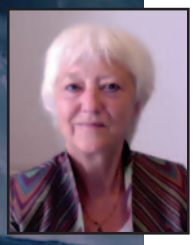


New challenges are being met by the inherent advantages of hydro and storage

Alison Bartle, Publisher,
The International Journal on Hydropower & Dams

Our country reports, reviewing progress in the past year in global hydropower, pumped-storage and water resources development, and the increasing use of other renewable energy systems, are encouraging, but they clearly demonstrate the need to accelerate the transition to clean, renewable sources of electricity generation.

The 17 UN Sustainable Development Goals set ambitious targets. To date, success in meeting the goals has been limited, and with 2030 less than eight years away, it seems highly unlikely that many, if any, targets will be met. Most of the SDGs have can be linked with the development of clean renewable hydropower and multipurpose storage reservoirs.

The outcomes of COP26 in Glasgow last year were also less than spectacular. The need to accelerate the phasing out of fossil fuels globally, without any nations being exceptions, and within a meaningful time frame, has become all the more compelling.

For a number of nations, time is literally running out. In the past year, we have seen Cyclone Ana put Malawi's major Kapichira dam and powerplant out of action. As we were working on the statistics for this *Atlas*, a massive area of Pakistan was submerged by floodwaters. In contrast, Algeria reports that in May this year, its second largest reservoir, Koudiat Acerdoune, with a normal capacity of $640 \times 10^6 m^3$, was depleted to just 6 per cent of its storage volume. Forest fires have raged in countries with usually moderate climates, while some normally arid nations have experienced flash floods.

Meanwhile, we contemplate the development of aircraft without pilots, cars without drivers, and more and more elaborate space travel to distant planets. Research is valuable and fascinating, but surely our own planet needs to be sorted out as a first priority?

In the post-pandemic era, it has been acknowledged by the International Energy Agency, the African Union, the EU, and others, that renewable energy, especially hydropower and pumped storage, will have a vital role to play as economies recover. The invasion of Ukraine by Russian forces in February this year adds another dimension. In addition to the deaths, injuries, destruction of cities and miscellaneous atrocities for the population of Ukraine, the war and resulting sanctions, and the rearrangements of grid connections, has also had a major impact on energy sectors across the world, either directly or indirectly. This underlines the well known, but perhaps sometimes underrated characteristic of hydropower: its ability to ensure energy independence, with the 'fuel' being local water resources, in nations where these are available.

Our country reports show that governments are indeed aiming to prioritize renewable energy development; most have set ambitious targets to eliminate fossil-fuel based generation. New hydropower schemes, and pumped-storage plants to operate with solar and wind power, have been identified, studied and planned. There has never been a time when so many nations are studying their first pumped-storage projects; others are adding pumped-storage at existing schemes.

Impressive results are being achieved in many parts of the world, evidenced, for example, by the fact that hydro generation in Africa has increased by 40 per cent over the past ten years, and in Asia it has increased by 65 per cent. These increases, especially in Africa, have not been evenly spread across the continents, but we can see that this is being addressed with more cross-border schemes (bi-national or tri-national), as well as new or extended transmissions systems between neighbouring nations or across large regions.

But a number of projects which are reported as 'planned for the long term' have been mentioned in this way for many years (in some cases since the first editions of the *Atlas* were published). The problems of getting these schemes off the drawing board are generally financial, bureaucratic or occasionally political. Clearly a more concerted effort is required to overcome these barriers, not only to assist nations where total available capacity may be less than 100 MW, but also to fulfil global targets to protect the planet from excessive CO_2 emissions, and to enhance living standards and thus reduce the chances of future epidemics and pandemics.

ICOLD, during its Congress, Symposium, and Roundtable discussion in Marseille this year, as well as the World Water Council, and speakers at the Stockholm Water Week meeting and HYDRO 2022 in Strasbourg, have all worked to highlight key issues that could help to accelerate hydropower and water storage schemes, and have pointed the way to innovative approaches. We can hope that outcomes will be evident in next year's *Atlas*.

Meanwhile, the following pages present some examples to typify developments and priorities throughout the world, which have been reported for our world survey this year.

AFRICA

Angola has prioritized the development of 20 large and medium-sized hydropower projects with a combined capacity of around 4 GW, in its power sector strategy to 2025. In addition to the Caculo Cabaça scheme under construction, seven storage projects totalling 1836 MW are planned in the Kwanza river basin. Three are for the middle reaches of the river, and one for the upper Kwanza. Other schemes will go ahead on the Luando, Lucala, Queve, Catumbela and Cubango rivers. These could provide nearly 2850 MW of new capacity.

