

# Renewable Energy Essentials: Hydropower

- Hydropower is currently the most common form of renewable energy and plays an important part in global power generation. Worldwide hydropower produced 3 288 TWh, just over 16% of global electricity production in 2008, and the overall technical potential for hydropower is estimated to be more than 16 400 TWh/yr.
- The BLUE scenario of the IEA publication *Energy Technology Perspectives 2010*, which aims to achieve a 50% reduction in energy-related CO<sub>2</sub> emissions by 2050, projects that hydro could produce up to 6 000 TWh in 2050.
- Hydropower's storage capacity and fast response characteristics are especially valuable to meet sudden fluctuations in electricity demand and to match supply from less flexible electricity sources and variable renewable sources.
- The costs of power production from hydropower can vary widely depending on project details, but usually fall into a range of USD 50 to 100/MWh. Upgrading existing hydropower plant projects offers further options for cost-effective increases in generation capacity.
- The environmental and social effects of hydropower projects need to be carefully considered. Countries should follow an integrated approach in managing their water resources, planning hydropower development in co-operation with other water-using sectors, and take a full life-cycle approach to the assessment of the benefits and impacts of projects.

## Market status

### Hydropower production

Hydropower worldwide produced 3 288 TWh, equivalent to 16.3% of global electricity production (20 181 TWh) in 2008. Hydropower production in OECD countries reached 1 381 TWh, accounting for 12.9% of gross electricity production; hydropower in non-OECD countries produced 1 906 TWh, equal to 20.1% of gross electricity production.

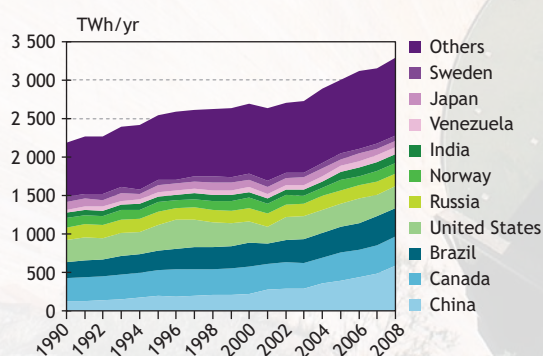


Figure 1: Evolution of global hydropower generation between 1990 - 2008

Data source: IEA Electricity Information 2010

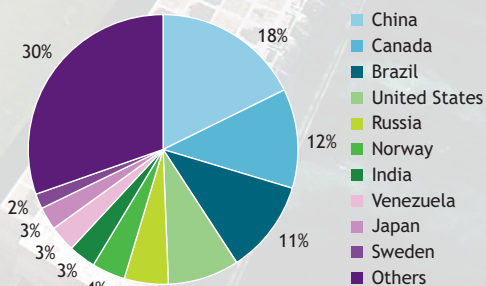


Figure 2: Shares in hydropower generation in 2008

Data source: IEA Electricity Information 2010

Since 1990, global hydropower generation has increased by 50% (Figure 1), with the highest absolute growth in China.

Hydropower generation by the top ten countries accounted for about two-thirds of the world's hydropower generation (Figure 2) in 2008.

### Hydropower potential

The global technically exploitable hydropower potential is estimated at more than 16 400 TWh<sup>1</sup> per year. This potential is unevenly distributed. The five countries with the highest potential (China, United States,

1. World Energy Council (WEC), Survey of Energy Resources 2007, which defines the technically exploitable potential as the annual energy potential of all natural water flows which can be exploited within the limits of current technology.



Russia, Brazil and Canada) could produce about 8 360 TWh per year, and the next five countries (DR Congo, India, Indonesia, Peru and Tajikistan) have a potential of about 2 500 TWh per year. These ten countries account for about two-thirds of the global hydropower potential.

The hydropower production and potential for the world regions and for the top five countries with the highest potential are shown in Figure 3. Data for the countries which have developed the largest proportion of their hydro potential and a production level of over 30 TWh/yr are shown in Figure 4.

Globally, around 19% of the potential has been developed. Countries which have actively developed hydropower use around 60% of their potential. Numerous other countries have a huge amount of untapped hydropower potential.

Although climate change may affect water resources and may lead to significant variations of the potential for hydropower at a country level, these variations are expected to cancel out roughly on the global scale, leaving the overall potential virtually unaffected.<sup>2</sup>

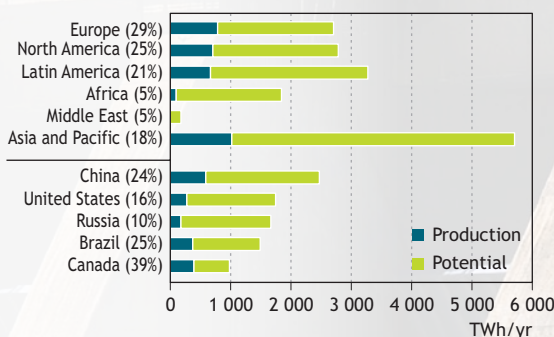


Figure 3: Hydropower development ratio for world regions and top five countries with the highest potential

