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Hydro

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Strategic insight

1. Introduction and Global Status

Hydropower provides a significant amount of energy throughout the world. There has been deployment in more than 100 countries, contributing approximately 15% of the global electricity production.

The top 5 largest markets for hydropower in terms of capacity are China, Brazil, the United States, Russia, and Canada, with China far exceeding the others at 249GW. Added to these, India, Norway, Japan, France and Turkey complete the top 10 countries in terms of capacity.

In addition, in several countries, hydropower accounts for over 50% of all electricity generation including: Iceland, Brazil, Canada, Nepal and Mozambique.

During 2012, an estimated 27-30GW of new hydropower and 2-3GW of pumped storage hydropower was commissioned during the year. In many cases, this development was accompanied by renewable energy support policies and current and planned regional carbon markets.

Global growth in installed capacity of hydropower has been concentrated in the emerging markets in Asia and South America, where increased access to electricity is and improved reliability are major requirements to support rapid economic development. This trend is most visible in China where over 15GW was deployed in 2012. China expects this growth to continue through 2015 to 284 GW to meet the requirements of the 12th 5- year plan. It is also expected that China will see pumped storage capacity grow to 41GW during this period. If China reaches the goals in its 5 year plan reports indicate it will be exploiting 71% of its available hydroelectric power.

In recent years, the increasing demand for the security of supply of both water and energy continues to drive hydropower development on a regional basis. Hydropower operators are seeing increased trans-boundary collaboration in the development and operation of hydropower projects, and in regional interconnections to enable the cross-border sale of the resulting electricity. In many cases, this cooperation brings benefits in terms of improved energy access in one or more country, economic opportunities, and improved water services.

In addition, the tremendous advances in wind and solar power deployment in many countries have changed the energy mix substantially, and this trend is clearly set to continue. This development is having a profound impact on how existing hydropower stations are operated and modernized, and how new hydropower stations are designed.

Policy

Hydropower development is in many cases supported by renewable energy policies. This support can be either direct – where hydropower qualifies for a feed-in-tariff or is an eligible technology under a renewable portfolio standard; or indirect – where hydropower development is spurred by the increased penetration of other renewables that are eligible for this kind of policy/financial support.

Carbon markets also continue to influence hydropower deployment, particularly in developing countries. The UN FCC Clean Development Mechanism (CDM)and the EU Emissions Trading Scheme (ETS) are the most prominent players in this area. The CDM is an implementing mechanism of the Kyoto Protocol, where projects can be registered to receive and sell Certified Emissions Reductions certifications. As of 5 March 2013, of the 8,013 renewables projects active in the CDM pipeline, 2,899 are hydropower projects with a potential combined installed capacity of 138GW.

CDM projects have historically been concentrated in China and India, with those two countries accounting for 80% of CDM credits issued to date. However, new host countries in 2012 were Albania, Cambodia, Georgia, Kenya, Lao PDR, Macedonia, and Nicaragua. In 2012-13 the UN also opened two collaboration centres in Africa to encourage further update of CDM projects on the continent.

The EU ETS is the world's largest carbon market, established by the EU to help meet its Kyoto Protocol targets. The EU ETS purchases the vast majority of CERs issued under the CDM. However, other countries currently working towards establishment of a carbon market are California, Australia, Canada and Japan. The World Bank is also providing support to exploration of carbon markets in Brazil, Mexico, Colombia, Thailand, Vietnam, and South Africa.

Other policies relevant to hydropower at a domestic level include water policies, energy regulatory policies, and environmental and social regulation.

2. Technical and economic considerations

Technology

Hydropower – harnessing the energy of moving water for power - has been in use since ancient times. However, the turbine technology as well as developments in design and construction techniques have advanced significantly and continue to do so today.

There are four broad hydropower typologies:

- Run-of-river hydropower – provides regular base-load supply, with some flexibility of operation for daily fluctuations in demand through water flow that is regulated by the facility)
- Storage hydropower – provides base- and peak-load supply, with enough storage capacity to operate independently of the hydrological inflow for periods of weeks/months, and the ability for generation to be shut down and started up at short notice)
- Pumped-storage hydropower – provides peak-load supply, utilizing water which is cycled between lower and upper reservoirs by pumps which utilize surplus energy from the system at times of low demand, normally on a daily/weekly basis).
- Offshore hydropower – a suite of technologies using basic hydropower technology in a marine environment. This includes wave and tidal technologies.

However, the boundaries between these types of hydropower are not concrete; for example, storage projects may incorporate a component of pumping to supplement the water that flows into the upper reservoir naturally. Run-of-river projects may benefit from greater flow regulation (generation flexibility) from a storage project located upstream. Run-of-river projects may also incorporate a few hours up to a few days of storage capability. There is no standard that completely differentiates each typology from the others, but in general these typologies represent the hydropower sector.

Outside of ocean hydropower, with regard to turbine types, there are two main categories: reaction and impulse. Impulse turbines utilize the pressure of the water column falling on the turbine through a concentrated jet. For maximum efficiency, the direction of the water striking the turbine is turned through 180°, and then falls to a tail-water channel which is open to the atmosphere. Reaction machines utilize both the pressure of the water entering the turbine and the suction of the water exiting the turbine through a draft-tube passageway, while flowing towards the downstream water body.

Examples of impulse turbines are Pelton type units; these tend to be used at sites when the available head at the site is very high and the discharge is small. Reaction turbines tend to be used when the ratio between head and discharge moves towards lower available head with higher flows. Moving from higher to lower head, examples are Francis, Kaplan and Bulb type turbines.

All the above turbine types are at advanced echelons of technical design. Consequently, extraordinary levels of efficiency can now be expected. Modern hydropower turbines can achieve efficiencies of 95% across their operating range (design limits of head/discharge) – something unparalleled in any other turbine technology. Efficiency gains and the trend for higher capacity equipment to provide peaking generation, continue to drive the market for the modernization of power stations throughout the world. The upgrading and replacement of turbine equipment at existing stations currently represents about 15% of the investment in the hydropower sector. This proportion is likely to remain constant, but will grow in absolute terms as the world's fleet of hydropower stations continues to increase (currently estimated to be about 15,000 in total).

Nonetheless, hydropower technology is regularly refined to optimize performance and minimize local impacts. Recent advances in hydropower technology include ongoing improvement and increased deployment of tidal hydropower; technological refinements to turbine operations to enable rapid ramp up and ramp down to accommodate increased penetration of renewables into electricity systems (i.e., more variable sources of energy in an electricity system require a technology such as storage or pumped storage hydropower to balance that variability); improved pumping technology for pumped storage hydropower; and fish-friendly infrastructure. For example, ongoing developments with variable speed pumps in pumped storage stations will help enable penetration of more variable renewable energy sources. In addition, technological advances have the potential to improve the environmental performance of hydropower. For example, the US Electric Power Research Institute (EPRI) is currently undertaking research both in the area of development of fish-friendly hydropower turbines that cause minimal injury to passing fish and in the collection of more general information on fish behavior at passages and ladders, and the effectiveness of such measures.

With regard to scale, all the above turbine types can be utilized at sites from the very smallest through the largest capacities. A Francis type turbine, for example, can be used at sites to generate less than 0.1MW through to 800MW. The basic turbine would look exactly the same; the only difference would be the dimensions.

As a growing number of low-head sites are being exploited, the number of Bulb type turbine applications is increasing. For example, on the Madeira River in Brazil, two power plants are under construction: the Santo Antônio and Jirau projects. Each will utilize 44 Bulb turbines – an unprecedented number of turbines in single power stations. The projects will add more than 6000MW capacity to the Brazilian electricity system, enough to power two cities the size of São Paulo.

Sustainability

Water use for energy, hydropower in particular, is important throughout the world. The specific characteristics of hydropower are fundamental for the balancing of supply and demand in electric power systems. In particular, the supportive role of hydropower in backing up the growing contribution from wind and solar is essential for security of supply. Hydropower's ability to store both water and energy is also increasingly valued. Despite the long history of hydropower development, record levels of deployment have occurred in the last five years. Notwithstanding this, sustainable development in the context of hydropower has been the subject of debate. Today, a broad consensus on basic good practice exists, which has been developed through multi-stakeholder processes, and tools are available for the measurement of sustainability in the hydropower sector. The following describes some of the hydropower-specific sustainability aspects.

- The potential impacts of hydropower projects are well documented[1], for example:
  - Hydrological regimes;
  - Land-use change;
  - Water quality;
  - Sediment transport;
  - Biological diversity;
  - Resettlement; Downstream water users;
  - Public health;
  - Cultural heritage.

- The gravity of the particular negative impacts varies from project to project, as does the scope for their avoidance or mitigation. Also, the opportunity to maximize positive impacts (beyond the renewable electricity generated) varies from site to site.

- Tools, such as the IFC Performance standards, World Bank Safeguards, and the Equator Principles, have all contributed to increased awareness of the need to balance technical and economic benefits with protecting environmental and social outcomes. The Hydropower Sustainability Assessment Protocol, a hydropower-specific tool, provides a means of measuring a project's performance throughout project's life-cycle, across all aspects of sustainability. This tool is the result of a multi-stakeholder process with the objective of guiding sustainability in the hydropower sector, and is currently being implemented worldwide (www.hydrosustainability.org).

- Increasingly, hydropower developers and owners are using tools such as the Protocol to guide project decision-making, implementation and operation. As a growing hydropower practice, the sustainability benefits are considerable: besides environmental and social issues being treated with parity to other considerations, such tools ensure that international practices are applied locally irrespective of variations in national regula-

1. IPCC SRREN, Chapter 5Kumar, A., T. Schei, A. Ahenkorah, R. Caceres Rodriguez, J.-M. Devernay, M. Freitas, D. Hall, A. Killingtveit,Z. Liu, 2011: Hydropower. In IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation [O. Edenhofer, R. Pichs-Madruga, Y. Sokona, K. Seyboth, P. Matschoss, S. Kadner, T. Zwickel, P. Eickemeier, G. Hansen, S. Schlomer, C. von Stechow (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, at 463, citing IEA, 2000a,b,c,d,e.

tions, and provide common frameworks around which project stakeholders can engage in dialogue around specific projects and their impacts.

- Some examples of how specific impacts are being addressed include:
  - An increased awareness of the need to identify projects with a strategic fit in a national or regional context, and the use of offsets to compensate for a biodiversity impact. This ranges from identification of no-go project areas to the protection of other areas to compensate for project impacts.
  - In depth interaction with project affected communities, including Indigenous people, is moving from impact mitigation and compensation to benefit sharing and livelihood improvement through long term collaborative initiatives. This includes increased recognition of risks and identification of opportunities to avoid or mitigate negative aspects, and to optimize positive impacts through committed engagement with the affected community. Where resettlement is unavoidable, community-led decision-making on plans made in partnership with the developer is increasingly being used to address this most challenging of impacts.
  - Greater understanding of environmental flows and the impacts of changes to these flows has moved consideration from revenue generation and flood control driven practises to the adoption of environmental flow policies that recognise the limitations of pre-determined minimum flows and focus on maintaining flows to support a broader spectrums of riverine species, processes and services, adapted to suit individual contexts.
  - Upstream land use is increasingly being recognized for its impacts on sedimentation issues, and land-use management practices included in reservoir management plans.

