Chapter 8

Hydro Energy

8.1 Summary

KEY MESSAGES

- Hydroelectricity is a mature electricity generation technology and an important source of renewable energy.
- Hydroelectricity is a significant energy source in a large number of countries, although its current share in total primary energy consumption is only 2.2 per cent globally and 0.8 per cent in Australia.
- Hydroelectricity is currently Australia's major source of renewable electricity but there is limited potential for future further development.
- Water availability is a key constraint on future growth in hydroelectricity generation in Australia.
- Future growth in Australia's hydroelectricity generation will be underpinned by the development of small scale hydroelectricity facilities and efficiency gains from the refurbishment of large scale hydro plants.
- The share of hydro in Australia's total electricity generation is projected to fall to around 3.5 per cent in 2029–30.

8.1.1 World hydro energy resources and market

- Global technically feasible hydro energy potential is estimated to be around 16 500 TWh per year.
- World hydroelectricity generation was 3078 TWh in 2007, and has grown at an average annual rate of 2.3 per cent since 2000.
- Hydro energy is the largest source of renewable energy, and currently contributes nearly 16 per cent of world electricity production.
- In the OECD region, hydroelectricity generation is projected by the IEA to increase at an average annual rate of only 0.7 per cent between 2007 and 2030, mainly reflecting limited undeveloped hydro energy potential.
- In non-OECD countries, hydroelectricity generation is projected by the IEA to increase at an average annual rate of 2.5 per cent between 2007 and 2030, reflecting large, undeveloped potential hydro energy resources in many of these countries.

8.1.2 Australia's hydro energy resources

- Australia's technically feasible hydro energy potential is estimated to be around 60 TWh per year.
- 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.
- High variability in rainfall, evaporation rates and temperatures occurs between years, resulting in Australia having very limited and variable surface water resources.
- Australia currently has 108 operating hydroelectric power stations with total installed capacity of 7.8 GW (figure 8.1).

8.1.3 Key factors in utilising Australia's hydro energy resources

- Potential for the development of new large scale hydroelectricity facilities in Australia is limited. However, the upgrade and refurbishment of existing hydroelectricity infrastructure will increase efficiency and extend the life of facilities.
- There is potential for small scale hydroelectricity developments in Australia, and this is likely to be an important source of future growth in capacity.
- Water availability, competition for scarce water resources, and broader environmental factors are key constraints on future growth in Australian hydroelectricity generation.

8.1.4 Australia's hydroelectricity market

- In 2007–08, Australia's hydroelectricity use represented 0.8 per cent of total primary energy consumption and 4.5 per cent of total electricity generation. Hydroelectricity use has declined on average by 4.2 per cent per year between 1999–00 and 2007–08, largely as a result of an extended period of drought.

