years to meet its growing demand and reduce its dependency on fossil fuels. This has benefited Malaysia's hydropower sector, which has in the past largely been concentrated in Peninsular Malaysia, but due to its high rainfall and geography, the state of Sarawak on the island of Borneo is expected to experience the lion's share of new developments.

In 2009, the Malaysian Government established the Sarawak Corridor of Renewable Energy (SCORE) programme, designed to take advantage of the state's vast natural resources and to diversify its economy by providing reliable, low-cost electricity to its growing manufacturing base. SCORE is looking to capitalise on the 51 potential hydropower sites that the government has identified which could provide an estimated 20 GW of capacity.

In recent years, the 2,400 MW Bakun plant developed by Sarawak Hidro was opened in 2011, becoming Malaysia's largest hydropower plant, and this was followed in 2015 by Sarawak Energy's 944 MW Murum plant beginning full operations. Sarawak Energy also received state government approval for its 1,285 MW Baleh project in 2016, and there are several other hydro projects in the pipeline which could represent a further 4 GW of new capacity.

It is forecasted that 60 per cent of Sarawak's power generation is to be sourced from hydropower by 2020, up from 35 per cent in 2012. Electricity exports to the Indonesian province of West Kalimantan already under way, and further plans are also in place to export to both Brunei and Sabah by 2025.

Tenaga Nasional Berhad (TSB), the country's largest utility company, also recently completed the construction of two plants in Peninsular Malaysia – the 250 MW Hulu Terengganu project and the 382 MW Ulu Jelai project in the state of Pahang, coming online in 2015 and 2016 respectively. There is a further 1,700 MW of hydropower projects either at a planning or feasibility stage in Peninsular Malaysia.

Small-scale hydropower projects, which Malaysian regulations classify as run-of-river schemes up to 30 MW in installed capacity, are also contributing to the country's electricity supply, especially in rural areas. Their development has been incentivised by a feed-in tariff (FiT) scheme adopted in 2011, which allows small generators to sell electricity to the national utility through the grid.

As of January 2017, installed capacity of small hydropower under the FiT scheme is 30 MW, with plants in progress representing over 200 MW, the largest share of all renewables.

As well as contributing to a more balanced energy mix, hydropower development is fundamental to the Malaysian Government's efforts to reduce its greenhouse gas emissions intensity of GDP by 45 per cent by 2030 relative to 2005 levels. The government is confident of reaching the target, claiming it had already recorded a 33 per cent reduction by the end of 2015.

The government's target will be further supported by the purchasing of up to 100 MW of hydroelectricity from Laos, via Thailand, following the signing of a memorandum of understanding in 2016. It's expected to take place by 2018 and it could be increased further in the future.

POPULATION
30,331,007

GDP
USD 296 BN

INSTALLED HYDROPOWER CAPACITY
6,094 MW

HYDROPOWER GENERATION
17,926 GWh

The 2,400 MW Bakun hydropower project in Sarawak, opened in 2011

ABOUT THE INTERNATIONAL HYDROPOWER ASSOCIATION

Who we are

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.

ABOUT THE INTERNATIONAL HYDROPOWER ASSOCIATION

1 Advancing policies and strategies

With universal access to energy a cornerstone of the Sustainable Development Goals, hydropower has a vital role to play in providing clean and reliable energy across the world. We provide a strong, credible voice for hydropower at national, regional and international forums, building close partnerships with leading organisations in the fields of water and energy.

By collaborating with our partners at strategic events such as COP and the International Renewable Energy Conference, as well as representing the sector on the working group of the Climate Bonds Initiative, we strive to ensure that hydropower's vital contribution is realised.

2 Building a vibrant community

In May 2017 in Addis Ababa, we host the sixth World Hydropower Congress. Now established as the reference event for the sector's decision-makers and experts, the congress brings together delegates from countries of all the world's regions to discuss the future of sustainable hydropower. They comprise representatives from governments, financial institutions, non-governmental organisations, research institutes and private sector companies.

Hosting the congress in Africa helps our members to connect in one of the world's most important regions for future hydropower development. In 2019, the next World Hydropower Congress will be hosted in France.

3 Creating a platform for knowledge

We provide unbiased and authoritative information on a range of issues affecting the sector, as well as the most up-to-date statistics. We are working closely with our extensive network to build a global database, which already contains information on over 11,000 of the world's hydropower stations.

We are also improving standards through the implementation of the Hydropower Sustainability Assessment Protocol, a tool that measures the sustainability of projects across a range of social, environmental, technical and economic considerations.

4 Delivering value for members

We are constantly working to improve our benefits for both corporate and individual members, and to encourage more direct involvement in our work and mission.

Our members benefit from participating in knowledge networks. This initiative aims to foster discussion and build knowledge on specialised hydro topics. The networks provide members with a means of accessing global expertise on particular subjects.