- Technological developments contributing to sustainability considerations include refined fish ladders and other effective upstream transportation options, 'fish friendly' turbines lowering downstream passage fish mortality, incorporation of generating capacity into existing storage facilities where previously there was none, and design changes to minimize or avoid lubricating oil discharges from turbine equipment. Perhaps most important, is the orientation of equipment and operations at hydropower stations, to back up the variable generation from other renewables such as wind and solar. This evolution in the role of hydropower will facilitate an even greater contribution from all renewable energy sources in the future.

3. Market trends and outlook

Markets

Hydropower development has traditionally been led by public sector developers supported at least partly by public finances, either from national governments or multilateral development banks. However, in recent years, hydropower investment is becoming increasingly global with investors exploring new regions, and a shift toward more private sector involvement in hydropower development. Examples include South Korea's investment in Nepal, Pakistan, and the Philippines, as well as China and India driving investments in Africa.

Private sector investment often enables projects to be built in a shorter timeframe, and also can enable infrastructure development in areas where local entities are unable to provide the high level of investments needed to build a hydropower facility. However, private sector investors will typically require a more solid return on investment and much stronger assurance of future sales through strong power purchase agreements with the local customer. This also shifts the responsibility for ensuring environmental and social impacts are properly mitigated and managed to the local planning agencies and regulators, who in many cases need external support for capacity building in these areas.

With regard to power pools, regional markets for electricity often support the business case for hydropower development, particularly in locations with hydropower resources and/or potential that exceed their domestic electricity demand. For example, Ethiopia has tremendous hydropower potential, but does not have sufficient domestic demand to justify its full development. Neighbouring countries Kenya and Sudan, on the other hand, do not have domestic hydropower potential and can benefit from the electricity provided by hydropower development in Ethiopia. Countries may opt to pool their investment resources to jointly develop hydropower projects such as, for example, the Governments of Burundi, Rwanda, and Tanzania under the umbrella of the Nile Basin Initiative/Nile Equatorial Lakes Subsidiary Action Program. These countries, along with the World Bank, are developing a 90-megawatt hydropower plant at a cost of 400 billion Burundian francs (USD 312 million).

In addition, regional electricity interconnections (and market structures) promote stability in the electricity system while reducing the need for costly system redundancy. Regional power pools support this trade in electricity across countries. Examples of regional power pools that are supported by hydropower assets include the Central American Electrical Interconnection System (SIEPAC), the Eastern African Power Pool (EAPP), the Southern African Power Pool (SAPP), and the European system, and several regional Canadian-US trading markets.

Traditionally, hydropower has been designed to provide steady base-load supply, with plant factors exceeding 80%. Projects with storage reservoirs can also release water in a controlled way so as to follow the demand in the electricity grid. With the increasing penetration of more variable renewable energy services, hydropower is called on to play a supportive role: starting up at short notice when there is a deficit in the power system, and shutting down when there is a surplus, rather than providing base load power. In such situations, the stations may need to be available to operate most of the time, but only utilizing energy when the demand calls for it; hence the station might be available for 90% of the time but only be needed to operate for 20% of time. This shift in the way hydropower is operated is benefited by a shift in the market dynamics and structure. Increasingly, electricity markets are incentivizing this type of flexible generation by rewarding it with much higher prices when energy is most needed, and giving a price signal to deter generation when there is a surplus in the system. However, many countries have yet to change their market structures to accommodate shifting generation patterns.

Global tables

Table 1
Hydropower capability

	Gross theoretical capability	Technically exploitable capability	Economically exploitable capability
Country	GWh/year	GWh/year	GWh/year
Angola	150000		
Argentina	U	169000	
Australia	150000		
Austria	150000	75000	56100
Bhutan	263000		
Bolivia	126000		
Brazil	3040000	1250000	817600
Bulgaria	26540	15056	NA
Cameroon		115000	
Canada	757579.60	U	U
Chile	162		
China	5920000		
Colombia	1000		
Congo (DRC)	1400		
Costa Rica	223500		
Croatia	20000	12000	10500
Czech Republic	13100	3978	NA
Ecuador	167000		106000
Estonia	2000	400	250
Ethiopia	650000		
Finland	30865	22645	16026
France		100	70
Guinea	26000		
Iceland	184000		
India	2638000		
Indonesia	2150		
Iran	179000	50000	
Italy	200000	65000	47500
Japan	U	136520	U
Kazakhstan	170000	62000	29000

Latvia	U	U	U
Lithuania	2200		
Madagascar	321		180
Malaysia	123	16	
Myanmar (Burma)		140	
Nepal			140160
Norway	22.10		
Pakistan	475		
Paraguay	111		68
Peru	260		
Poland	23000	12000	5000
Portugal	U	U	U
Romania	70000	36000	21000
Russian Federation	2295		
Serbia	27200	19447	17733
Spain	162		
Sudan	19		
Sweden	65000	35000	20000
Tajikistan	2635		
Turkey	432000	216000	170000
United Kingdom	4.10		
United States of America	2040.00		
Uruguay	32	10	
Venezuela	731		
Vietnam	300		

Table 2
Hydropower installed capacity and production in 2011

	Installed capacity	Actual generation in 2011	Capacity under construction
Country	**MW**	**GWh**	**MW**
Afghanistan	400		
Albania	1 432		
Algeria	278		
Angola	790		80
Argentina	10 025	31 847	60
Australia	7 800	12 000	80
Austria	13 200	37 701	1 000
Azerbaijan	1 020	2 646	
Bangladesh	230	1 485	
Belarus	13		
Bhutan	1 488	7 134	
Bolivia	440	2 300	800
Bosnia-Herzegovina	2 380	7 946	
Brazil	82 459	428 571	21 100
Bulgaria	2 018	2 366	

Cameroon	729	3 850	
Canada	75 104	348 110	3 720
Central African Republic	19		
Chile	5 946	20 799	342 000
China	249 000	714 000	3 833
Colombia	9 185	45 583	
Congo (DRC)	2 410	7 771	
Congo (Republic of)	89		
Costa Rica	1 510		150
Cote d'Ivoire	606		
Croatia	2 141	4 620	
Cuba	7		
Cyprus	1		
Czech Republic	1 055	2 134	
Denmark	9		
Ecuador	804	9 544	
Egypt	2 942	13 540	
El Salvador	472		
Equatorial Guinea	1		
Estonia	8	30	1
Ethiopia	663		
Finland	3 084	12 278	
France	25 332	50 300	
Gabon	170		
Georgia	2 635		
Germany	4 740	18 188	
Ghana	1 180	5 600	400
Greece	3 243	3 793	
Guinea	75	220	80
Hungary	51		
Iceland	1 900	12 600	
India	38 106	131 000	15 627
Indonesia	3 881	12 419	
Iran	8 746	11 820	5 083
Iraq	2 273	700	
Ireland	529	28	
Israel	7		
Italy	18 092	45 823	
Jamaica	24		
Japan	22 362	72 639	291
Jordan	12		
Kazakhstan	2 267	7 849	300
Korea (DRC)	4 780		
Korea (Republic)	1 605	4 676	
Kyrgyzstan	2 910	10 227	
Laos	700		5 361
Latvia	1 550	2 810	
Lebanon	280		
Lesotho	76		
Lithuania	101		3
Macedonia	528		29
Madagascar	124	700	
Malawi	300		

Malaysia	1 910	7 334	3 344
Mali	155		
Mauritania	30		
Mexico	11 499	35 796	750
Moldova	64		
Mongolia	28		
Montenegro	658		
Morocco	1 265		
Mozambique	107		
Myanmar (Burma)	1 541	3 900	1 500
Nepal	600		
Netherlands	37	56	
New Zealand	5 250	24 828	
Nicaragua	105		
Norway	1 521	6 800	1 021
Pakistan	6 481	27 700	1 600
Paraguay	8 130	53 524	
Peru	3 242	21 384	
Philippines	3 291	9 346	
Poland	940	2 331	
Portugal	5 352	12 114	1 447
Puerto Rico	85	149	
Romania	6 144	14 954	
Russian Federation	49 700	180 000	3 000
Rwanda	55		
Senegal	60		
Serbia	2 891	9 165	
Sierra Leone	4		
Slovakia	2 523	4 105	
Slovenia	1 253	3 523	
Somalia	5		
South Africa	661	2 117	
Spain	18 540	25 000	450
Sri Lanka	1 300	5 578	
Sudan	575	3 804	
Suriname	189		
Swaziland	61	69	
Sweden	16 197	66 000	
Switzerland	13 723	32 069	1 995
Syria	1 505		
Taiwan	1 938		
Tajikistan	5 500	11 200	
Tanzania	561	2 548	
Thailand	3 481	8 085	
Togo	66		
Tunisia	70		
Turkey	17 259	57 472	8 270
Turkmenistan	1		
Uganda	340		250
Ukraine	4 514	13 020	
United Kingdom	1 630	5 700	
United States of America	77 500	319 355	
Uruguay	1 538	6 479	

Uzbekistan	1 710	10 087	
Venezuela	14 627	86 700	
Vietnam	5 500	24 000	
Zambia	1 730	11 160	
Zimbabwe	754	4 089	
World Total	934 733	3 229 607	-

Country notes

The Country Notes on Hydropower have been compiled using the information submitted by WEC Member Committees in 2012 and various national and international reference publications and other sources, including the International Hydropower Association, *The International Journal on Hydropower & Dams*, published by Aqua~Media and other sources. Note: U stands for an unknown value.

Angola

Gross theoretical capability (TWh/yr)	150
Capacity in operation (MW)	790
Actual generation (GWh)	U
Capacity under construction (MW)	

Angola's estimated hydropower potential is 150 TWh/yr, one of the highest in Africa. However, so far only a small fraction of the country's hydro potential has been harnessed. Feasibility Studies are in progress on major hydro schemes at Lauca and Caculo-Cabaca on the Kwanza river, each with an installed capacity of 2 000 MW, and on a bi-national project at Baynes Mountain on the Cunene (see country note on Namibia).

Argentina

Gross theoretical capability (TWh/yr)	U
Capacity in operation (MW)	10 025
Actual generation (GWh)	31 847
Capacity under construction (MW)	60

Hydroelectricity is an important component of Argentina's power profile. Though hydroelectric output fluctuates and has declined in recent years, it accounts for between one-quarter and one-third of Argentina's total electricity generation. Argentina's most significant hydroelectric capacity is located in Neuquén, followed by border provinces that share hydroelectric output with surrounding countries.

Argentina and Paraguay divide power from the large Yacyreta plant, which sits astride the Paraná River (Corrientes province) with a total installed capacity of 3.1 GW. Likewise, the Salto Grande hydroelectric plant on the Uruguay River (along Entre Ríos province) has a capacity of 1.89 GW, from which output is split evenly between Argentina and Uruguay. In 2011, total hydroelectric generation was 39,339 GWh, according to CAMMESA.

The WEC Argentine Member Committee reports that there is an ongoing updating and improvement of cost-estimation procedures, the review of existing projects using consistent criteria, and the evaluation of the resource up to the level of technical and economic pre-feasibility.

The Committee also reports that Argentina possesses 75 small, mini and micro hydro plants (of up to 30 MW capacity), with an aggregate capacity of 377 MW and an annual generation equivalent to 1.6% of national electricity demand.

Australia

Gross theoretical capability (TWh/yr)	150
Capacity in operation (MW)	7 800
Actual generation (GWh)	12 000
Capacity under construction (MW)	80

Australia is the driest inhabited continent on earth, with over 80 per cent of its landmass receiving an annual average rainfall of less than 600 mm per year and 50 per cent less than 300 mm per year. There is also high variability in rainfall, evaporation rates and temperatures between years, resulting in Australia having very limited and variable surface water resources. Much of Australia's economically feasible hydro energy resource has already been harnessed.