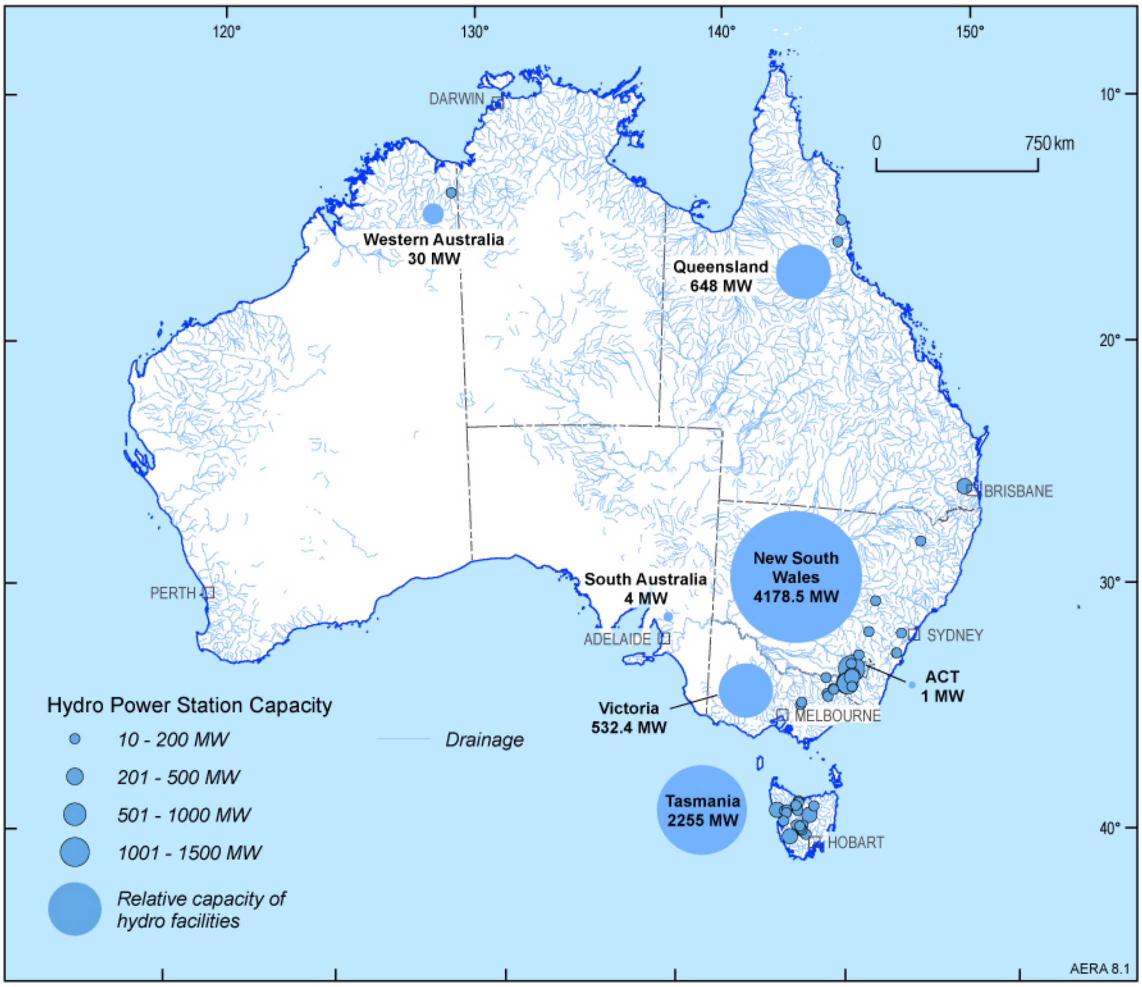

Figure 8.1 Major Australian operating hydro electric facilities with capacity of greater than 10 MW

Source: Geoscience Australia

- In 2007–08, hydroelectricity was mainly generated in the eastern states, including Tasmania (57 per cent of total electricity generation), New South Wales (21 per cent), Victoria (13 per cent) and Queensland (8 per cent).

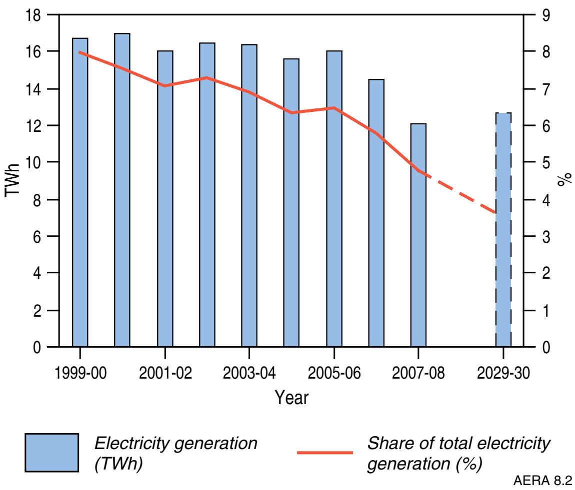

Figure 8.2 Australia's hydroelectricity generation to 2029–30

Source: ABARE 2009a, 2010

- In ABARE's latest long-term energy projections that include the Renewable Energy Target, a 5 per cent emissions reduction target and other government policies, hydroelectricity generation is projected to increase from 12 TWh in 2007–08 to 13 TWh in 2029–30, representing an average annual growth rate of 0.2 per cent (figure 8.2).
- The share of hydro in total electricity generation is projected to fall to 3.5 per cent in 2029–30.
- Hydro energy is expected to be overtaken by wind as the leading renewable source of electricity generation during the outlook period.