The Lom Pangar project (30 MW) is nearing completion in **Cameroon**, at the toe of the Lom Pangar dam. It is scheduled for completion at the end of this year. Bini à Warak (70 MW) will be commissioned in early 2025. Its 6 km^3 reservoir capacity will increase the year-round production at the two hydro plants on the Sanaga river, Edea and Song Loulou, and will enable a large cascade development of hydro plants to be built downstream. Meanwhile, the 420 MW Nachtigal scheme is now under construction, with a scheduled completion date of 2024. The 283 MW Kpep hydro project is planned. This storage scheme has been optimized

for firm energy/dry season production and will link into the Southern Interconnected Grid. The project is the first site to be developed as part of a proposed cascade of five schemes on the river Katsina Ala, and is scheduled for completion in 2029.

The uprating of Boali 2, in the **Central African Republic**, with the addition of the 10 MW Boali 2 Bis plant, was completed recently, and generators have been refurbished at Boali 1. With the additional commissioning of a new solar plant, national capacity will shortly be 75 MW, which is a rise from 40 MW last year. This is a perfect example of the very significant impact that can be made to a national power system from two relatively small-scale renewable schemes.

The country has enormous surface water resources that could be exploited, particularly for further hydropower development. Villages in rural areas are depending largely on diesel units.

A number of dam projects have been identified which could be constructed in the future. The Bac, Bongoumba and Lotémo dams could be built on the Lobaye river; Dimoli dam could be built on the Kadéi river, Kotto Kembé on the Kotto river, Mbi dam on the Mbi river, and Palambo on the Oubangui river

In April last year, the Minister of Energy and Hydraulics of the **Republic of Congo** (Congo Brazzaville) with his counterpart in Cameroon, signed a concession agreement for implementation of the binational 600 MW Chollet hydro scheme, with China Gezhouba Group Company. CGGC will now construct the 106 m-high dam on the Dja river, based on a BOT contract, for completion in 2025. It is possible that power from this major project could be exported to other neighbouring countries, such as the Central African Republic and Gabon.

In **Côte d'Ivoire**, the most important project under construction is the 112 MW Gribo Popoli dam and hydro project on the river Sassandra, downstream from the Soubré dam. It is due for completion in 2024.

Eswatini's Maguga hydro plant is now to be upgraded, with the addition of a 10-20 MW plant to be called Lower Maguga; feasibility studies were done last year, and as we went to press, bids were being invited for technical advisory services for the upgrade. The Government is also committed to developing the 13.6 MW Lower Maguduza run-of-river scheme on the Lusutfu river. Preparations for construction are reported to be at an advanced stage. As the country's total capacity is currently only 170 MW, these developments represent a significant contribution to national electricity supply.

The Grand Ethiopian Renaissance dam (GERD) in **Ethiopia**, with its 145 m-high RCC dam, reached a new milestone in August this year: the third stage of impounding of the reservoir, to allow for early generation from two turbines, was successfully achieved. The units are now operating with a total capacity of more than 500 MW. Meanwhile the Koyisha dam and 2160 MW hydro plant, formerly known as Gibe IV (with an RCC dam), is under construction in the Gibe-Omo basin as the fourth cascade dam.

A 5 MW floating solar PV plant was installed on the reservoir at Bui dam in **Ghana** last year and a further 65 MW FPV installation is now going ahead. Meanwhile the 55 m-high Juale embankment dam is to be built on the Oti river (a tributary of the Volta). It will have an 87 MW hydro plant.

The 450 MW Souapiti plant was completed in **Guinea** last year. This is an important regional scheme, and will supply power also to Mali, Liberia, Sierra Leone and The Gambia. On 3 September this year a ceremony was held in Boké to mark the official launch of the transmission of electricity from the Kaléta and Souapiti dams through the OMVG interconnection. Guinea is committed to exploiting its hydroelectric resources, and continuing regional integration through OMVG, OMVS and WAPP.

As we went to press, the World Bank agreed funding, through IDA, for the restoration of operation at the Kapichira powerplant in **Malawi**, following the extensive damage caused by Cyclone Ana. The scheme also aims to improve the resilience of the dam to natural disasters.

In **Mali**, the Minister of Energy and Water announced last year a desire to move towards more renewable energy development; the country currently depends for 60 per cent of its electricity on thermal power. More hydropower will be needed to operate alongside solar and wind power installations. Hydro projects will play a key role in large-scale irrigation schemes, and the export of hydro capacity will also be important. Interconnections are in progress with Côte d'Ivoire (initially for the transmission of 60 MW and finally for 200 MW), Ghana and Guinea. The planned Taoussa dam project (for which a construction contract has now been awarded), is an essential part of Mali's poverty reduction programme, and aims to improve living conditions by enabling the population to be self-sufficient in food.

Morocco currently has 21 major dams under construction, and 20 smaller ones planned. These will mainly serve for water supply and irrigation, and will be critical in ameliorating the effects of the droughts which have been increasing recently.

Mphanda Nkuwa is the most important and strategic hydro project being implemented in **Mozambique**. With an HVDC transmission line and a run-of-river facility on the Zambezi river, 60 km downstream of Cahora Bassa, this scheme will have a capacity of 1500 MW, and is planned to be in service by 2030. The IFC and AfDB have signed agreements with the Government of Mozambique to support the project, and to finance the studies to update and conclude the technical and feasibility studies.