Australia has more than 100 operating hydroelectric power stations with total installed capacity of about 7800 megawatts (MW). These are located in the areas of highest rainfall and elevation and are mostly in New South Wales (55%) and Tasmania (29%). The Snowy Mountains Hydro-electric Scheme, with a capacity of 3800MW, is Australia's largest hydro scheme and is one of the most complex integrated water and hydroelectricity schemes in the world.

The Scheme collects and stores the water that would normally flow east to the coast and diverts it through trans-mountain tunnels and power stations. The water is then released into the Murray and Murrumbidgee Rivers for irrigation. The Snowy Mountains Scheme comprises sixteen major dams, seven power stations (two of which are underground), a pumping station, 145km of inter-connected trans-mountain tunnels and 80km of aqueducts. The Snowy Mountains Hydro-electric Scheme accounts for around half of Australia's total hydroelectricity generation capacity and provides base load and peak load power to the eastern mainland grid of Australia.

Hydro energy is particularly important in Tasmania where it provides much of the state's electricity. The Tasmanian integrated hydropower scheme harnesses hydro energy from six major water catchments and involves 50 major dams, numerous lakes and 29 power stations with a total capacity of over 2600MW. The scheme provides base and peak load power to the National Electricity Market, firstly to Tasmania and then to the Australian network through Basslink, the undersea interconnector which runs under Bass Strait. There are also hydroelectricity schemes in north-east Victoria, Queensland, Western Australia, and a mini-hydroelectricity project in South Australia.

Austria

Gross theoretical capability (TWh/yr)	150
Capacity in operation (MW)	13 200
Actual generation (GWh)	37 701
Capacity under construction (MW)	1 000

Out of a total gross theoretical hydro potential of 150 TWh/yr, Austria's technically feasible potential is estimated at about 75 TWh/yr, of which 75% is considered to be economically exploitable. At present, the total installed capacity of hydro-electric power stations (excluding pumped-storage plants) is 13 200 MW; with net generation of approximately 37 TWh. Most of Austria's HPPs are of the run-of-river type.

The construction of a number of (mostly fairly small) pure hydro plants and the refurbishment/ extension of some existing stations is under way or planned, but the construction of large hydro installations in Austria is currently confined to a number of pumped-storage schemes. Kops II (450 MW) was completed in 2009, while work is continuing at Limburg II, which will add 480 MW to the capacity of the Kaprun pumped-storage plant in 2012, and at Reisseck II (430 MW), part of the Reisseck-Kreuzeck hydro complex, scheduled to be completed in 2014.

Bhutan

Gross theoretical capability (TWh/yr)	263
Capacity in operation (MW)	1 488
Actual generation (GWh)	7 134
Capacity under construction (MW)	1 209

Bhutan possesses a huge hydropower resource, its gross theoretical potential being assessed at over 263 TWh/yr, with a technically feasible capability of more than 99 TWh/yr (corresponding to a potential generating capacity of around 23 500 MW). Current installed hydro capacity is 1 488 MW, having recently been augmented by the commissioning of the 1 020 MW Tala HPP, Bhutan's first bi-national project, developed in conjunction with India.

Two more hydro plants are under construction - Punatsangchhu I (1 095 MW, for completion by 2015) and Dagachhu (114 MW). A further 2 400 MW of capacity is at the planning stage, notably Punatsangchhu II (circa 1 000 MW) and Mangdechhu (circa 720 MW).

The Governments of Bhutan and India are jointly planning to construct a total of ten HPPs, with an anticipated aggregate installed capacity of 11 576 MW, for development by 2020. The programme includes a number of massive projects, the largest being the Sunkosh Reservoir (4 000 MW), Kuri Gongri (1 800 MW) and Wangchhu Reservoir (900 MW) schemes. The principal function of the bi-national plants will be to boost Bhutan's exports of electricity to India.

Bolivia

Gross theoretical capability (TWh/yr)	126
Capacity in operation (MW)	440
Actual generation (GWh)	2 300
Capacity under construction (MW)	800

Bolivia has a considerable hydro potential, its technically feasible potential being assessed at 126 TWh/yr, of which 50 TWh/yr is considered to be economically exploitable. Only a small proportion of the total potential has been harnessed so far. The country's hydro capacity, according to OLADE, was 440 MW, with an output of about 2.3 TWh.

Hydropower & Dams World Atlas 2009 reports that 88 MW of additional hydro capacity was under construction in early 2009. A wide range (2 338-3 064 MW) is quoted for planned hydro capacity, some of which relates to projects forming part of the Rio Madeira scheme outlined below.

Bolivia is working with Brazil on a huge joint project to exploit the hydro-electric potential of the Rio Madeira complex in the Amazon region. Within this project are the 800 MW Cachuela Esperanza plant sited entirely in Bolivia and the Guajara-Mirim plant (3 000 MW) to be located on the border between the two countries.

Brazil

Gross theoretical capability(TWh/yr)	3 040
Capacity in operation (MW)	82 459
Actual generation (GWh)	428 571
Capacity under construction (MW)	21 100

Hydroelectric power is one of Brazil's principal energy assets: the country has by far the largest hydropower resources on the continent. The Brazilian WEC Member Committee reports that the gross theoretical capability is estimated to be 3 040 TWh/yr, with an economically exploitable capability of about 818 TWh/yr, of which over 45% has so far been harnessed..

According to the Member Committee, Brazil had 82 458 MW of operational hydropower capacity at the end of 2011, generating in that year 428 571 GWh of electricity. The country had 21 100 MW of additional hydro capacity under construction at the end of 2011, with an estimated annual generation of around 41 TWh. Further hydro capacity reported to be planned for future development totalled 68 000 MW, with a projected annual output of some 327 TWh.

Furthermore, small-scale hydro (since 1998, defined in Brazil as plants with a capacity of <30 MW) has an economically exploitable capability of 11 200 GWh/yr. ThJe aggregate installed capacity of small HPPs was 1 237 MW at end-2008, and they produced a total of 6 280 GWh in 2008, equivalent to just over 56% of the assessed economic potential. A total of 513 MW of small-hydro capacity is planned for future installation which, if all the plans are implemented, will add some 2.5 TWh to Brazil's electricity supply.

Cameroon

Gross theoretical capability (TWh/yr)	U
Capacity in operation (MW)	729
Actual generation (GWh)	3 850
Capacity under construction (MW)	0

The technically exploitable hydro capability (115 TWh) is the fourth largest in Africa but the current level of utilisation of this potential is, like that in other hydro-rich countries in the continent, very low. Within a total hydro capacity of 729 MW, Cameroon's major stations are Song Loulou (installed capacity 396 MW) and Edéa (264 MW), for both of which contracts have been awarded for refurbishment. Annual hydro-electric output is about 3 850 GWh, implying a capacity factor of around 0.60.The Cameroon WEC Member Committee reported that a number of projects is being negotiated but no further details are available.

Canada

Gross theoretical capability(TWh/yr)	758
Capacity in operation (MW)	75 104
Actual generation (GWh)	348 110
Capacity under construction (MW)	3 720

Canada possesses enormous hydropower potential – the Canadian Hydropower Association assessed Canada's 'total unexploited technical hydro potential' in 2011 as 163 GW, of which over half was in Québec, Alberta and British Columbia. At the end of 2011, total installed hydroelectric capacity was 75 104 MW.

Approximately 475 hydroelectric generating plants across the country produce an average of 350 terawatt-hours per year — one terawatt-hour represents enough electricity to heat and power 40,000 houses. In 2011 the actual total generation for the year was 348 TWh.

With many rivers across the country, Canada has hydropower in all regions. The top-producing provinces are Quebec, British Columbia, Manitoba, Ontario, and Newfoundland and Labrador, with more than 95 percent of the total hydropower generation in Canada.

Canada still has immense undeveloped potential — over twice the current capacity — and all provinces and territories have some hydropower potential.

There are a number of significant hydroelectric projects under construction. In total, these projects will increase hydro generation capacity by more than 2 350 MW, with a probable annual generation of 11.15 TWh. According to Natural Resources Canada, hydro capacity reported to be in the course of planning adds up to a massive 14 500 MW, potentially supplying more than 68 TWh/yr.

The total installed capacity of small hydro plants (of <10 MW) totalled 1 001 MW, with an estimated annual generation of 4 650 GWh. Small-scale HPPs are located throughout the country, notably in British Columbia, Ontario, Québec, Nova Scotia, Newfoundland and Labrador. A total of 188 MW of additional small hydro capacity is reported as planned, with a projected generation of 873 GWh/yr.

Chile

Gross theoretical capability (TWh/yr)	162
Capacity in operation (MW)	5 946
Actual generation (GWh)	24 300
Capacity under construction (MW)	0

There is a substantial hydropower potential, with a technically exploitable capability estimated at about 162 TWh/yr, of which about 15% has so far been harnessed. Hydro output in 2011 was 24.3 TWh, equivalent to just over 40% of Chile's total net electricity generation.

More than 5 800 MW of new HPPs is at the planning stage, including major projects at Alto Maipo (531 MW), Angostura (309 MW), Neltume and Choshuenco (580 MW) and Rio Cuervo (440-600 MW), together with five plants (total capacity of approximately 2 750 MW) on the Baker and Pascua rivers in the southern region of Aysen.

China

Gross theoretical capability(TWh/yr)	5 920
Capacity in operation (MW)	231 000
Actual generation (GWh)	714 000
Capacity under construction (MW)	111 000

With its vast mountain ranges and numerous rivers, China's hydropower potential is the largest in the world. China is the world's largest producer of hydroelectric power and is aggressively building dams. Hydropower accounts for about 16 percent of China's electricity and 7 percent of its total energy consumption. It is planned to increase hydro-generating capacity by nearly two-thirds over the next five years.

While China is racing ahead to install more wind- and solar-power capacity, the energy generated by these technologies is considered too costly and insufficient to satisfy the country's huge power needs. The drought in 2011 reduced the output of hydroelectric power, contributing to a government decision to raise the cost of electricity for industrial use in 15 areas.

In 2010, China generated 714 TWh of electricity from hydroelectric sources. Installed hydroelectric generating capacity was 231 GW in 2011, according to FACTS Global Energy, accounting for over a fifth of total installed capacity. The China Electricity Council has plans to increase hydro capacity to 342 GW by 2015. The world's largest hydro power project, the Three Gorges Dam along the Yangtze River, was completed in July 2012 and includes 32 generators with a total capacity of 22.7 GW. The dam's annual average power generation is anticipated to be 84.7 TWh.

JBesides the Three Gorges project, there are many other massive plants in hand. Examples of such projects inclJJude Xiluodu (12 600 MW), Xiangjiaba (6 000 MW), Longtan (6 300 MW), Jinping II (4 800 MW), Xiaowan (4 200 MW), Laxiwa (4 200 MW), Jinping I (3 600 MW), Pubugou (3 600 MW), Dagangshan (3 600 MW) and Goupitan (3 000 MW).

Colombia

Gross theoretical capability (TWh/yr)	1 000
Capacity in operation (MW)	9 185
Actual generation (GWh)	45 583
Capacity under construction (MW)	3 833

Colombia's theoretical potential for hydropower is considerable, up to 1 000 TWh/yr, of which 20% is classed as technically feasible. Hydro output represents around 30% of the economically exploitable capability of 140 TWh/yr and accounted for about three-quarters of Colombia's electricity generation.