8.2 Background information and world market

8.2.1 Definitions

Hydroelectricity is electrical energy generated when falling water from reservoirs or flowing water from rivers, streams or waterfalls (run of river) is channelled through water turbines. The pressure of the flowing water on the turbine blades causes the shaft to rotate and the rotating shaft drives an electrical generator which converts the motion of the shaft into electrical energy. Most commonly, water is dammed and the flow of water out of the dam to drive the turbines is controlled by the opening or closing of sluices, gates or pipes. This is commonly called penstock.

Hydropower is the most advanced and mature renewable energy technology and provides some level of electricity generation in more than 160 countries worldwide. Hydro is a renewable energy source and has the advantages of low greenhouse gas emissions, low operating costs, and a high ramp rate (quick response to electricity demand).

Hydroelectricity has been used in some form since the 19th century. The main technological advantage of hydroelectricity is its ability to be used for either base or peak load electricity generation, or both. In many countries, hydro is used for peak load generation, taking advantage of its quick start-up and its reliability. Hydroelectricity is a relatively simple but highly efficient process compared with other means of generating electricity, as it does not require combustion.

BOX 8.1 HYDROELECTRICITY TECHNOLOGIES

Hydroelectricity generation

The energy created depends on the force or strength of the water flow and the volume of water. As a result, the greater the difference between the height of the water source (head) and the height of the turbine or outflow, the greater the potential energy of the water. Hydropower plants range from very small (10 MW or less) to very large individual plants with a capacity of more than 2000 MW and vast integrated schemes involving multiple large hydropower plants. Hydropower is a significant source of base load and, increasingly, peak load electricity in parts of Australia and overseas.

Rivers potentially suitable for hydropower generation require both adequate water volume through river flows, which is usually determined by monitoring using stream gauges, and a suitable site for dam construction. In Australia virtually all hydropower is produced by stations at water storages created by dams in major river valleys. Many have facilities to pump water back into higher storage locations during off-peak times for re-use in peak times. In some cases, the hydro plant can be built on an existing dam. The development of a hydro resource involves significant time and cost because of the large infrastructure requirements. There is also a requirement for extensive investigation of the environmental impact of damming the river. This generally involves consideration of the entire catchment system.

Pumped storage hydroelectricity stores electricity in times of low demand for use in times of high demand by moving water between reservoirs. It is currently the only commercial means of storing electricity once generated. By using excess electricity generated in times of low demand to pump water into higher storages, the energy can be stored and released back into the lower storage in times of peak demand. Pumped-storage systems can vary significantly in capacity but commonly consist of two reservoirs situated to maximise the difference in their levels and connected by a system of waterways with a pumping-generating station. The turbines may be reversible and used for both pumping and generating electricity.

Pumped storage hydroelectricity is the largest-capacity form of grid energy storage where it can be used to cover transient peaks in demand and to provide back-up to intermittent renewable energy sources such as wind. New concepts in pumped-storage involve wind or solar energy to pump water to dams as head storage.

Mini hydro schemes are small-scale (typically less than 10 MW) hydroelectric power projects that typically serve small communities or a dedicated industrial plant but can be connected to an electricity grid. Some small hydro schemes in North America are up to 30 MW. The smallest hydro plants of less than 100 kW are generally termed micro hydro. Mini hydro schemes can be ‘run-of-river’, with no dam or water storage (see below), or developed using existing or new dams whose primary purpose is local water supply, river and lake water-level control, or irrigation. Mini hydro schemes typically have limited infrastructure requiring only small scale capital works, and hence have low construction costs and a smaller environmental impact than larger schemes. Small scale hydro has had high relative costs ($ per MW) but is being considered both for rural electrification in less developed countries and further hydro developments in OECD countries, often supported by environmental policies and favourable tariffs for renewable energy (Paish 2002). Most recent hydropower installations in Australia, especially in Victoria, have been small (mini) hydro systems, commencing with the Thompson project in 1989.