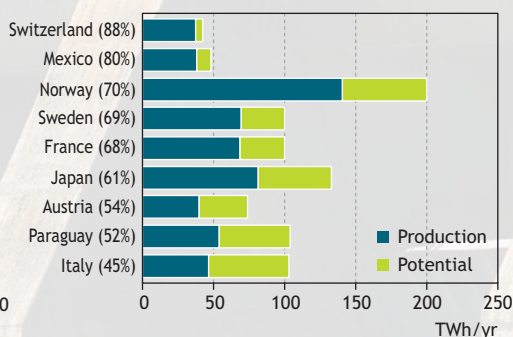


Figure 4: Countries with largest developed proportion of their hydro potential (countries with hydropower production over 30 TWh/yr)

Data source: WEC Survey of Energy Resources 2007, IEA Renewables Information 2010 (2008 data)

## Economics Investment costs

Construction costs for new hydropower projects in OECD countries are usually less than USD 2 million/MW for large scale hydro (> 300 MW), and USD 2 to 4 million/MW for small- and medium-scale hydro (< 300 MW) (Table1). The initial investment needs for particular projects must be studied individually due to the unique nature of each hydropower project. Parameters affecting investment costs and the return on investment include the project scale, which can range from over 10 000 MW to less than 0.1 MW; the project location; the presence and size of reservoir(s); the use of the power supplied for base or peak load or both; and possible other benefits alongside power production, such as flood control, irrigation, fresh water supply, etc. The way in which the project is financed is also a key factor. The capacity of many existing hydropower plants could be raised by 5 to 20%. Such refurbishment projects may be easier from a technical and social point of view, and faster and more cost effective than new plants.

Table 1. Classification of hydropower

Category	Output/unit	Storage	Power use (load)	Investment costs (USD M/MW)
1 small	< 10 MW	run-of-river	base load	2-4
2 medium	10-100 MW	run-of-river	base load	2-3
3 medium	100-300 MW	dam and reservoir	base and peak	2-3
4 large	> 300 MW	dam and reservoir	base and peak	< 2

Data source: IEA Hydropower Implementing Agreement

## Generation costs

The generation costs of electricity from new hydropower plants vary widely, though they often fall into a range of USD 50 to 100/MWh. It should be noted that generation costs per MWh will be determined by the amount of electricity produced annually and that many hydropower plants are deliberately operated for

2. Hamududu and Killingtveit (2010), "Existing Studies of Hydropower and Climate Change: An Overview", Hydropower 10, 6<sup>th</sup> International Conference on Hydropower, Tromsø, Norway.



peak load demands and back-up for frequency fluctuation, so pushing up both the marginal generation costs and the value of the electricity produced. As most of the generation cost is associated with the depreciation of fixed assets, the generation cost decreases if the projected plant lifetime is extended. Many hydropower plants built 50 to 100 years ago are fully amortised and still operate efficiently today.

Operation and maintenance costs are estimated at between USD 5 to 20/MWh for new medium to large hydro plants, and approximately twice as much for small hydro.

Climate change and other negative effects of using fossil fuels for power production, along with a growing demand for energy coupled with concerns over energy security, are driving the expansion of renewable sources of energy. Hydro is a well established source of low-carbon power that can meet these needs, and at present is the largest source of electricity from renewable sources.

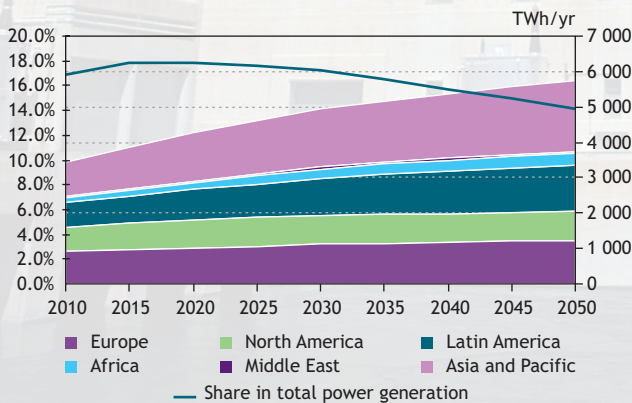
Over the last two decades, decisions on many hydropower development projects have been affected by controversy about the environmental and social effects of hydropower. Analysing the benefits and impacts of such projects is both difficult and time consuming. In deciding on the role of hydropower within an electricity supply portfolio which addresses climate change and energy security concerns, energy policy makers have to consider a whole range of issues including:

- Enhancing economic equity among citizens.
- Protecting the lives and property of citizens from floods and droughts.
- Securing the rights of citizens with respect to expropriation of land to be inundated.
- Protecting the environment concerning air, land, water and biodiversity.

Some or all of these competing, and sometimes conflicting, policy objectives bring major hydropower decisions into the political arena. The interests of the communities who are positively and negatively affected by hydropower projects – and the economic, social and environmental benefits and impacts – need to be carefully analysed on a case-by-case basis before proceeding with projects.<sup>3</sup>

The BLUE Map scenario in the *Energy Technology Perspectives 2010*, which aims to achieve a 50% reduction in energy-related CO<sub>2</sub> emissions by 2050, suggests that hydropower could provide 5 749 TWh in 2050. Under this scenario, hydropower would see its share in the global electricity production increase slightly from 16.3% in 2008 to 17.3% in 2030 but then reduce to 14.1% by 2050 as other power-generation technologies grow at faster rates (Figure 5). Hydro will continue to be a major source of renewable electricity on a global scale, contributing to base load and providing the flexibility needed to meet peaks in demand.