According to the Colombian Member Committee of WEC, there was 9 185 MW of hydropower in operation in 2011, generating a total of 45 583 GWh of electricity in that year.

Congo (Democratic Republic)

Gross theoretical capability (TWh/yr)	1 400
Capacity in operation (MW)	2 410
Actual generation (GWh)	U
Capacity under construction (MW)	0

The assessed potential for hydropower is by far the highest in Africa, and one of the highest in the world. The gross theoretical potential of the Congo River is almost 1 400 TWh/yr and the technically feasible exploitable capacity is put at 100 000 MW. The current level of hydro-electric output is equivalent to only around 3% of the republic's economically exploitable capability. Hydro provides virtually the whole of its electricity.

The national public electricity utility SNEL has 17 hydro plants, of which 11 plants have an installed capacity of over 10 MW. The total rated capacity of SNEL's hydropower plants is 2 410 MW; with the largest stations being Inga 1 (351 MW) and Inga 2 (1 424 MW). The power plants of these stations are either being (or planned to be) refurbished, in order to boost their faltering performance by an additional 660 MW. Moreover, a significant increase in capacity would be provided by the Inga 3 project (4 320 MW), which is currently in the planning phase.

There is also a huge scheme (Grand Inga, 40 000 MW or more), incorporating the supply of electricity to other parts of Africa via new long-distance high-voltage transmission lines. Both the power generating plant and transmission network have been the subject of preliminary investigations and pre-feasibility studies.

These studies identified three major African interconnection HVDC projects:

- Northern Highway (Inga to Egypt);
- Southern Highway (Inga to South Africa);
- Western Highway (Inga to Nigeria).

These electricity Highways would supply the five African power pools: SAPP, WAPP, PEAC, EAPP and COMELEC.

Costa Rica

Gross theoretical capability (TWh/yr)	223.5
Capacity in operation (MW)	1 510
Actual generation (GWh)	U
Capacity under construction (MW)	150

Costa Rica has a large hydroelectric potential. Its gross theoretical potential is estimated at 223.5 TWh/yr, within which a hydropower capacity of 5 694 MW has been assessed as economically feasible (after exclusion of areas within national parks).According to the Instituto Costarricense de Electricidad, aggregate installed hydro capacity was 1 510 MW at end-2008, equivalent to about 64% of Costa Rica's total generating capacity, and about 27% of its estimated economic potential.

Several new hydro plants are under construction or planned: nearing completion are Pirris (128 MW) and Toro 3 (50 MW), both due to enter service in 2011, together with three BOT schemes, each with 50 MW capacity and scheduled for operation in 2013: Torito on the Reventazon river, at the end of the tail-race of the Angostura HPP, and Capulin-San Pablo and Chucas on the Tarcoles. Two larger projects reported to be at the feasibility stage in 2009 were Diquís (622 MW), planned for completion in 2016, and Reventazón (298 MW), planned for 2014.

Czech Republic

Gross theoretical capability (TWh/yr)	13.1
Capacity in operation (MW)	1055
Actual generation (GWh)	2 134
Capacity under construction (MW)	0

The overall potential for all sizes of hydropower is quite modest (technically exploitable capability: 3 978 GWh/yr, as reported by the Czech WEC Member Committee). Total hydro-electricity output in 2011 was 2 134 GWh, representing 51% of this potential. Hydropower furnishes less than 3% of the republic's electricity generation.

A relatively high proportion (nearly 40%) of the technically exploitable capability is classified as suitable for small-scale schemes; installed capacity in this category at the end of 2011 was 297 MW, equivalent to about 28% of the Czech Republic's total hydro capacity. Actual generation from small-scale schemes in 2011 was 1 159 GWh.

The *State Energy Concept* provides support for the construction of further small-scale HPPs, in particular through favourable feed-in tariffs, which guarantee a positive return on investment. Investment subsidies serve as another effective stimulus. The number of sites available for the construction of small hydro plants is reported to be small. Licensing procedures are fairly complex and often somewhat protracted.

The only planned extensions to the Czech Republic's hydro generating capacity comprise two small plants presently under construction; a 5 MW plant at Litomerice on the Elbe (Energo-Pro Co.) and a 0.5 MW plant at Melnik (CEZ, plc). Over half of the existing small HPPs use obsolete technology (dating from 1920-1950). There are plans to modernise the technology, with the aim of improving efficiency by up to 15%.

Ecuador

Gross theoretical capability (TWh/yr)	167
Capacity in operation (MW)	804
Actual generation (GWh)	U
Capacity under construction (MW)	U

The gross theoretical hydro potential is substantial, at about 167 TWh/yr, within which there is estimated to be an economically feasible capability of nearly 106 TWh/yr. Preliminary work at the site of the largest of the plants is under way, Coca Codo Sinclair (1 500 MW), have been completed; commercial operation is scheduled to commence in 2015.

Most of Ecuador's hydro capacity is located in Azuay province, in the south-central highlands. Paute-Molino is the country's single-largest hydroelectric complex, and alone claims almost 1.1 GW of capacity. Droughts in late 2009 affected flows in Paute River and caused the government to implement rolling blackouts from November 2009 to January 2010. To address capacity shortages, Ecuador plans to build six new hydroelectric power plants in the coming decade. Financing for all of the new projects have come from China.

Ethiopia

Gross theoretical capability (TWh/yr)	650
Capacity in operation (MW)	663
Actual generation (GWh)	U
Capacity under construction (MW)	2 150

There are enormous resources for hydro generation, the gross theoretical potential (650 TWh/yr) being second only to that of Congo (Democratic Republic) in Africa. The Ethiopian WEC Member Committee reports that only a small share of the assessed potential has been developed. Currently, hydropower provides more than 95% of Ethiopia's electricity.

Further capacity increases, at various stages of planning, total more than 7 500 MW. A contract was signed with China in July 2009 for constructing the Gibe IV and Halele Werabesa schemes, which will add 2 150 MW to Ethiopia's hydro capacity.

Finland

Gross theoretical capability (TWh/yr)	174
Capacity in operation (MW)	3 084
Actual generation (GWh)	12 278
Capacity under construction (MW)	U

Hydropower accounts for about 4% or Finland's total energy consumption. Hydropower's share of electricity production in Finland has varied in recent years within the range 10-15%, depending on precipitation levels and other hydrological conditions. Hydropower is Finland's second most widely exploited renewable energy source, after bioenergy. These plants have a total capacity of approximately 3,084 MW. Their total annual production has varied between 9.5 and 16.8 TWh, according to water conditions, in 2011 production totalled almost 12.3 TWh.

It could still be possible to increase Finland's hydropower capacity, though the main potential sources are generally well exploited. The total unexploited hydropower potential along river systems that are not protected for landscape or nature conservation is estimated at more than an annual production potential of 2 468 GWh. Of this potential 1 330 GWh/year is considered as economically exploitable. It is unlikely that hydropower developments could be launched along any remaining totally unharnessed rivers, for conservation reasons.

France

Gross theoretical capability (TWh/yr)	100
Capacity in operation (MW)	25 332
Actual generation (GWh)	50 300
Capacity under construction (MW)	U

France is one of Western Europe's major producers of hydroelectricity, but its technically feasible capacity has now been very largely exploited. The total hydroelectric generating capacity (excluding pumping) stands at
25 332 MW. The year's net production of 50.3 TWh compares with an estimated technically exploitable capability of 100 TWh/yr, of which 70% is considered to be economically exploit-able.

The total output capacity of small-scale (less than 10 MW) plants is approximately 1 850 MW, which generated almost 7 TWh.

The PPI (long-term plan for investments in electricity generation) for the period 2009-2020 envisages targets for an increase of 3 TWh/yr in electricity output and of 3 000 MW in installed capacity through the installation of new small units and the enlargement of existing facilities.

Ghana

Gross theoretical capability (TWh/yr)	U
Capacity in operation (MW)	1 180
Actual generation (GWh)	5 600
Capacity under construction (MW)	400

There are 17 potential hydro sites, of which only Akosombo (upgraded in 2005 from 912 to 1 038 MW) and Kpong (160 MW) have so far been developed; their total net capacity, according to the Volta River Authority (VRA) website, is 1 180 MW. Electricity generation in Ghana is a responsibility of the VRA, which was established in 1961. The average annual output of its two existing hydro stations (circa 5 600 GWh) is equivalent to about half of Ghana's technically exploitable hydro capability.

Construction of the 400 MW Bui dam on the Black Volta is underway by China's Sino Hydro Corporation, and scheduled for completion in 2012.

Guinea

Gross theoretical capability (TWh/yr)	26
Capacity in operation (MW)	75
Actual generation (GWh)	U
Capacity under construction (MW)	80

Guinea is well-endowed with water resources, having 1 165 watercourses draining into 23 hydrographic basins, of which 16 are shared with neighbouring countries. The WEC Member

Committee reported that the gross theoretical hydro capability had been assessed as 26 TWh/yr, the technically exploitable capability as 19.3 TWh/yr and the economically exploitable capability as 19 TWh/yr.

The capacity potential corresponding to the technically exploitable capability of 19.3 TWh/yr is 6 100 MW, located mainly in the regions of Basse Guinée (46%) and Moyenne Guinée (43%), with minor amounts in Haute Guinée (8%) and Guinée Forestière (3%). Some 40% of the national hydro potential lies in the basin of the River Konkouré.

Additional hydro output which might feasibly become available in the longer term was put at over 5 100 GWh/yr. Taken together with the planned development of hydro capacity, this would imply an eventual total output of some 9.5 TWh/yr, equivalent to more than half the currently assessed economically exploitable capability.

Guinea intends to use its hydroelectric potentials to replace the supply of electricity by thermal power stations which is considerably more expensive. The country still faces some problems in this area. In the capital Malabo, power supply is assured 60% by one thermal power station and 40% by private generating sets. Unfortunately the supply of these private generating sets is small. To overcome these differences, the hydroelectric power station at Musala near Luba was built where its network covers an area of 1460km. In the same light, a hydroelectric power station with a capacity of 3.6 megavolts was built on the Rio Riaba. On the mainland, the thermal power station of Bata on Rio Muni has been equipped with two sets with a unit capacity of 700kw.

Iceland

Gross theoretical capability(TWh/yr)	184
Capacity in operation (MW)	1 900
Actual generation (GWh)	12 600
Capacity under construction (MW)	0

Hydropower is the main source of electricity production in Iceland. Today, hydroelectric plants account for approximately three-quarters of all electricity generated and consumed in Iceland. The remaining quarter comes from geothermal power stations. Hydro's gross theoretical potential of 184 TWh/yr including 40 TWh of economically exploitable output.

The largest hydroelectric stations utilize the flow of Iceland's glacial rivers, while numerous smaller hydropower plants are located in clear-water streams and rivers all around the country. All the major hydroelectric stations get their water from reservoirs, ensuring that these stations offer stable production year-round.

The 690 MW Fljótsdalur HPP, which is part of the Kárahnjúkar hydro scheme, came into operation in November 2007 and reached its full load in February of the following year. A further 80 MW of hydro capacity is under construction at the Búdarháls site on the Tungnaá river in southern Iceland. A number of other projects have been awarded licences or are at the planning stage.

The technically exploitable capability of small-scale hydro plants has been reported to be 12.3 TWh/yr, equivalent to about 19% of the level for total hydro. Installed capacity of small hydro at end-2008 was 55 MW, equivalent to 2.9% of total hydro capacity.