Run-of-river systems rely on the natural fall (head) and flow of the river to generate electricity through power stations built on the river. Large run-of-river systems are typically built on rivers with consistent and steady flow. They are significant in some overseas locations, notably Canada and the United States. Mini run-of-river hydro systems can be built on small streams or use piped water from rivers and streams for local power generation. Run-of-river hydro plants commonly have a smaller environmental ‘footprint’ than large scale storage reservoirs. The Lower Derwent and Mersey Forth hydro developments in Tasmania, for example, each comprising six power stations up to 85 MW capacity, use tributary inflows and small storages in a step-like series.

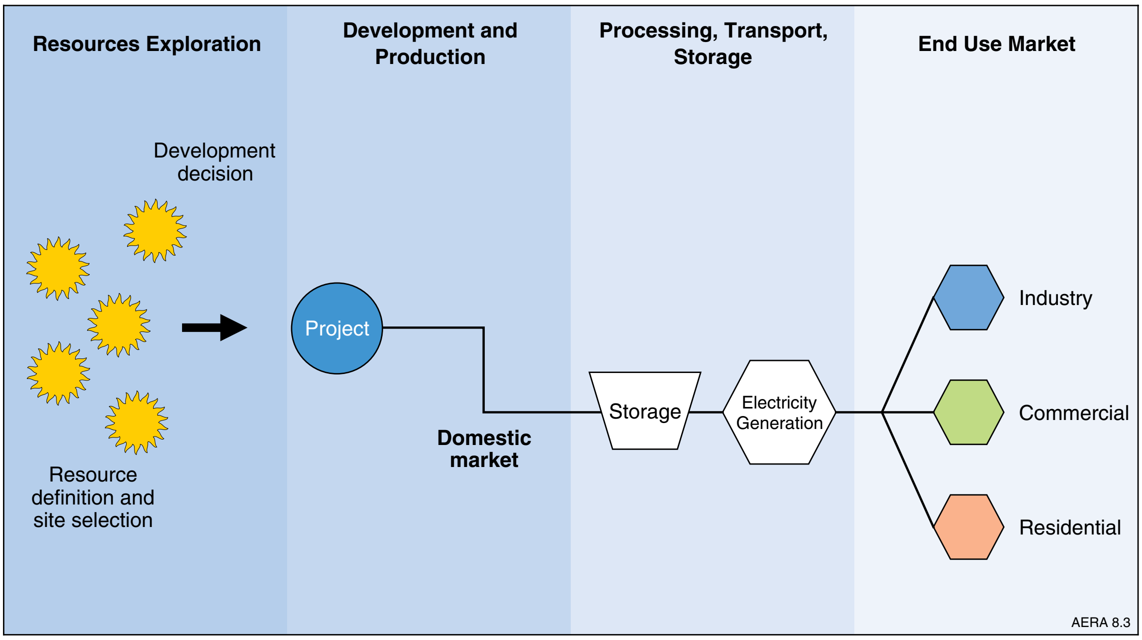

Figure 8.3 Australia's hydro energy supply chain

Source: ABARE and Geoscience Australia

Hydroelectricity generation is often considered a mature technology with limited scope for further development. Plants can be built on a large or small scale, each with its own characteristics:

- **Large scale hydroelectricity plants** generally involve the damming of rivers to form a reservoir. Turbines are then used to capture the potential energy of the water as it flows between reservoirs. This is the most technologically advanced form of hydroelectricity generation.
- **Small scale hydroelectricity plants**, including mini (less than 5 MW), micro (less than 500 kW) and pico facilities, are still at a relatively early stage of development in Australia, and are expected to be the main source of future growth in hydroelectricity generation. While there is no universally accepted definition of small scale hydroelectric projects, small projects are generally considered as those with less than 10 MW capacity.