The Zungeru RCC dam, being built for hydropower, is still under construction in **Nigeria**; it is close to completion, but in August this year, work was delayed by civil unrest around the site.

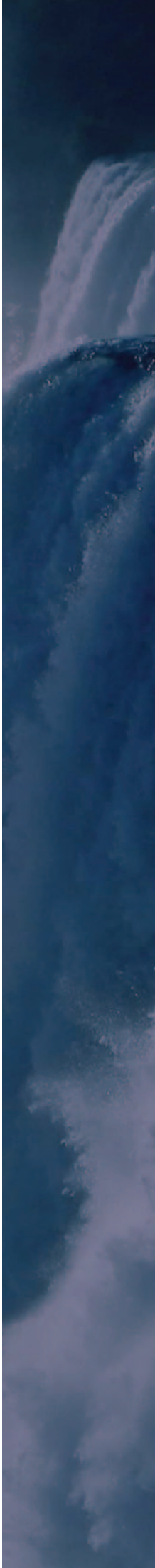
In **Tanzania**, construction is continuing on the 134 m-high arch dam for the Julius Nyerere (Rufiji) project at Stiegler's Gorge. It will impound a reservoir with a surface area of around 1200 km^2, and storage capacity of 34 × $10^9 m^3$. Meanwhile, the 358 MW Ruhudji hydro plant, on the river of the same name, is planned for the south of the country, about 760 km southwest of Dar Es Salaam. This is expected to generate 2000 GWh/year, and will incorporate a 70 m-high embankment dam.

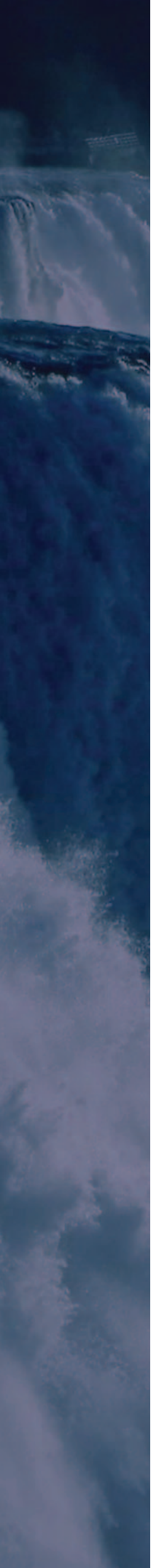
A further 26.7 MW of hydro capacity will be available from Rusumo Falls, now nearing completion on the border with Rwanda and Burundi as part of the Nile Basin Initiative.

Hydro projects have been identified in Tanzania that could total 2230 MW of new capacity.

The Karuma hydro scheme is nearing completion in **Uganda**. Phased commissioning is expected to begin very shortly (October), with full commissioning scheduled for June next year. Together with small schemes, it will increase Uganda's installed capacity to almost 2000 MW. According to the National Development Plan III, Uganda's target for installed capacity by 2025 is 3500 MW, and hydropower is expected to provide the major share of this. Other large hydro projects planned by Uganda along the Nile, which are at some stage of planning, are the 840 MW Ayago, 450 MW Oriang and 390 MW Kiba schemes.

The 750 MW Kafue Gorge Lower





scheme in **Zambia** was completed at the end of 2020, and 300 MW of its total 750 MW capacity was commissioned in 2021. Zambia is now planning a further 1342.5 MW of hydropower capacity at eight large and medium-scale schemes. One of the most important is the binational 2400 MW Batoka Gorge scheme, to be implemented jointly with Zimbabwe on the border between the two countries (the capacity is to be shared equally). This is part of the PIDA initiative led by the African Union and the AfDB, and it is regarded as a PIDA Priority Project.

ASIA

Azerbaijan, in its efforts to achieve 30 per cent generation from renewable energy by 2030, is planning to develop 520 MW of hydropower, mainly at medium-scale run-of-river schemes, along with solar, wind and bioenergy. As well as conventional hydropower, the 1000 MW Shamkyr pumped-storage scheme is planned, which will complement up to 27 GW of renewable energy, which could be developed. Private investment will be sought to help meet these targets.

Power exports to India continue to be the most important source of revenue for **Bhutan**, and four large schemes are under construction for that purpose: Punatsangchhu I and II (1200 and 1020 MW, respectively); Kholongchhu (600 MW); and Nikachhu (118 MW). Three more projects, totalling 6350 MW, are planned. Solar and wind power schemes, on a smaller scale, are now moving ahead, and this is leading the Government to consider implementing storage schemes, in addition to the run-of-river projects under way.

At the time we began publishing our *Atlas* back in 1997, **Cambodia** had a total installed capacity of just 100 MW, so it is good to see that this has risen to 3033 MW, 44 per cent of which is hydropower. Cambodia currently plans for a total of 13 medium sized hydro plants to go ahead by 2025, and three large schemes have been studied on the Lower Mekong; the latter seem less likely to go ahead in the next 10 years.