Iceland's precipitation has an enormous energy potential or up to 184 TWh/yr. Much of it is stored in ice caps and groundwater, and dissipated by evaporation, groundwater flow and glacier flow.

In total, all the hydropower stations in Iceland have a capacity of just under 1 900 MW and generate around 12 600 GWh annually. Due to new hydropower projects the capacity and generation will increase substantially in the next few years.

Iceland's largest hydropower station is Fjótsdalsstöð (Fljotsdalur Station) in Northeast Iceland, with a capacity of 690 MW. It generates close to 4,700 GWh annually. This is almost three times more than the power plant that comes in second place, which is Búrfellsstöð (Burfell Station) in the highlands of South Iceland. The powerful glacial rivers of South Iceland are the main source of Iceland's hydropower generation; numerous reservoirs and power stations in this area now generate more than 5,000 GWh annually.

India

Gross theoretical capability (TWh/yr)	2 638
Capacity in operation (MW)	38 106
Actual generation (GWh)	U
Capacity under construction (MW)	15 627

India's hydro resource is one of the largest in the world, its gross theoretical hydropower potential is estimated to be 2 638 TWh/yr, within which is a technically feasible potential of some 660 TWh/yr and an economically feasible potential of 442 TWh/yr. Out of the total power generation installed capacity in India of 1,760,990 MW (June, 2011), hydro power contributes about 21.6% i.e. 38,106 MW. A total capacity addition of 78,700 MW is envisaged from different conventional sources during 2007-2012 (the 11th Plan), which includes 15,627 MW from large hydro projects. In addition to this, a capacity addition of 1400 MW was envisaged from small hydro up to 25 MW station capacity. The total hydroelectric power potential in the country is assessed at about 150,000 MW, equivalent to 84,000 MW at 60% load factor. The potential of small hydro power projects is estimated at about 15,000 MW.

As part of India's 11th Five Year Plan, Teesta V (510 MW) in Sikkim and Omkareshwar (520 MW) in Madhya Pradesh have both recently been commissioned. Large hydro plants currently under construction within the 11th Five Year Plan include Subansiri Lower (2 000 MW) in Assam, and Parbati II (800 MW) and Parbati III (520 MW) in Himachal Pradesh.

Numerous other hydro projects are under way or at the planning stage. In addition, 55 hydro schemes have been designated as suitable for renovation and upgrading, which could in due course result in an increment of some 2 500 MW to India's generating capacity.

Indonesia

Gross theoretical capability (TWh/yr)	2 150
Capacity in operation (MW)	3 881
Actual generation (GWh)	12 419
Capacity under construction (MW)	0

At some 2 150 TWh/yr, Indonesia's gross theoretical hydro potential is the third largest in Asia. Its technically feasible potential is just over 400 TWh/yr, of which about 10% is considered to be economically exploitable. Average annual hydro output is about 12.5 TWh, indicating the evident scope for further development within the feasible potential. Hydro presently provides approximately 8% of Indonesia's electricity supply.

Iran (Islamic Rep)

Gross theoretical capability (TWh/yr)	179
Capacity in operation (MW)	8 746
Actual generation (GWh)	U
Capacity under construction (MW)	5 083

Hydropower & Dams World Atlas 2009 quotes the gross theoretical hydropower potential as 179 TWh/yr, of which 50 TWh/yr is regarded as technically feasible.

The Iranian WEC Member Committee reports that installed hydropower capacity was 8 746 MW at end-2011, and that Iran had 5 083 MW of hydro capacity under construction and that a further 10 426 MW was in various phases of planning.

Italy

Gross theoretical capability (TWh/yr)	200
Capacity in operation (MW)	18 092
Actual generation (GWh)	45 823
Capacity under construction (MW)	0

In Italy 67% of energy produced by renewable sources comes from hydroelectric. In Europe, Italy is one of the three major producers of hydroelectric energy, together with France and Spain. According to the Italian Member Committee of WEC current installed capacity is 18 092 MW. In 2011, total hydropower production amounted to 45 TWh of electricity. It has been calculated that the hydroelectric potential of the Italian territory could be approximately 200 TWh, of which 47 TWh is economically exploitable. When compared with the amount of energy produced, this indicates that the potential of the hydroelectric resources in Italy is exploited to about 95% and the maximum limit of possible exploitation has been reached. It therefore does not seem to be a sector that can expand further.

The fact that more favourable and convenient sites, from a technical and economical point of view, are already being utilized, contributes to the "closing" of this sector, and a number of technical, environmental and economic obstacles have arisen with regard to the realization of new high-capacity and high-output power stations. Consequently the future of hydroelectricity in Italy seems to consist in the realization of only the low-output (<100 kW) so-called micro-hydro plants, that imply a poor economic and technical commitment and have a very low impact on the environment.

The gross theoretical capability of small-scale HPPs in Italy is put at 38 000 GWh/yr (one-fifth of total hydro), within which the economically exploitable component is estimated to be 12 500 GWh/yr, as derived from the aforementioned *Italian Position Paper*.

Plants with a capacity of less than 10 MW represented approximately 14% of total installed hydro capacity, with facilities in the 1-10 MW class accounting for about 11% and the smaller plants for around 3%. As there are problems in building large HPPs, future increases in hydro output may be provided very largely by small hydropower projects.

Japan

Gross theoretical capability (TWh/yr)	U
Capacity in operation (MW)	22 362
Actual generation (GWh)	72 639
Capacity under construction (MW)	291

A high proportion of Japan's massive potential for hydro generation has already been harnessed. Most of the sites suitable for the installation of large-scale conventional hydro-electric plants have now been developed. The great majority of the larger hydro projects presently under construction or planned in Japan are pumped-storage schemes. In 2011 Japan had about 291 MW of all types of hydro capacity under construction.

The technically exploitable capability for small-scale hydro developments is reported by the Japanese Member Committee to be 47 TWh/yr, a relatively high proportion (34%) of the total hydro level. Developed small-hydro capacity at end-2011 was about 3.5 GW, equivalent to 12.5% of total conventional hydro capacity. Small-scale capacity planned for construction totalled 30 MW, with a probable annual generation of 304 GWh.

Jordan

Gross theoretical capability (TWh/yr)	U
Capacity in operation (MW)	0
Actual generation (GWh)	0
Capacity under construction (MW)	10

The Jordanian WEC Member Committee reported that pre-feasibility studies had indicated a technical hydro potential of 400-800 MW through exploiting the difference in elevation of about 400 metres between the Red Sea and the Dead Sea. Terms of Reference for this project were approved by the three parties concerned (Jordan, Palestine and Israel) during a conference held at the Dead Sea in May 2005. In July 2008, the World Bank awarded a contract for a feasibility study, which was expected to take 24 months to complete.

Conventional hydropower resources in Jordan are limited, owing to the fact that surface water resources are almost negligible at present. There are two small HPPs: the King Talal Dam with a rated capacity of 5 MW and a scheme at Aqaba thermal power station which utilises the available head of returning cooling seawater, also with a capacity of 5 MW. There are no plans for the expansion of conventional hydro capacity.

Kazakhstan

Gross theoretical capability(TWh/yr)	170
Capacity in operation (MW)	2 267
Actual generation (GWh)	7 849
Capacity under construction (MW)	300

The WEC Member Committee reports that the main hydropower resources are located in the eastern and southeastern regions of the country:

- on the Irtysh river – Bukhtarma (675 MW), Ust-Kamenogorsk (332 MW) and Shulbinsk (702 MW);
- on the Ili river – Kapchagay (364 MW);
- on the Syrdarya river – Shardara (100 MW).

The Moinak HPP (300 MW) is presently under construction. By 2020 it is planned to commission Kerbulak (50 MW), Bulak (68 MW) and number of smaller HPPs with a total installed capacity of 56 MW.

In Kazakhstan, according to existing legislation, small-scale HPPs include those with a capacity of up to 35 MW.

Laos

Gross theoretical capability (TWh/yr)	U
Capacity in operation (MW)	700
Actual generation (GWh)	U
Capacity under construction (MW)	5 361

Only a very small proportion of Laos's massive hydro endowment has so far been harnessed. Its technically feasible potential is quoted by *Hydropower & Dams World Atlas 2009* (HDWA) as 18 000 MW, whereas its total installed hydropower capacity at end-2008 was less than 700 MW.

According to HDWA, the Ministry of Energy and Mines lists 60 HPPs, with a total installed capacity of 16 061 MW, as being at various stages of construction or planning. Six hydro schemes, with a total capacity of 2 131 MW, were under construction in 2009, with twelve more totalling 3 230 MW reported to be at an advanced stage of negotiation. An additional 42 projects, totalling 10 700 MW, are the subject of feasibility studies.

Much of the new hydro generating capacity is destined to meet demand from neighbouring countries; export arrangements are already in place with Thailand, Vietnam and Cambodia. Among the plants presently under construction, the largest are:-

- Nam Ngum 2 (615 MW), scheduled for completion in 2013;
- Nam Theun 1 (424 MW), due to enter operation in 2014 (exporting to Thailand);
- Xe Kaman 3 (250 MW, completion expected in 2010 (90% of its output to be sold to Vietnam).

In March 2010, the Nam Theun 2 HPP (1 070 MW) began commercial exports of electricity to the Thai state utility EGAT.

Lithuania

Gross theoretical capability (TWh/yr)	2
Capacity in operation (MW)	101
Actual generation (GWh)	U
Capacity under construction (MW)	3

The Lithuanian WEC Member Committee states that, based on the provisions of the National Energy Strategy, the possibility of constructing HPPs (with capacities of more than 10 MW) on the River Neris could be considered. However, their construction is uncertain, in view of environmental restrictions.

The Kruonis pumped storage plant was built in 1992-1998 and comprises four units, each with a capacity of 225 MW. The plant serves to supply the peak and semi-peak loads of Lithuanian consumers and neighbouring countries.

Opportunities for the construction of small HPPs with capacity of less than 10 MW are limited. The total probable annual generation of existing and new small hydro plants is expected by the Member Committee to reach about 160 GWh in 2020.

Up to now, hydropower has been the main renewable energy source for power production. Due to the topographical conditions, the potential for hydropower is rather low. The economically feasible potential for hydro resources is estimated at 2.2 TWh/ year . Approximately 14% of this resource is currently being exploited. Legislation protecting many of Lithuania's rivers from development for ecological and cultural reasons hampers further exploitation of hydropower . 130 possible locations have been identified for the renovation or construction of small hydropower plants, with a potential production of up to 60 million kWh/year.

Macedonia (Republic)

Gross theoretical capability (TWh/yr)	U
Capacity in operation (MW)	528
Actual generation (GWh)	U
Capacity under construction (MW)	29

Out of a number of hydro plants being planned as BOT schemes in 2009, the largest were Galishte (194 MW) on the river Vardar, and a 333 MW pumped-storage plant at Chebren on the Black river.

Madagascar

Gross theoretical capability (TWh/yr)	321
Capacity in operation (MW)	124
Actual generation (GWh)	700
Capacity under construction (MW)	29

Madagascar has a considerable land area (greater than that of France, for example) and heavy annual rainfall (up to 3 600 mm). Consequently, the potential for hydropower is correspondingly large: gross theoretical potential is put at 321 TWh/yr, within which the technically feasible potential is 180 TWh/yr, of which about 27% is deemed to be economic. With current installed capacity standing at 124 MW and annual hydro output about 700 GWh, the island's hydro capability has scarcely begun to be utilised.