Figure 5: Hydropower development for world regions in ETP BLUE Map scenario



Data source: IEA Energy Technology Perspectives 2010.

In order to implement hydropower projects in a sustainable manner, all environmental and social impacts need to be explored and anticipated early in the planning process so that appropriate steps can be taken to avoid, mitigate, or compensate for impacts. The IEA Hydropower Implementing Agreement has done

3. Koch F. H. (ed.) (2002, November), *Energy Policy: Special Issues: Hydropower, Society and the Environment in the 21st Century*, Vol. 30, No. 14.

Operation and maintenance (O&M) costs

Outlook  
Growth drivers

Barriers

Long-term scenarios

System-related aspects

Hydropower's role in stabilising electricity systems

Environmental impacts



## Environmental and social impacts

pioneering work in this field and has recently updated its Recommendations for Hydropower and the Environment.<sup>4</sup> The International Hydropower Association has developed a Draft Hydropower Sustainability Assessment Protocol which aims to provide a broadly supported sustainability assessment tool to measure and guide performance in the hydropower sector.

## Carbon balance in reservoir

In the early 1990s, some stakeholders raised the issue of a potential adverse carbon balance resulting from the creation of new freshwater reservoirs. This related primarily to emissions of carbon dioxide and methane and a number of attempts have been carried out to measure "a gross emission" from specific reservoirs. In order to ensure that projects are sustainable and do in fact lead to a reduction in carbon emissions, a full life-cycle analysis, including the likely impacts of inundation, needs to be carried out. The IEA Hydropower Implementing Agreement, under Brazil's leadership, has recently initiated further work on the "Management of the Carbon Balance in Freshwater Reservoirs".

## Public acceptance of hydropower

The issue of public acceptance has become a high priority for hydropower development over the last two decades. Local citizens, including those stakeholders most impacted by developments, need to be fully consulted as part of the project development process.

This has also implications for the financing of hydro power plants. For instance, World Bank lending for hydropower bottomed out in 1999 due to growing opposition from environmental and other non-governmental organisations. However, there is now a growing awareness that countries must follow an integrated approach in managing their water resources, planning hydropower development in co-operation with other water-using sectors and taking environmental, safety and social factors properly into account. World Bank lending is now expanding in this sector, reflecting a Water Resources Sector Strategy, approved in 2003, which recognises that significant levels of investment in water infrastructure are required throughout the developing world.

## Technology status and development

### Hydropower technology and technology advances

Hydroelectric power is the energy derived from flowing water. This can be from rivers or from man-made installations, where water flows from a high-level reservoir down through a tunnel and away from a dam. Turbines placed within the flow of water extract its kinetic energy and convert it to mechanical energy. This causes the turbines to rotate at high speed, driving a generator that converts the mechanical energy into electrical energy. The amount of hydroelectric power generated depends on the water flow and the vertical distance (known as "head") the water falls through.

There are three main types of hydroelectric projects:

#### Storage schemes

In storage schemes, a dam impounds water in a reservoir that feeds the turbine and generator, which is usually located within the dam itself.

#### Run-of-river schemes

Run-of-river schemes use the natural flow of a river, where a weir can enhance the continuity of the flow. Both storage and run-of-river schemes can be diversion schemes, where water is channelled from a river, lake or dammed reservoir to a remote powerhouse, containing the turbine and generator.

#### Pumped storage

Pumped storage incorporates two reservoirs. At times of low demand, generally at night, electricity helps pump water from the lower to the upper basin. This water is then released to create power at a time when demand, and therefore price, is high. Although not strictly a renewable energy (because of its reliance on electricity), pumped storage is very good for improving overall energy efficiency.

While hydropower is a well proven and mature technology, it is still advancing and expanding its scope of application, for example by developing cheaper technologies for small-capacity and low-head applications so as to enable the exploitation of smaller rivers and shallower reservoirs. Hydrokinetic technologies are being developed that do not require a hydraulic head but extract energy from water flows in rivers and waterways.

## Lifetime

Many hydropower plants built 50 to 100 years ago are still operating today. Hydropower is the most proven, efficient, flexible and reliable source of electricity based on more than a hundred years of experience. Upgrades and refurbishment can readily extend lifetime of plants which contribute to the low cost of electricity from hydropower.

## R&D priorities

Equipment manufacturers are striving for higher efficiency, reliability and longevity through computational fluid dynamics design, advanced manufacturing processes and new materials. R&D is also directed into IT systems, *i.e.* automation, remote control and diagnostics.

4. [http://www.ieahydro.org/reports/AnnexXII\\_Task2\\_BriefingDocument\\_March2010.pdf](http://www.ieahydro.org/reports/AnnexXII_Task2_BriefingDocument_March2010.pdf)