The total grid capacity in **China** has now reached 2377 GW, of which hydropower accounts for 391 GW. Nearly 21 GW of new hydro capacity came on line during 2021, including the 10.2 GW Wudongde plant. Then, in early 2022, eight of the 1 GW units were commissioned at the 16 GW Baihetan scheme; when complete, this will be the world's second largest hydro plant after Three Gorges. Meanwhile, the 3000 MW Lianghekou scheme, with its 295 m-high rockfill dam, is reaching final completion on the Yalong river in Sichuan; it is the sixth major plant to be built on the river. There are many other large (>1000 MW) schemes ongoing at present, and as of early this year, there are 30 large pumped-storage schemes under construction. China also has 328.5 GW of wind power and 306.5 GW of grid-connected solar power on line, and according to the current 5-year plan, annual production from non-hydro renewable energy will reach 3300 TWh by 2025.

Steady progress in commissioning hydro plants over the past years in **Georgia**, many by private developers, has resulted in hydro contributing 73.5 per cent to total installed capacity and more than 80 per cent to national electricity production. A number of new schemes are planned, including Khudoni (702 MW), which would have a 202.5 m-high concrete arch dam. Refurbishment of existing plants is under way, including the Enguri-Vardnili cascade. Small hydro also plays an important role, with at least 73 plants in operation.

The Government of **India** is aiming to increase its hydro capacity to provide peaking power and grid stabilization as the country moves away from coal and seeks to integrate large volumes of variable renewables. India has set an ambitious target to increase non-fossil fuel capacity to 500 GW by 2030, by which time it expects conventional storage and run-of-river hydro capacity to have increased by more than 50 per cent to 70 GW. The Government has announced significant new and/or expanded projects over the last year, in particular in the states of Uttarakhand, Himachal Pradesh, Sikkim, Kashmir and most notably in Arunachal Pradesh. A total of 510 MW of hydropower was commissioned last year, and there are large-scale schemes nearing completion, for example the 2000 MW Lower Subansiri, 500 MW Teesta VI project, the 1000 MW Tehri pumped-storage plant, the 444 MW Vishnugad Pipalkoti and the 520 MW Tapovan Vishnugad schemes. More projects, totalling 23.5 GW have been approved by CEA, pending final permitting. It is known that final approvals can delay the implementation of schemes.

Indonesia reports 22 large dams currently under construction (the highest being Bener, a 169 m-high CFRD, due for completion next year), and six more major multipurpose schemes are planned. Medium to large hydro schemes, which will bring 2342 MW of new capacity, are currently under construction, including the 1040 MW Upper Cisokan pumped-storage scheme. Several other significant projects are being developed in North Kalimantan, on the island of Borneo, to supply power to a planned industrial park and international port in Tanah Kuning. The 576 km-long river Kayan and at least three other large rivers flowing through North Kalimantan are crucial to the province's hopes for 'green industry'. It is estimated that these waterways could provide up to 23 GW of hydropower, equal to nearly one-third of Indonesia's total generating capacity.

Iran continues with its impressive programme of water resources development, with 47 large dams (≥60 m high) under way, to provide more than $15 \times 10^9 m^3$ of storage. These are scheduled for completion by 2031. Many are multipurpose, usually with irrigation and water supply as primary purposes, but at least 20 also serving for hydropower production. More than 3000 MW of hydro capacity is currently under construction. Despite its large fossil fuel reserves, Iran remains committed to increasing its portfolio of renewable energy plants, and aims to have 7.5 GW of renewable capacity in operation by 2030.

Japan has nearly 500 MW of conventional hydropower planned, and about 60 MW will be obtained by upgrading schemes. Work is continuing at three pumped-storage projects, totalling 5420 MW of capacity (Kyogoku, Kazunogawa and Kannagawa); some units at all of them are already on line, and final commissioning will follow over the next two years. Our country report demonstrates that small hydro is also playing an important role in Japan.

A significant amount of hydro development is under way by both private and state-owned developers in **Kazakhstan**, although coal remains the dominant fuel source for power generation. The 25 MW Turgusun 1 plant, the first in a cascade development of three plants, was commissioned in the past year; the second and third schemes will have capacities of 43.8 and 120 MW, respectively. Further development of the country's hydro resources is being undertaken by Samruk Energy, the country's largest power utility, including a series of schemes along the Ili and Shelek rivers in the east of the country. This includes the 50 MW Kerbulak scheme on the Ili, which will increase capacity at the existing 434 MW Kapchagai plant on the same river by 160 MW, to provide peaking power in the winter.

In the **DPR Korea**, the Orangchon dam was recently commissioned as part of a four-dam cascade on the Orang river.

In **Laos**, the 650 MW Nam Theun 1 project is reported to be 85 per cent complete; it has a 177 m-high RCC dam. About ten major dams (≥ 60 m

high) are under way in the country.