There are three HPPs of over 10 MW installed capacity in service: Mandraka (24 MW), Andekaleka (58 MW) and Sahanivotry (15 MW). An additional 29 MW unit is being installed at Andekaleka, while Mandraka II (57 MW) will be developed to utilise the full head available at the site.

With the abundance of small rivers on the island, hydropower has become the environmentally sound choice for generating electricity, and Madagascar's seven hydro-electric power stations contribute two-thirds of the country's electric power.

The 15-MW Sahanivotry Hydro-Electric Power Station was commissioned in 2008 on the Sahanivotry River south of Antsirabe in the province of Antananarivo. It is Madagascar's first privately owned and operated hydro plant and the first to be built on the island since 1982. Currently producing 10 percent of the island's electricity supply, Sahanivotry feeds the Antananarivo and Antsirabe grid, which have experienced chronic power outages.

Malaysia

Gross theoretical capability (TWh/yr)	123
Capacity in operation (MW)	1910
Actual generation (GWh)	7346
Capacity under construction (MW)	3 344

There is a substantial potential for hydro development in Malaysia, with a total technically feasible potential of about 123 TWh/yr, most of which is located in Sarawak (87 TWh/yr) and Sabah (20 TWh/yr); a considerable proportion of Peninsular Malaysia's technically feasible potential of 16 TWh/yr has already been developed.

Construction of the 2 400 MW Bakun hydro plant in Sarawak is being completed. Work on the 944 MW Murum hydro project (also in Sarawak) is progressing, with the plant due to commence operations in 2013.

Mexico

Gross theoretical capability (TWh/yr)	42 000
Capacity in operation (MW)	11 499
Actual generation (GWh)	35 796
Capacity under construction (MW)	750

Historically, Mexico has derived much of its power from hydroelectric facilities. Many small, technologically-dated hydroelectric power plants are still operating in remote areas of the country, some of which date back to the 1920s. Hydroelectric plants presently account for more than 11,499 megawatts (MWe) of electric generation capacity, or about one-fourth of the total generation capacity in Mexico.

Mexico has not exhibited a policy promoting large-scale expansion of hydroelectric power like many of its Latin American neighbours. Because of the relative arid conditions over much of the northern part of the country, there are relatively few sites suitable for new hydroelectric development. Current estimates for Mexico's total hydroelectric potential are about 42,000 MWe. However, environmental concerns and the need to relocate rural communities stand in the way of greater utilization of the country's water resources for hydroelectric energy.

Projects to harness the Usumacinta River and other waterways have been cancelled due to opposition from local groups. One such project was the El Caracol power plant on the Balsas River, where a doubling of the facility's 609 MWe capacity had been planned.

However, severe droughts in parts of Mexico in the past few years have significantly curtailed hydroelectric power generation. The drought of summer 2000 took 900 MWe of hydroelectric capacity in northeast Mexico offline and forced the CFE to depend on hydroelectric facilities in the southeast where water levels allowed normal hydroelectric operations. As of June 2002, dry conditions in Sinaloa and Sonora states

For the present *Survey*, the Mexican WEC Member Committee has reported that La Yesca (750 MW) is under construction for CFE, and that 1 374 MW of hydro capacity is planned by CFE for future development. Generating capacity at La Villita Michoacán is being boosted by 400 MW, and at Infiernillo Guerrero by 200 MW, through refurbishment and uprating programmes. The start of construction work on CFE's La Parota (900 MW) hydro project on the Papagayo river has been put back by three years, with completion now scheduled for 2021.

Installed capacity of small-scale hydropower is reported by the Mexican WEC Member Committee to have been 125 MW.

Mozambique

Gross theoretical capability (TWh/yr)	U
Capacity in operation (MW)	107
Actual generation (GWh)	U
Capacity under construction (MW)	1 500

The main electricity authority in the country is Electricidade de Mozambique (EDM), established by the state in 1977, two years after independence. EDM is responsible for generation, transmission and distribution, but there are other companies that produce and distribute electricity. The main one is Hidroelectrica de Cahora Bassa, a company jointly owned by Portugal (82%) and Mozambique (18%) and the biggest hydroelectric scheme in Southern Africa.

Operations at Cahora Bassa, on the south side of the Zambezi River, are operating at higher capacities following restoration of the DC transmission line from Cahora Bassa to South Africa by EDM and Eskom, the South African power utility. Other large hydro power plants in Mozambique have continued to operate at less than full capacity, including Mavuzi (44.5 MW effective capacity out of 52 MW nominal capacity); Chicamba (34 MW of 38.4 MW); and Corumana (14 of 16.6 MW).

Mozambique is seeking to boost power output as demand grows in South Africa. The country also needs to meet a national growing demand from a planned titanium plant and a possible future expansion to an aluminium plant.

Mozambique is one of the largest power producers in the SADC region. It is also a member of the Southern African Power Pool (SAPP).

By mid-2009, a framework agreement had been signed for the 1 500 MW Mphanda Nkuwa hydro scheme, and environmental studies had been completed. Other potential future hydro projects in Mozambique include Boroma (444 MW) and Lupata (654 MW).

Myanmar (Burma)

Gross theoretical capability (TWh/yr)	140
Capacity in operation (MW)	1 541
Actual generation (GWh)	3 900
Capacity under construction (MW)	1 500

The country is well endowed with hydro resources: its technically feasible potential is given by *Hydropower & Dams World Atlas* as 39 720 MW. At an assumed annual capacity factor of 0.40, this level would imply an annual output capability of almost 140 TWh; actual output in 2011 was only 3.9 TWh. There thus appears to be ample scope for substantial development of hydropower in the long term.

The Shweli 1 plant (600 MW) on the Shweli river in northeast Myanmar was completed in 2008. Work on the Yeywa (790 MW) project on the Myitnge river, towards the centre of the country, is nearing completion. Longer-term projects include a major export-orientated scheme, Ta Sang (7 110 MW) on the Thanlwin (or Salween) river, from which it is planned to supply 1 500 MW to Thailand.

In March 2010, construction of this project (the first of a planned series of five HPPs on this river) was reported to be getting under way. More than 5 000 MW of additional hydro capacity is planned, involving 14 projects, including Shweli 2 (640 MW), Shweli 3 (360 MW), Shwezaye (660 MW) and Tanintharyi (600 MW).

Namibia

Gross theoretical capability (TWh/yr)	U
Capacity in operation (MW)	0
Actual generation (GWh)	0
Capacity under construction (MW)	0

Namibia's only perennial rivers are the Kunene and Kavango (forming borders with Angola and Zambia in the north) and the Orange River bordering South Africa in the south. Any plans to develop hydro power are thus subject to lengthy bilateral negotiations. Another problem leading to limited exploitation of hydro resources is the scarcity of rain and the extensive droughts.

Nepal

Gross theoretical capability (TWh/yr)	U
Capacity in operation (MW)	600
Actual generation (GWh)	U
Capacity under construction (MW)	U

Nepal has a huge hydropower potential. In fact, the perennial nature of Nepali rivers and the steep gradient of the country's topography provide ideal conditions for the development of some of the world's largest hydroelectric projects in Nepal. Current estimates are that Nepal has approximately 40,000 MW of economically feasible hydropower potential. However, the present situation is that Nepal has developed only approximately 600 MW of hydropower.

Therefore, bulk of the economically feasible generation has not been realized yet. Besides, the multipurpose, secondary and tertiary benefits have not been realized from the development of its rivers.

The hydropower system in Nepal is dominated by run-of-river Projects. There is only one seasonal storage project in the system. There is shortage of power during winter and spill during wet season. The load factor is quite low as the majority of the consumption is dominated by household use. This imbalance has clearly shown the need for storage projects, and hence, cooperation between the two neighbouring countries is essential for the best use of the hydro resource for mutual benefit.

HDWA reports that there are 42 small and mini hydro schemes in operation, with an aggregate capacity of very nearly 20 MW. Additional small plants under construction or planned for installation in the near term total some 30 MW.

Norway

Gross theoretical capability (TWh/yr)	22
Capacity in operation (MW)	1 521
Actual generation (GWh)	6 800
Capacity under construction (MW)	1 021

Norway possesses Western Europe's largest hydro resources, both in terms of current installed capacity and of economically feasible potential. Hydro generation provides virtually all of Norway's electric power.

According to HDWA, more than fifty (mostly quite small) hydro plants were under construction in Norway. The economically exploitable capability applicable to small-scale hydro schemes was reported by HDWA to be 22.1 TWh/yr. Installed capacity of small hydro plants was stated to be 1 521 MW, with an average annual output capability of 6.8 TWh. Some 326 were planned, with an installed capacity totalling 1 021 MW and annual output averaging 3 663 GWh.

Pakistan

Gross theoretical capability (TWh/yr)	475
Capacity in operation (MW)	6 481
Actual generation (GWh)	27 700
Capacity under construction (MW)	1 600

The total Hydropower resource in Pakistan is estimated at about 50,000 MW. Most of the resources are located in the North of the country, which offers sites for large scale (100 MW to 7,000 MW) power projects. Smaller (less than 50 MW) sites are available throughout the country. In addition, canal system with total of 58,450 km watercourses, farm channels and field ditchers running another 160,000 km in length has a huge hydropower potential at numerous sites/locations on each site, ranging from 1 MW to more than 10 MW hydro plants can be installed.

The total installed hydro capacity was 6 481 MW, almost exactly one-third of total national generating capacity. According to *Hydropower & Dams World Atlas*, Pakistan has a gross theoretical hydro potential of approximately 475 TWh/yr, of which some 204 TWh/yr is regarded as technically feasible. The main potential sources of hydropower are on the rivers Indus and Jhelum, plus sites at Swat and Chitral.

Hydro capacity in operation included major plants at Tarbela (3 478 MW), Ghazi Barotha (1 450 MW) and Mangla (1 000 MW); gross hydro-electric output during the year was 27.7 TWh, accounting for 30% of Pakistan's electricity generation.

In 2009 the 969 MW Neelum Jhelum hydro scheme and various smaller schemes in the 70-130 MW bracket were reported to be moving ahead. Several huge public sector projects – including Bunji (7 100 MW), Diamer Basha (4 500 MW) and Dasu (4 320 MW), all sited on the Indus – are being developed, as well as private-sector schemes such as Kohala (1 100 MW) on the Jhelum. Total hydro capacity reported to be under construction in early 2009 was some 1 600 MW. About 17 000 MW of additional hydro capacity is planned for construction starts over the next ten years.

HDWA quotes Pakistan's small-scale (1-22 MW) hydro potential as 302 GWh/yr, but states that only 68 MW out of an installed capacity of 107 MW is actually in operation. A total of 350 MW of small hydro capacity is reported to be planned.

Paraguay

Gross theoretical capability (TWh/yr)	111
Capacity in operation (MW)	8 130
Actual generation (GWh)	0
Capacity under construction (MW)	U

Paraguay has replaced all thermal power by hydro power in 1970s. Now the country completely relies on 2 hydroelectric plants for electricity.

The hydroelectric plants are Yacryetá and Itaipú. The Itaipu dam is situated in the eastern side of Paraguay, near the city of Ciudad del Este. The dam is built on the River Parana which is on the border between the two nations, Brazil and Paraguay. The original intention behind this project was to supply water to people, especially during the phase of drought. It is also the world's second largest hydroelectric plant.