Within these two broad classes of hydroelectric facilities, there are different types of technologies, including pumped storage and run-of-river (box 8.1). The type of system chosen will be determined by the intended use of the plant (base or peak load generation), as well as geographical and topographical factors. Each system has different social and environmental impacts which must be considered.

In this report, electricity generated from wave and tidal movements (coastal and offshore sources) is treated separately to that generated by harnessing the potential energy of water in rivers and dams (onshore sources). Wave and tidal energy is discussed in chapter 11.

8.2.2 Hydroelectricity supply chain

Figure 8.3 is a representation of hydroelectricity generation in Australia. In Australia virtually all hydroelectricity is produced by stations at water storages created by dams in major river valleys. A number have facilities to pump water back into higher storage locations during off-peak times for re-use in peak times. Electricity generated by the water turbines is fed into the electricity grid as base load and peak load electricity and transmitted to its end use market.

8.2.3 World hydroelectricity market

Hydro energy is a significant source of low cost electricity generation in a wide range of countries. At present, production is largely concentrated in China, North America, OECD Europe and South America. However, many African countries are planning to develop their considerable hydro energy potential to facilitate economic growth. World hydroelectricity generation is projected to grow at an average annual rate of around 2 per cent to 2030, largely reflecting the increased use of hydroelectricity in developing economies.

Resources

Most countries have some potential to develop hydroelectricity. There are three measures commonly used to define hydro energy resources:

- **Gross theoretical potential** – hydro energy potential that is defined by hypothesis or theory, with no practical basis. This may be based on rainfall or geography rather than actual measurement of water flows.
- **Technically feasible** – hydro energy potential that can be exploited with current technologies. This is smaller than gross theoretical potential.

- **Economically feasible** – technically feasible hydro energy potential which can be exploited without incurring a financial loss. This is the narrowest definition of potential and therefore the smallest.

The world's total technically exploitable hydro energy potential is estimated to be around 16 500 TWh per year (WEC 2007). Regions with high precipitation (rainfall or melting snow) and significant topographic relief enabling good water flows from higher to lower altitudes tend to have higher potential, while regions that are drier, that are flat or do not have strong water flows have lower potential. Asia, Africa and the Americas have the highest feasible potential for hydroelectricity (figure 8.4).

China's hydro energy resources are the largest of any country. China is estimated to have a theoretical potential of more than 6000 TWh per year, approximately double current world hydroelectricity generation, and economically feasible potential of more than 1750 TWh per year (Hydropower and Dams 2009). China is also home to the largest single hydroelectricity project in the world, Three Gorges. When completed, this site will have a capacity of 22 500 megawatts. It generated almost 50 TWh of electricity in 2006 (representing only around 31 per cent capacity utilisation), more than three times Australia's total hydroelectricity generation.

In Africa, the Democratic Republic of the Congo has the highest hydro energy potential, while Norway's potential resources are the highest in Western Europe. In South America, the highest hydro energy potential is in Brazil, where it exceeds 2200 TWh per year. Other countries with substantial potential include Canada, Chile, Colombia, Ethiopia, India, Mexico, Paraguay, Tajikistan and the United States. Nevertheless, almost all countries have some hydro energy potential.

Australia's theoretical hydro energy potential (265 TWh per year) is considered to be relatively small, ranking 27th in the world (figure 8.5). High rainfall variability, low average annual rainfall over most of the continent, and high temperatures and evaporation rates limit the availability of surface water resources (WEC 2007).