Of the many hydro schemes in progress, some of those now nearing completion are Nam Ngum 3 (480 MW) and Nam Sam 3 (156 MW). Nam Ngum 4 (220 MW) is at an early stage of construction. The country's central location within the Greater Mekong Sub-region enables Laos to continue to supply electricity to sizeable neighbouring markets, such as Thailand.

Peninsular **Malaysia** has largely exploited its hydro potential, but nevertheless launched construction of the 300 MW Nenggiri scheme in Kelantan earlier this year; it is scheduled for completion in 2027. The utility TNB has completed studies for the 168 MW Tekai scheme, which would comprise a cascade development of two dams. The main activity is in Sarawak, where the SCORE project (Sarawak Corridor of Renewable Energy) continues. The major dam and hydro plant currently under construction is Baleh, with a 188 m-high CFRD and a 1285 MW powerhouse; it is scheduled for commissioning in 2026.

In **Mongolia**, plans advanced in 2021 for the implementation of the 90 MW Erdeneburen scheme on the Hovd river, when an agreement was signed between the Ministry of Energy and PowerChina. Mongolia's Hydropower Masterplan indicates that a total of 1050 MW could be developed on the river Selenge, and around 1190 MW on other rivers in the centre of the country.

Nepal has commissioned 23 new hydro plants in the past year, totalling 776 MW, and one of the most important achievements was the commissioning last October of the 456 MW Upper Tamakoshi plant, in the Himalayas. Its development was delayed when works at the site were seriously damaged by the major earthquakes of 2015.

In May this year, an MoU was signed between NEA of Nepal and SJVN of **India** for the 695 MW Arun IV scheme, in the east of the country, which will be developed as a joint venture. As the country report shows, numerous other hydro schemes are moving ahead; a total of 131 have reached financial closure. Agreements were signed in 2021 between NEA and the PowerGrid of India to co-develop the Indian portion of the 400 kV New Butwal-Gorakhpur transmission line, and a feasibility study has been completed for the Nepalese part of the line.

Pakistan is continuing with its major programme of dam construction, with hydropower being one of the major functions of the dams, along with irrigation and water supply. The 98 m-high Karot dam was completed recently, and the first unit was commissioned at its 720 MW hydro plant. Work is ongoing at Diamer Basher (4500 MW), with a 272 m-high RCC dam, and at Dasu (2160 MW in its first phase), with a 242 m-high RCC dam. Projects with a total capacity of 11 300 MW are reported to be at various stages of construction. Financial closure is expected soon for the 1124 MW Kohala and 700 MW Azad Pattan schemes.

The National Irrigation Administration of **The Philippines** has two dams under development as part of the Jalaur river and the Balog-Balog multipurpose projects. The dam for Jalaur will be a 109 m-high RCC structure, impounding a reservoir for irrigation and mini hydro, and Balog-Balog is planned to have a 105.5 m-high zoned embankment, and will create a reservoir for irrigation, flood mitigation, fishing and possible hydro generation. The utility FirstGen is at the pre-development phase with four run-of-river projects, ranging in size from 30 to 49 MW. Private sector plants, which could be implemented by 2037, total nearly 7800 MW of hydro capacity. There are also 26 small hydro plants under construction, totalling 210 MW.

In **Sri Lanka**, the 35 MW Broadlands scheme, with its 24 m-high concrete dam and 19 m-high diversion weir, was commissioned in February this year by CEB. Two more dams and hydro plants are due for completion shortly: the 120 MW Uma Oya multipurpose scheme, which was delayed by a leakage problem in its main tunnel; and, 30 MW Moragolla, with a 37 m-high concrete gravity dam. A further 570 MW is at various stages of planning. The country's first pumped-storage scheme is under study, and could be built between 2028 and 2032.

In **Tajikistan**, concrete pouring began in July at the Rogun rockfill dam, which will be the world's highest dam at 335 m, when complete. Its underground powerhouse will be equipped with six 600 MW units. The Tajik Government is prioritizing the development of its vast hydro resources, and plans for eight new projects to go ahead, which will have a combined capacity of 6045 MW. The ongoing rehabilitation of the 3015 MW Nurek plant aims to increase the availability of its nine generating units by around 10 per cent. At the other end of the scale, there has been an upsurge of interest in small hydro in recent years, as the Government lifted legislative and bureaucratic requirements for investors, and introduced green tariffs for mini hydro plants.

In **Turkey**, the 275 m-high Yusufeli dam, in the northeastern province of Artvin, with its 558 MW hydro plant, is scheduled to be commissioned soon. It is one of a number of major multipurpose schemes being developed by both DSI and the private sector. Plenty more projects are planned, including a cascade development of six dams and hydro plants on the Murat river, and four new projects on the Zap river. A Turkish-Chinese consortium is currently studying Turkey's first pumped-storage scheme, a 1 GW development that could be built in the western province of Isparta.