We also conduct an annual issues survey with the aim to take the pulse of the sector, identify where new development is happening and ensure that our work programme reflects the issues currently facing the global hydropower community.

"By bringing our clients to the World Hydropower Congress, they gain a clear understanding of what are considered to be the international best practices in sustainable hydropower development" – **Rikard Liden, senior hydropower specialist, World Bank Group**

WORLD HYDROPOWER INSTALLED CAPACITY AND GENERATION 2016

AFRICA

Country	Total installed capacity including pumped storage (MW)	Pumped storage (MW)	Generation (TWh)
Algeria	228	-	0.26
Angola	1,267	-	4.95
Benin	1	-	-
Botswana	-	-	-
Burkina Faso	32	-	0.10
Burundi	54	-	0.14
Cameroon	751	-	4.50
Cape Verde	-	-	-
Central African Republic	25	-	0.20
Chad	-	-	-
Comoros	1	-	-
Congo	209	-	0.96
Côte d'Ivoire	604	-	1.80
Democratic Republic of the Congo	2,509	-	8.31
Djibouti	-	-	-
Egypt	2,800	-	13.10
Equatorial Guinea	127	-	0.12
Eritrea	-	-	-
Ethiopia	3,813	-	9.67
Gabon	170	-	0.80
Gambia	-	-	-
Ghana	1,584	-	8.33
Guinea	368	-	1.36
Guinea-Bissau	-	-	-
Kenya	818	-	3.50
Lesotho	80	-	0.55
Liberia	22	-	-
Libya	-	-	-
Madagascar	164	-	0.86
Malawi	364	-	1.43
Maldives	-	-	-
Mali	157	-	0.79
Mauritania	97	-	0.38
Mauritius	60	-	0.09
Morocco	1,770	464	2.60
Mozambique	2,187	-	10.50
Namibia	341	-	1.52
Niger	-	-	-
Nigeria	2,040	-	5.66
Réunion	121	-	0.45
Rwanda	103	-	0.28
São Tomé and Príncipe	4	-	0.01
Senegal	-	-	-
Seychelles	-	-	-
Sierra Leone	59	-	0.14
Somalia	-	-	-
South Africa	3,583	2,912	0.95
South Sudan	-	-	-
Sudan	2,250	-	6.31
Swaziland	60	-	0.26
Tanzania	562	-	1.92
Togo	65	-	0.09
Tunisia	66	-	0.07
Uganda	706	-	1.90
Western Sahara	-	-	-
Yemen	-	-	-
Zambia	2,392	-	7.09
Zimbabwe	769	-	5.45
TOTAL	**33,624**	**3,376**	**106**

SOUTH AND CENTRAL ASIA

Country	Total installed capacity including pumped storage (MW)	Pumped storage (MW)	Generation (TWh)
Afghanistan	442	-	1.16
Bahrain	-	-	-
Bangladesh	230	-	1.01
Bhutan	1,615	-	7.01
India	51,975	4,786	120.51
Iran	11,196	1,040	18.20
Iraq	2,753	240	4.65
Israel	7	-	0.02
Jordan	12	-	0.06
Kazakhstan	2,282	-	6.94
Kuwait	-	-	-
Kyrgyzstan	3,091	-	13.32
Lebanon	221	-	0.94
Nepal	867	-	2.80
Oman	-	-	-
Pakistan	7,320	-	34.42
Qatar	-	-	-
Russia	48,086	1,385	178.31
Saudi Arabia	-	-	-
Sri Lanka	1,629	-	4.51
Syria	1,505	-	2.71
Tajikistan	5,190	-	18.74
Turkey	26,249	-	67.03
Turkmenistan	1	-	-
United Arab Emirates	-	-	-
Uzbekistan	1,731	-	10.59
TOTAL	**166,402**	**7,541**	**493**

EAST ASIA AND PACIFIC

American Samoa	-	-	-
Australia	8,790	1,340	17.07
Brunei	-	-	-
Cambodia	1,267	-	2.22
China	331,110	26,720	1,180.70
Chinese Taipei	4,683	2,602	4.19
Cook Islands	-	-	-
Fiji	125	-	0.52
French Polynesia	47	-	0.29
Indonesia	5,305	-	17.86
Japan	49,905	27,637	92.00
Kiribati	-	-	-
Laos	4,818	-	22.57
Malaysia	6,094	-	17.93
Marshall Islands	-	-	-
Micronesia, Federated States Of	-	-	-
Mongolia	-	-	-
Myanmar	3,140	-	9.79
Nauru	-	-	-
New Caledonia	78	-	0.34
New Zealand	5,346	-	25.14
Niue	-	-	-
North Korea	5,000	-	12.04
Papua New Guinea	234	-	0.61
Philippines	4,235	685	9.34
Samoa	12	-	0.04
Singapore	-	-	-
Solomon Islands	-	-	-
South Korea	6,471	4,700	3.00
Thailand	4,510	1,000	7.47
Timor-leste	-	-	-
Tonga	-	-	-
Tuvalu	-	-	-
Vanuatu	-	-	-
Vietnam	16,306	-	71.14
TOTAL	**457,473**	**64,684**	**1,497**