The project began producing electricity in 1984. It has about 3,200 employees and has sales revenue of about 3.369 million dollars. The total power produced is 14,000 MW from 20 generators. The construction took 16 years. This dam is 5 miles in length and 643 feet heighted. A large amount of steel and iron have been used in the project.

The country's gross theoretical capability for hydroelectricity is about 111 TWh/yr, of which 68 TWh is estimated to be economically exploitable.

The bi-national plant at Yacyretá, downstream from Itaipú has an installed capacity of 3 100 MW. There are 20 generating units, each of 155 MW capacity but operating at only 120 MW per unit, owing to the level of the reservoir being held below that originally planned. The level of the Yacyréta reservoir is being raised, which will enable the bi-national plant's turbines to operate nearer to their design capacity of 155 MW each.

Paraguay has a wholly-owned 210 MW hydro plant (Acaray), which will probably be uprated by 45 MW during the next few years. The state electric utility, ANDE, also plans to install two 100 MW units at the existing Yguazu dam. An environmental impact study has been conducted for the projected bi-national Corpus Christi dam (2 880 MW, to be shared with Argentina), sited on the Paraná, downstream of Itaipú and upstream of Yacyretá. The 300 MW Aña-Cuá scheme constitutes another bi-national project with Argentina.

Peru

Gross theoretical capability (TWh/yr)	260
Capacity in operation (MW)	3 242
Actual generation (GWh)	U
Capacity under construction (MW)	U

Peru's topography, with the Andes running the length of the country, and many fast-flowing rivers, endows the republic with an enormous hydroelectric potential. Its hydro capability is one of the largest in the whole of South America, with an economically exploitable capability of some 260 TWh/yr. Current utilisation of this capability is very low - at around 7%. Hydro provides nearly 60% of Peru's electric power.

There is deemed to be scope for additional hydro capacity capable of producing about 2 552 GWh/yr. If all this capacity were to be developed, the presently estimated economically exploitable capability would be exceeded, but installed capacity would still be well within the assessed technical limit.

Small-scale hydro accounts for 274 MW of installed capacity, which produce an estimated 491 GWh. Planned capacity increases in the less-than-10 MW category amount to some 111 MW, of which 61 MW relates to units of between 4 and 10 MW and 50 MW to smaller units. Altogether these new units would produce an estimated 426 GWh/yr.

Romania

Gross theoretical capability (TWh/yr)	36
Capacity in operation (MW)	6 144
Actual generation (GWh)	14 954
Capacity under construction (MW)	0

Romania has an estimated total usable hydro power of approximately 36 TWh per year and a significant part of this potential is already used for electricity generation.

Hydro power is one of the main contributors to the total electricity generation in Romania, with a contribution of around 30% of the total power delivered to the grid. In 2010 hydro power plants had a total installed capacity of over 6400 MW and produced 19.8 TWh electricity.

The vast majority of this production results from large-scale reservoir hydro power plants.

Run-of-the-river Small Hydro Power Plants (SHP) were built for a long period of time, but only recently, after the emergence of the Renewable Energy Act 220/2008, the interest in building and operating such power generators was revamped

Russian Federation

Gross theoretical capability(TWh/yr)	2 295
Capacity in operation (MW)	49 700
Actual generation (GWh)	180 000
Capacity under construction (MW)	3 000

Russia's hydro resource base is enormous - the gross theoretical potential is some 2 295 TWh/yr, of which 852 TWh is regarded as economically feasible. The bulk of the Federation's potential is in its Asian regions (Siberia and the Far East). Hydro generation in 2011 (approximately 180 TWh) represented 21% of the economic potential and accounted for about 19% of total electricity generation.

The largest hydro scheme currently under construction in the Russian Federation is the 3 000 MW plant at Bogucchany on the Angara river in southeast Siberia..

Major hydro developments are under consideration for the Volga-Kama cascade (expanding capacity by 2 010 MW), and for up to seven HPPs on the Timpton river in South Yakutia (with a total installed capacity of 9 000 MW). The first plant to be built under the latter scheme would be Kankunskaya (1 600 MW).

South Africa

Gross theoretical capability (TWh/yr)	U
Capacity in operation (MW)	661
Actual generation (GWh)	U
Capacity under construction (MW)	U

The current emphasis in South Africa is very much on the development of pumped-storage facilities. Two large plants - Ingula (1 332 MW) and Lima (1 500 MW) are under construction, and further projects are being studied.

The US department of energy estimates that there are 6 000 to 8 000 potential sites in South Africa suitable for small hydro-utilisation below 100 megawatts, with the provinces of KwaZu-lu-Natal and the Eastern Cape offering the best prospects.

The largest hydroelectric power plant in South Africa is the 1 000 megawatt Drakensberg Pumped-Storage Facility, part of a larger scheme of water management that brings water from the Tugela River into the Vaal watershed.

The country’s second-largest plant is situated on the Palmiet River outside Cape Town.

Spain

Gross theoretical capability (TWh/yr)	162
Capacity in operation (MW)	18 540
Actual generation (GWh)	25 000
Capacity under construction (MW)	450

In terms of hydro-electric resources, Spain stands in the middle rank of West European countries, with a gross theoretical capability of 162 TWh/yr. The average level of hydro-electricity generation (excluding pumped-storage plants) in 2011 (approximately 25 TWh) indicates that Spain has already harnessed a considerable proportion of its economic hydro resources.

Currently some 450 MW of small hydro capacity is scheduled to be added, leading to an eventual total output from small-scale hydro of around 6 000 GWh/yr.

Sudan

Gross theoretical capability (TWh/yr)	19
Capacity in operation (MW)	575
Actual generation (GWh)	U
Capacity under construction (MW)	U

The economically feasible potential is some 19 TWh/yr. Until recently, hydro development had been on a very limited scale, with end-2008 installed capacity only about 575 MW. However, following the completion of the 1 250 MW Merowe HPP in early 2010, the country’s hydro capacity has risen to over three times its 2008 level.

In 2008, a contract was awarded for the design of five hydro schemes in northern Sudan. Most of Sudan's pre-2008 hydro plant is at least 40 years old, providing a potential for uprating estimated at about 200 MW.

Swaziland

Gross theoretical capability (TWh/yr)	U
Capacity in operation (MW)	61
Actual generation (GWh)	69
Capacity under construction (MW)	0

According to the Swaziland Electricity Company, there is 60.4 MW of hydropower capacity in operation in 2011. These plants produce approximately 15% of the country's total electricity demand, the remainder being imported from neighbouring countries.

Sweden

Gross theoretical capability (TWh/yr)	65
Capacity in operation (MW)	16 197
Actual generation (GWh)	66 000
Capacity under construction (MW)	0

Today the total number of hydropower plants in Sweden is 2 057 of which 1 615 have an installed capacity of maximum 10 MW. The total capacity is 16 197 MW of which 1 050 MW is small hydro (plants less than 10 MW).

The total electricity production is 66 TWh during a normal year 4.6 TWh of which is produced in SHP. According to the BlueAGE study issued by ESHA in 2001, Sweden has a fifth position in energy winning in small hydropower in Europe having Italy, France, Germany and Spain ahead.

The construction of new hydro plants has largely ceased, on account of environmental and political considerations. Future activity is likely to be very largely confined to the modernisation and refurbishment of existing capacity.

As in many European countries large hydro is considered almost fully developed, but there is still a potential for developing small hydro in Sweden. The BlueAGE study shows a Swedish potential of almost 2 TWh in upgrading existing plants and constructing new plants taking into account technical, economical and environmental constraints.

The Swedish manufacturing industry has been very successful with the first commercial turbines manufactured in 1845 and with well known manufacturers as KMW, NOHAB, Finshyttan and ASEA with products spread all over the world.

Switzerland

Gross theoretical capability (TWh/yr)	U
Capacity in operation (MW)	13 723
Actual generation (GWh)	32 069
Capacity under construction (MW)	1995

Today there are 556 hydropower plants in Switzerland that each have a capacity of at least 300 kilowatts, and these produce an average of around 35,830 GWh per annum, 47% of which is produced in run-of-river power plants, 49% in storage power plants and approximately 4% in pumped storage power plants.

Two-thirds of hydroelectricity are generated in the mountain cantons of Uri, Grisons, Ticino and Valais, while Aargau and Bern also generate significant quantities. Roughly 11% of Switzerland's hydropower generation comes from facilities situated on bodies of water along the country's borders.

Whilst Switzerland has already developed a relatively high proportion (over 85%) of its substantial economically exploitable hydro capability, attention is now being focused on small-scale hydropower (defined in Switzerland as schemes below 300 kW). Under the new feed-in regime introduced in 2008, mini-hydro projects totalling 354 MW, with an estimated output of 1 464 GWh, have qualified for feed-in tariffs and are thought likely by the Swiss WEC Member Committee to be built in the coming years.

Tajikistan

Gross theoretical capability (TWh/yr)	263.5
Capacity in operation (MW)	5 500
Actual generation (GWh)	11 200
Capacity under construction (MW)	0

The terrain and climate are highly favourable to the development of hydropower. Apart from the Russian Federation, Tajikistan has the highest potential hydro generation of any of the FSU republics. Its economically feasible potential is estimated to be 263.5 TWh/yr, of which only about 6% has been harnessed so far. Hydropower provides about 95% of Tajikistan's electricity generation.

Installed hydro capacity amounts to about 5 500 MW, of which just over 5 000 MW was reported to be operational in early 2009. The principal site is Nurek (3 000 MW), which produces approximately 11.2 TWh/yr. The fourth and last unit at the Sangtuda 1 plant on the river Vakhsh came into operation in May 2009; together, the four units have added 670 MW to Tajikistan's capacity.

An enormous hydro potential exists on the river Panj (the principal tributary of the Amu-Darya): 14 HPPs with an aggregate capacity of 18 720 MW could eventually be developed. (As the Panj forms Tajikistan's border with Afghanistan..

Tanzania

Gross theoretical capability (TWh/yr)	U
Capacity in operation (MW)	561
Actual generation (GWh)	U
Capacity under construction (MW)	U

The 900 MW Stieglers Gorge hydro project on the river Rufiji appears to be moving ahead, with the Canadian-registered company Energem Resources acquiring a 40% stake in the scheme.

Tanzania's interconnected grid system has an installed capacity of 773MW, of which 71% is hydropower. The largest hydropower complexes are the Mtera and Kidatu Dams and they are situated on the Great Ruaha River. The Mtera Dam is the most important reservoir in the power system providing over-year storage capability. It also regulates the outflows to maintain the water level for the downstream Kidatu hydropower plant

The installed capacity of the hydropower facilities are: - the Kidatu power station, which has the capacity of 204 MW; - the Kihansi power station, which has the capacity of 180 MW; - the Mtera power station, which has the capacity 80 MW; - the Pangani power station, which has the capacity of 68 MW; - the Hale power station, which has the 21 MW; and - Nyumba ya Mungu, which has the capacity of 8 MW The total capacity of hydropower generation is 561 MW.

Turkey

Gross theoretical capability (TWh/yr)	432
Capacity in operation (MW)	17 259
Actual generation (GWh)	57 472
Capacity under construction (MW)	8 270

There is about 432 TWh per year in hydropower potential in Turkey. About 35 per cent of hydropower potential is used to generate electricity and hydropower plants with an installed capacity of 17 MW in operation, generating 57 GWh in 2011. Many private companies are developing small and medium size hydropower projects.