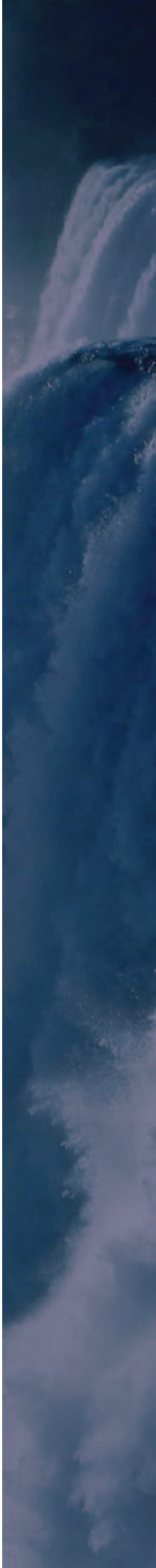
Uzbekistan is currently active in hydropower development, following the Government's declared commitment in 2020 to move ahead with projects totalling 1723 MW, in addition to schemes already underway, by 2030. This is to include new projects and upgrades. According to the current development plan (2022-2026), 15 new hydro plants will be built, and five existing ones will be uprated. By 2030, the Government aims to increase generating capacity to 29.2 GW, which will mean doubling capacity within 10 years.

As our country report shows, **Vietnam** has a large number of small and medium-scale hydro plants under construction. Its power development plan to 2030, with a vision to 2045, underlines commitment to renewable energy development, but is likely to restrict the scale of hydro plants to 30 MW. However, 10 pumped-storage schemes have been studied. The country is keen to attract private investors.

EUROPE

In **Albania**, work is being 'fast-tracked' on the 210 MW Skavica storage plant on the Drin river, following an agreement signed by the Ministry of Infrastructure and Energy with a US consultant to prepare an implementation plan. Work is underway on a technical investigation, preliminary road construction and an environmental and social impact assessment. The Albanian Government has declared that hydropower will continue to be the dominant source of power in the country. Four hydro schemes are underway by private developers, and KESH is to undertake an upgrade of the 500 MW Fierze plant.

Austria is Europe's most active market for new pumped storage, with four new projects totalling 865 MW currently under construction, and a number of upgrades in progress at existing pumped-storage installations, such as the Malta Oberstufe (Galgenbichl) plant), at which a repowering project with the addition of new variable speed units



allowed for a capacity increase from 40 to 160 MW.

Eesti Energia of **Estonia** is progressing towards the implementation of its innovative 500 MW underground pumped hydro scheme in Paldiski (as mentioned in last year's *Atlas*, and described in detail in *H&D* Issue 2, 2021).

Meanwhile early this year, the utility announced plans to develop a 225 MW conventional pumped-storage plant, to enhance energy security after desynchronization from the Russian grid.

In **France**, nearly 600 MW of new hydro is under development, and EDF is studying several new pumped-storage projects, including one in the Vallée de la Truyère.

CNR plans to invest €500 million over 15 years in development and optimizing its hydropower plants on the Rhône. Auctions are being held over the next two years for small hydro plants totalling 210 MW, with 35 already having been given development rights. Small hydro has been promoted in line with French climate resilience legislation.

Germany has revived plans for the 1400 MW Atdorf pumped-storage scheme, which was planned some years ago; this would be one of the largest pumped-storage plants in Europe. Other possible schemes have been identified and are pending economic feasibility studies.

Landsvirkjun, in **Iceland**, is planning to build three hydro projects on the Lower Thjorsa in the south of the country, with a combined capacity of 292 MW. The Government says that new capacity will be needed to meet estimated demand growth of 3.8 TWh over the next 10 years, and considers new hydropower to be more competitive than geothermal; the optimum mix will be hydro, solar and wind power (with geothermal).

A priority in **Lithuania** is the addition of a new 110 MW unit at the 900 MW Kruonis pumped-storage plant; this long-planned project was approved last year, and the technical studies are now under way. One of the existing units is also being refurbished at Kruonis.

Montenegro began work on the 172 MW Komarnica dam, which is to have a 171 m-high concrete arch dam, but work was halted by environmental protesters. This is a multipurpose project that would include hydro generation, and the development of fisheries, tourism and agricultural development. Meanwhile, EPCG issued tenders this year for a study of the hydro potential of the Piva river, downstream of the 342 MW Piva plant, with a view to developing the 120 MW Krusevo hydro scheme.

In **North Macedonia**, ESM has been seeking a private sector partner for development of the 333 MW Cebren pumped-storage scheme, and expects to select one before the end of this year. The US$615 million project will involve the construction of two concrete arch dams. ESM is also upgrading six hydropower plants, and uprating the 84 MW Spilje scheme with the addition of a new 70 MW unit.