EUROPE

Country	Total installed capacity including pumped storage (MW)	Pumped storage (MW)	Generation (TWh)
Albania	1,608	-	5.64
Andorra	45	-	0.10
Armenia	1,249	-	2.39
Austria	13,177	5,200	38.60
Azerbaijan	1,118	-	2.40
Belarus	73	-	0.11
Belgium	1,427	1,307	0.14
Bosnia and Herzegovina	2,504	420	5.54
Bulgaria	3,129	864	4.52
Croatia	2,141	293	6.13
Cyprus	-	-	-
Czech Republic	2,212	1,147	3.17
Denmark	9	-	0.02
Estonia	8	-	0.03
Faroe Islands	39	-	0.11
Finland	3,198	-	16.09
France	25,405	6,985	64.52
Georgia	2,727	-	8.05
Germany	11,258	6,806	21.50
Gibraltar	-	-	-
Greece	3,396	699	4.86
Greenland	90	-	0.23
Hungary	56	-	0.23
Iceland	1,986	-	12.18
Ireland	529	292	1.14
Italy	21,884	7,555	42.80
Kosovo	36	-	0.11
Latvia	1,576	-	2.33
Liechtenstein	-	-	-
Lithuania	876	760	0.35
Luxembourg	1,134	1,100	0.09
Macedonia	674	-	2.52
Malta	-	-	-
Moldova	76	-	0.40
Montenegro	658	-	1.80
Netherlands	37	-	0.10
Norway	31,626	1,392	144.01
Poland	2,351	1,782	1.98
Portugal	6,293	1,563	15.30
Romania	6,705	92	18.08
San Marino	-	-	-
Serbia	2,835	614	10.14
Slovakia	2,522	916	4.63
Slovenia	1,479	180	4.67
Spain	20,354	3,329	39.50
Sweden	16,419	99	61.24
Switzerland	16,657	2,817	31.19
Ukraine	6,785	1,315	12.20
United Kingdom	4,450	2,744	4.53
TOTAL	**223,008**	**50,467**	**595**

WORLD TOTAL

Region	Total installed capacity including pumped storage (MW)	Pumped storage (MW)	Generation (TWh)
Africa	33,624	3,376	106
East Asia and Pacific	457,473	64,684	1,497
Europe	223,008	50,467	595
North and Central America	200,922	22,618	702
South America	164,071	1,004	709
South and Central Asia	166,402	7,541	493
TOTAL	**1,245,500**	**149,690**	**4,102**

NORTH AND CENTRAL AMERICA

Country	Total installed capacity including pumped storage (MW)	Pumped storage (MW)	Generation (TWh)
Antigua and Barbuda	-	-	-
Bahamas	-	-	-
Barbados	-	-	-
Belize	53	-	0.26
Bermuda	-	-	-
Canada	79,323	177	379.63
Costa Rica	2,123	-	7.25
Cuba	64	-	0.12
Dominica	6	-	0.03
Dominican Republic	543	-	1.95
El Salvador	472	-	1.83
Grenada	-	-	-
Guadeloupe	10	-	-
Guatemala	1,154	-	5.09
Haiti	61	-	0.19
Honduras	558	-	2.79
Jamaica	23	-	0.13
Mexico	12,092	-	29.14
Nicaragua	123	-	0.47
Panama	1,726	-	6.26
Puerto Rico	100	-	0.11
Saint Kitts and Nevis	-	-	-
Saint Lucia	-	-	-
Saint Vincent and the Grenadines	7	-	0.03
Trinidad and Tobago	-	-	-
United States	102,485	22,441	266.39
TOTAL	**200,922**	**22,618**	**702**

SOUTH AMERICA

Country	Total installed capacity including pumped storage (MW)	Pumped storage (MW)	Generation (TWh)
Argentina	11,170	974	38.86
Bolivia	494	-	1.72
Brazil	98,015	30	410.24
Chile	7,055	-	20.80
Colombia	11,606	-	46.79
Ecuador	4,409	-	15.59
French Guiana	119	-	0.48
Guyana	1	-	-
Paraguay	8,810	-	62.36
Peru	5,271	-	23.34
Suriname	189	-	1.22
Uruguay	1,538	-	7.55
Venezuela	15,393	-	80.00
TOTAL	**164,071**	**1,004**	**709**

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