A further 8.2 GW of capacity was under construction, with an envisaged total average output of around 25 TWh/yr. Some 23 TWh of additional capacity is planned for development over the longer term.

According to HDWA, Turkey's small-scale hydropower potential is an estimated 39 000 GWh/yr. The total installed capacity of such HPPs is quoted as 636 MW, providing an average output of 2 545 GWh/yr.

Uganda

Gross theoretical capability (TWh/yr)	U
Capacity in operation (MW)	340
Actual generation (GWh)	U
Capacity under construction (MW)	250

Following a successful financial closure at the end of 2008, contracts have been awarded for the 250 MW Bujagali scheme, and work is now well under way. The project is for five 50 MW units, to be installed at a site on the Victoria Nile, approximately 8 km downstream of the 180 MW Nalubaale (formerly Owen Falls) station, and is scheduled for commissioning in 2011-2012.

United Kingdom

Gross theoretical capability (TWh/yr)	4
Capacity in operation (MW)	1 630
Actual generation (GWh)	5 700
Capacity under construction (MW)	0

While the overall amount of installed hydro-electric capacity is extremely modest, opportunities for development do exist, especially in the small-hydro sector (defined in this context as plants up to 5 MW). *Hydropower & Dams World Atlas* quotes the technically feasible potential for small hydro so defined as 4 100 GWh/yr, with the economically feasible potential for undeveloped sites as 1 000 GWh/yr.

The UK WEC Member Committee reports that a study into the potential hydro resource is currently under way. The draft findings of this study show a potential of up to 248 MW of small-scale hydro left to be developed in England and Wales. This study complements one undertaken in Scotland on behalf of the Forum for Renewable Energy Development in Scotland, which showed a potential for up to 657 MW of small-scale hydropower.

The 2008 Energy Act provided the wherewithal for the Government to introduce feed-in tariffs (FIT). From 1 April 2010 renewable energy electricity-generating technologies, up to a maximum of 5 MW, qualify for generation and export tariffs. FITs will work alongside the Renewables Obligations. In the case of new hydro schemes, where both the product and installer are certificated, the generation tariffs are on a decreasing scale from GBP 0.199/kWh for up to 15 kW capacity to GBP 0.045/kWh for installations of 2-5 MW. These rates will remain the same for a period of 20 years (although adjusted for inflation through a link to the Retail Price Index). The tariff payable for electricity exported to the grid is GBP 0.03/kWh, regardless of the size of the installation.

The UK currently (2011) generates about 1.5% (5,700 Gwh) of its electricity from hydroelectric schemes - most of which are large-scale schemes in the Scottish Highlands.

Hydroelectric energy uses proven and efficient technology; the most modern plants have energy conversion efficiencies of 90% and above. Hydro has a typical load factor of 35 to 40%.

United States of America

Gross theoretical capability(TWh/yr)	2 040
Capacity in operation (MW)	77 500
Actual generation (GWh)	319 355
Capacity under construction (MW)	0

The hydro resource base is huge: the United States WEC Member Committee reports that the gross theoretical potential was assessed in 2006 as 2 040 TWh/yr, and that the annual technically exploitable capability is 1 339 TWh, based on publications of the U.S. Department of Energy (Idaho National Environmental and Engineering Laboratory), other U.S. Departments and the Electric Power Research Institute (EPRI). The end-2011 hydro capacity of 77.5 GW had an average annual capability of about 268 TWh, equivalent to 20% of the assessed technical potential.

The Member Committee states that there have been no comprehensive assessments of the U.S. potential for all economically exploitable hydropower, and that, moreover, the economics of these projects is unknown and is in constant flux due to policy and commodity pricing.

On the issue of Exploitable Capability, the U.S. Member Committee quotes from the 2006 report by the Idaho National Laboratory:

'It is concluded from the study results that there are a large number of opportunities for increasing U.S. hydroelectric generation throughout the country that are feasible based on an elementary set of feasibility criteria. These opportunities collectively represent a potential for approximately doubling U.S. hydroelectric generation (not including pumped storage), but more realistically offer the means to at least increase hydroelectric generation by more than 50%.

The reported technically exploitable capability of small-scale hydropower (5 MW and below) is 782 TWh, with about 198 TWh/yr rated as economically exploitable. The installed generating capacity of small hydro plants totalled 2.86 GW at end-2008; probable annual generation is put at 10 154 GWh, but actual generation in 2008 was some 18% higher, at 11 973 GWh, equivalent to 4.8% of total U.S. hydro output.

Various incentives for small-scale hydro exist in the form of Federal and State production tax credits and Federal grants and loan guarantees. Moreover the Federal Energy Regulatory Commission, which is responsible for the licensing of private, municipal and State hydro-electric projects, has an exemption for hydro projects with an installed capacity of 5 MW or less which also meet certain conditions.

In the United States, hydropower has grown steadily, from 56 GW in 1970 to more than 95 GW today.[4] As a percentage of the U.S. electricity supply mix, however, it has fallen to 10 percent, down from 14 percent 20 years ago, largely as a result of the rapid growth in natural gas power plants. In terms of electricity production, hydropower plants account for about seven percent of America's current power needs.[5]

In some parts of the country, hydropower is even more important. For example, the Pacific Northwest generates more than two-thirds of its electricity from 55 hydroelectric dams.[6] The Grand Coulee dam on the Columbia River is one of the largest dams in the world, with a capacity of nearly 6,500 megawatts (MW).

In addition to very large plants in the West, the United States has many smaller hydro plants. In 1940 there were 3,100 hydropower plants across the country, but by 1980 that number had fallen to 1,425. Since then, a number of these small plants have been restored; there are currently 2,378 hydro plants (not including pumped storage) in operation.[7]

These plants account for only a tiny fraction of the 80,000 dams that block and divert our rivers. As a result, there is a significant opportunity for growth according to the National Hydropower Association, which estimates that more than 4,300 MW of additional hydropower capacity can be brought online by upgrading existing facilities.[8]

Uruguay

Gross theoretical capability (TWh/yr)	32
Capacity in operation (MW)	1 538
Actual generation (GWh)	6 479
Capacity under construction (MW)	0

Between 2003 and 2007, 68% of Uruguay's energy needs were met by hydroelectric dams on the Uruguay River. The largest of these impoundments, the Salto Grande, a facility shared with Argentina, has generated up to half of Uruguay's electricity in the past. Apart from the bi-national Salto Grande, with a total capacity of 1,890 MW, existing plants are Terra (152 MW), Baygorria (108 MW), Constitucion (333 MW). All the potential for large hydro in Uruguay has already been developed.

According to the Uruguayan Member Committee of WEC the technically exploitable potential is 10 TWh/yr, within a gross theoretical potential of 32 TWh. Some 6 TWh/yr of hydro capacity is regarded as economically feasible for development at present. At the end of 2011 operational capacity was 1 538 MW with a total production of 6 479 GWh of electricity that year. No new capacity was under construction at the time.

During the 1980s almost all of Uruguay's incremental generating capacity was in the form of hydropower, notably through the commissioning of the bi-national Salto Grande (1 890 MW) plant on the river Uruguay; the republic shares its output with Argentina. No hydro plants are reported to be presently under construction and only about 70 MW is planned: future increases in generating capacity are likely to be largely fuelled by natural gas.

Venezuela

Gross theoretical capability (TWh/yr)	731
Capacity in operation (MW)	14 627
Actual generation (GWh)	86 700
Capacity under construction (MW)	0

Hydroelectricity provides the bulk of Venezuela's electricity supply. Most of the country's hydro production facilities are located on the Caroni River in the Guayana region. The 8,900-megawatt Guri Hydroelectric Power Plant on the Caroni is one of the largest hydroelectric dams in the world and provides the majority of Venezuela's electric power.

Water levels at the Guri Dam dropped to record-low levels during the 2009-2010 drought, forcing the country to implement rolling blackouts, reduce industrial production, and fine large users for excessive consumption. Venezuela plans to expand hydroelectric production in the future.

Hydropower & Dams World Atlas (HDWA) reports a gross theoretical hydropower potential of 731 TWh/yr, of which 261 TWh/yr is considered as technically feasible and approximately 100 TWh/yr economically exploitable. Hydro-electric output in 2008 was 86.7 TWh. About 73% of the republic's electricity requirements are met from hydropower.

In early 2009, hydro capacity in operation amounted to 14 627 MW. The principal HPPs under construction were Tocoma (2 160 MW) on the river Caroní and La Vueltosa (514 MW) in the Andean region.

A large increase in hydro-electric capacity occurred during the 1980s, the major new plant being Guri (Raúl Leoni), on the Caroní in eastern Venezuela - its installed capacity of 8 850 MW makes it one of the world's largest hydro stations. The Tocoma HPP, located 18 km downstream of Guri, is the last in the series of major hydro plants constructed by the state-owned company EDELCA on the lower Caroní. Eventually, the total installed capacity on the lower Caroní (comprising, in order of flow, Guri, Tocoma, Caruachi and Macagua) will exceed 16 000 MW.

HDWA states that no very large hydro plants are firmly planned for the next ten years, but mentions a number of schemes that have been studied, including several on the upper and middle reaches of the Caroní and others on the Colorada in the Andean region.

Vietnam

Gross theoretical capability (TWh/yr)	300
Capacity in operation (MW)	5 500
Actual generation (GWh)	24 000
Capacity under construction (MW)	0

Vietnam has abundant hydro resources, particularly in its central and northern regions. Its gross theoretical potential is put at 300 000 GWh/yr, with an economically feasible potential of 100 000 GWh/yr. Total installed hydro capacity was about 5 500 MW at end-2008 and an output of about 24 TWh provided about one-third of Vietnam's power supply. The largest HPPs currently in operation are Hoa Binh (1 920 MW), Yali (720 MW), Tri An (420 MW) and Ham Thuan (300 MW).under BOT or IPP arrangements.

Zambia

Gross theoretical capability (TWh/yr)	U
Capacity in operation (MW)	1 730
Actual generation (GWh)	U
Capacity under construction (MW)	U

Zambia's two major hydro plants are being refurbished and upgraded: the 900 MW Kafue Gorge (Upper) station by 90 MW and Kariba North Bank (presently 600 MW) by 120 MW. Economic and technical feasibility studies are being conducted on the Kafue Gorge Lower

IPP project (750 MW) and a 210 MW scheme at Kalungwishi. Further rehabilitation and new-build projects are being developed or studied, including the 120 MW Itezhi Tezhi scheme on the Kafue river and the 1 800 MW Baroka Gorge bi-national project with Zimbabwe.

The national installed capacity presently stands at 1,730 Mega Watts (MW) but the demand is more than 2, 000 MW.

So far, there are only two important inter-connectors to Zimbabwe and the Democratic Republic of Congo (DRC) which are the most important electricity export grids.

Apart from the Kabompo power project which was recently commissioned, other projects aimed at averting power deficit include the 120 MW Itezhi-tezhi power project, rehabilitation of the 360 MW Kariba North Bank Station and the 750MW Kafue Gorge Lower project.

Under the Power Rehabilitation Project (PRP) by Zesco, the projects involved the rehabilitation and up rating of the three major hydro power stations namely, Kafue Gorge, Kariba North Bank and Victoria Falls.

The major achievements of the PRP has been the rehabilitation and upgrading of the Kafue Gorge Power Station from 900 to 990MW, the reinstating of the Victoria Falls Power Station to its full generating capacity of 108 MW as well as the up-rating of the Kariba North Bank power station from 600 MW to 720 MW.