Detailed planning is to go ahead for a major upgrade at the Mauranger hydro plant in **Norway**, to increase its present 250 MW capacity to 880 MW, which would make it the fifth largest hydro plant in the country. Meanwhile 66 new hydro schemes are under construction. The Government confirms that hydro will continue to be the backbone of the Norwegian power system. The UK and Germany have both begun to benefit from imports of clean Norwegian hydropower in the past year, with the completion of two 1400 MW sub-sea interconnectors (NordLink and North Sea Link).

A milestone in the development of the 1158 MW Tâmega River complex in northern **Portugal** was the recent commissioning and start of impounding at the Daivões dam, where final tests at the plant are being completed; in the same complex, the full commissioning of Gouvães took place earlier this year. The Tâmega scheme comprises the 160 MW Alto Tâmega dam and plant, the 118 MW Daivões storage facility and 880 MW Gouvães pumped-storage station.

In **Spain**, Construction of the 200 MW Salto de Chira pumped-storage scheme began on the island of Gran Canaria this year. The project, which will use the existing Chira and Soria fresh water basins as the upper and lower reservoirs, is scheduled for completion in 2027. This will enable the island to increase renewable production by 37 per cent. Other news from Spain is that the 105 m-high Enciso RCC dam, one of the largest dams in the Ebro basin, is undergoing final loading tests. Operation is due to begin by the end of this year. The Ebro River Basin Authority has increased the height of the Yesa dam from 78 to 108 m, which doubles its storage capacity.

In **Switzerland** the 900 MW Nant de Drance pumped-storage plant has begun full commercial operation. Some small new schemes are under way, as well as some upgrades, one of the largest being a 76 MW expansion of the 44 MW Ritom scheme in Ticino, which is scheduled for completion next year. Swiss Energy Strategy to 2050 calls for further exploitation of hydropower and other renewable energy sources.

In March this year, the successful synchronization of **Ukraine's** power system with the Continental European Grid ended dependence on the Russian power grid and has allowed Ukraine to have a stable electricity system in place. European Commissioner for Energy Kadri Simson said that the project had shown extraordinary cooperation and determination from everyone involved, and he expressed thanks to the European Network of Transmission System Operators for Electricity (ENTSO-E) for doing a year's work in two weeks to achieve this. He also thanked the French Presidency of the Council and the member states for their support to the project, which was "not without risks."

In the opening plenary session of HYDR0 2022, a presentation was given by the Director of Hydro Energy Engineering on the current status of the Ukrainian power system, with reference to impacts of the Russian invasion (see *H&D* Issue 3, 2021). Meanwhile, as reported in *H&D On-line News* (on 16 September) there was a cruise missile attack on 14 September by Russian forces on the Karachun dam.

Gates and other hydro-mechanical equipment were destroyed, and there was downstream flooding, causing the destruction of about 112 homes, and the partial evacuation of the population of Kryvyi Rih. Swift action by Ukrainian authorities and engineers prevented a major disaster, and restored the damaged gateworks.

SOUTH AMERICA

In **Argentina**, there are projects totalling some 18 GW at some stage of implementation; some of the major ones under construction include Cóndor Cliff (950 MW) and La Barrancosa (360 MW) on the Santa Cruz river, totalling 1310 MW. The binational Yacyretá scheme (with Paraguay) is being uprated by 465 MW, and within the same complex the 270 MW Aña Cuá scheme is now under way.

Two more binational schemes with Paraguay are under consideration for the future, which could provide a further 2438 MW to be shared by the two countries.

Brazil was badly affected by droughts in the past year, which reduced the contribution of hydro to the lowest level ever. The past year has generally been characterized by the construction of a number of small and medium scale schemes (by the end of last year, 73 were under construction, totalling 1032 MW, of which nearly 90 per cent were small). Earlier this year, the 142 MW São Roque scheme was commissioned in the state of Santa Catarina.

All the generating units at Itaipú are to be refurbished, over a period of 14 years.

Brazil is one of many countries undertaking research on floating solar PV, with the largest pilot scheme involving 3792 solar panels on the reservoir at Sobradinho, to provide a capacity of 1 MWp, which will be uprated later to 2.5 MWp.

Ecuador is giving priority to private companies to develop large hydro schemes, along with other renewables. Four small schemes were commissioned in the past year, and about 365 MW is under construction at five medium-scale projects. One of the large planned schemes, which will go ahead by 2024, is Paute-Cardenillo (595.6 MW).

Colombia is now progressing with the Hidroituango scheme on the Cauca river, following the repair of its diversion tunnels. The first 1200 MW phase is expected to be commissioned before the end of this year; when the second phase is complete, it will be the largest hydro complex in the country, with a capacity of 2400 MW. Meanwhile, a contract has recently been awarded for the 171 MW Talasa scheme. More than 560 hydro schemes have been registered for future development; the majority will be run-of-river schemes.

The Government of **Bolivia** is committed to harnessing more hydropower resources, to enable the country to be an exporter of power in the region. The 200 MW Miguellas scheme is under construction, but the 600 MW Rositas scheme has been delayed as a result of environmental issues. Construction is continuing at the 296 MW Ivirizu storage scheme, which incorporates the country's largest dam, a 100 m-high gravity structure.

Chile has around 500 MW of hydropower under construction, at medium-scale schemes, with many other schemes planned or identified for the future. Some are being delayed for environmental or economic reasons, but the role of hydro is expected to remain significant, according to government strategy, and should continue to supply 40-45 per cent of electricity.

The contribution of hydropower had been declining in **Peru**, but is now on the increase again, and the Government regards the country's vast potential of >60 GW as being an important asset in meeting renewable energy targets, and capacity demand, which is increasing at a rate of around 300 MW/year. At present, the 206 MW San Gabon III project is the main hydro scheme under construction; a further 4000 MW is planned at nine schemes.

NORTH AND CENTRAL AMERICA

Canada, as usual, is the leading country in North and Central America for current hydropower activities. Its hydro capacity has now reached around 81.3 GW. A study by the Canadian Hydropower Association estimates that the remaining potential is equivalent to about double this amount. Assessments are now underway for pumped-storage potential. A 1000 MW pumped-storage plant is already planned for Ontario, as well as a 900 MW scheme at the Brazeau hydro plant in Alberta, and a 75 MW scheme in Alberta.

Hydro Québec is steadily progressing with La Romaine complex; Romaine 4 (245 MW) was delayed by the COVID-19 pandemic, but commissioning is expected by early next year at the latest. Hydro-Québec also has a large programme of hydro plant refurbishment under way, with at least five major upgrade schemes described in the country report.

There is currently a strong focus on refurbishing hydro assets across most provinces (especially British Columbia, Ontario and Saskatchewan).

The 695 MW Keeyask plant in Manitoba, commissioned last year, is now fully operational, and work is continuing at the 1100 MW Site C scheme in British Columbia.

Costa Rica recently upgraded its 100 MW Cachi scheme by 60 MW, and has also recently commissioned two 50 MW BOT schemes, which were recently integrated with the grid. About 1200 MW more hydro capacity could be developed at schemes under study.

The **Dominican Republic** plans to develop the 300 MW Las Placetas scheme, which would be the largest hydro plant in the Caribbean. Altogether, up to 900 MW of new hydro capacity could be implemented in the country.

El Salvador is one of the countries that could benefit from an IDB technical cooperation loan to help advance hydro development in the Latin American and Caribbean region. The initiative could assist with expansion of the 180 MW 15 de Septiembre and the 100 MW 5 de Noviembre plants. Meanwhile, a 261 MW scheme originally considered 10 years ago (Cimarron, on the Lempa river), is receiving renewed attention. The country is seeking private investors to support the development of up to 14 hydro projects, across three regions, which could add a total of more than 1500 MW of new capacity.

Work is nearing completion at Patuca III (104 MW) in **Honduras**, which will increase the country's renewable energy capacity by 24 per cent. A new downstream scheme, Patuca IIb, is now being studied, which would add a further 270 MW, and it could be accompanied by Patuca IIa (150-200 MW).

Jamaica is one of many countries contemplating a pumped-storage scheme; the project under study would involve pumping desalinated seawater from an aquifer to reservoirs at a higher elevation, using solar power for pumping. The country's renewable power generation could then increase from 13 to at least 50 per cent of the national total.

The 240 MW Las Cruces project is moving ahead in **Mexico**; it will incorporate a 185 m-high dam.

Machinery contracts were recently awarded for the 240 MW Chicoasen 2 scheme, and another 232 MW project (Copainalá) is likely to be approved for construction soon. A total of six dams with hydro plants are to go ahead soon, selected from more than 32 possible projects which were identified in recent years.

Water access and storage became a major issue in the **USA** during the past year, with many areas experiencing extreme or exceptional drought. Events classed as climate disasters during the first half of this year (seven severe storms and one drought) constituted the highest disaster count in more than 40 years, and caused an estimated US$9 billion worth of damage. This underlined the need for more water storage. The country has several dam heightening schemes under way and others were completed in recent years. The water shortages naturally impacted hydro generation, which was 14 per cent lower than average in the Pacific Northwest and California.

Major priorities for the USA are the uprating of existing dams and hydro plants (there are numerous examples in the country report), retrofitting existing dams, and planning more pumped storage.

This year, FERC issued a total of nine preliminary permits for pumped-storage schemes. Examples of some of the larger ones are: Dry Canyon in Idaho (1800 MW); Gregory County in South Dakota (also 1800 MW); White Pine in Nevada (1000 MW); Seminoe in Wyoming (90 MW); and, San Vicente in California (500 MW).

President Biden announced several new initiatives to tackle the climate crisis, specifically methane omissions; however, these were challenged in court, and the ruling was that the Clean Power Plan exceeded the mandate of the Environmental Protection Agency, by pushing utilities away from coal-fired generation. The USA is acknowledged to be responsible for nearly 30 per cent of global greenhouse gas emissions. ◊