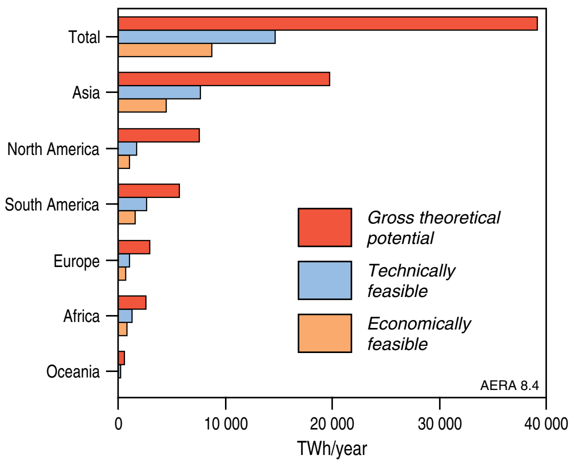

Figure 8.4 World hydroelectricity potential, by region

Source: Hydropower and Dams 2009

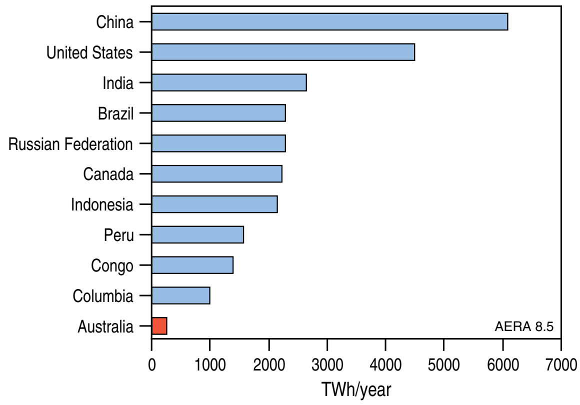

Figure 8.5 Gross theoretical hydroelectricity potential, major countries

Source: Hydropower and Dams 2009

Table 8.1 Key hydro statistics

	unit	Australia 2007–08	OECD 2008	World 2007
Primary energy consumption[a]	PJ	43.4	4654	11 084
Share of total	%	0.8	2.0	2.2
Average annual growth, from 2000	%	-4.2	-0.3	2.0
Electricity generation				
Electricity output	TWh	12	1293	3078
Share of total	%	4.5	12.2	15.6
Electricity capacity	GW	7.8	366.9	848.5

a Energy production and primary energy consumption are identical
Source: IEA 2009a; ABARE 2009a; Hydropower and Dams 2009

Primary energy consumption

Hydroelectricity generation has been growing globally, reflecting its increasing popularity in developing economies as a relatively cheap, simple and reliable source of energy (figure 8.6).

Hydroelectricity generation accounted for 2.2 per cent of total primary energy consumption in 2007 (table 8.1). World hydroelectricity consumption has grown at an average annual rate of 2 per cent between 2000 and 2007. However, in the OECD, hydroelectricity consumption has been declining at an average annual rate of 0.3 per cent.

Consumption of hydroelectricity has also declined in Australia due to the prolonged period of drought, particularly in New South Wales and Victoria, that has affected hydroelectricity generation.

Electricity generation

Hydroelectricity accounted for 16 per cent of world electricity generation in 2007. Hydroelectricity's share in total electricity generation has declined from 22 per cent in 1971 to 16 per cent (figure 8.6), because of the higher relative growth of electricity generation from other sources. Latin American countries account for the largest proportion of hydroelectricity generation, followed by OECD North America. The most rapid growth in hydroelectricity generation has been in China, which is now the fourth largest generator. Many African economies are also developing their hydro energy potential, and have become a source of growth.

Total installed hydroelectricity generation capacity is currently around 849 GW, with around 158 GW of new capacity under construction in late 2008 (Hydropower and Dams 2009). Some 25–30 GW of new large scale hydro energy capacity were added in 2008, mostly in China and India (Ren21 2009). China has the world's largest installed hydroelectricity capacity with around 147 GW (17 per cent of world capacity), followed by the United States, Brazil, Canada and the Russian Federation. These economies account for half of the world's installed hydroelectricity generation capacity. In 2008 there were around 200 large (greater than 60 m high) dams with hydroelectricity facilities under construction.

The total installed capacity of small hydro energy is estimated to be about 85 GW worldwide (Ren21 2009). Most of this is in China where some 4–6 GW per year have been added for the past several years, but development of small hydro plants has also occurred in other Asian countries.

In 2007, world production of hydroelectricity was 3078 TWh (around 11 000 PJ). The largest producers were China, Brazil, Canada and the United States (figure 8.7a). Australia ranked 31st in the world. Hydroelectricity accounted for a large share of total

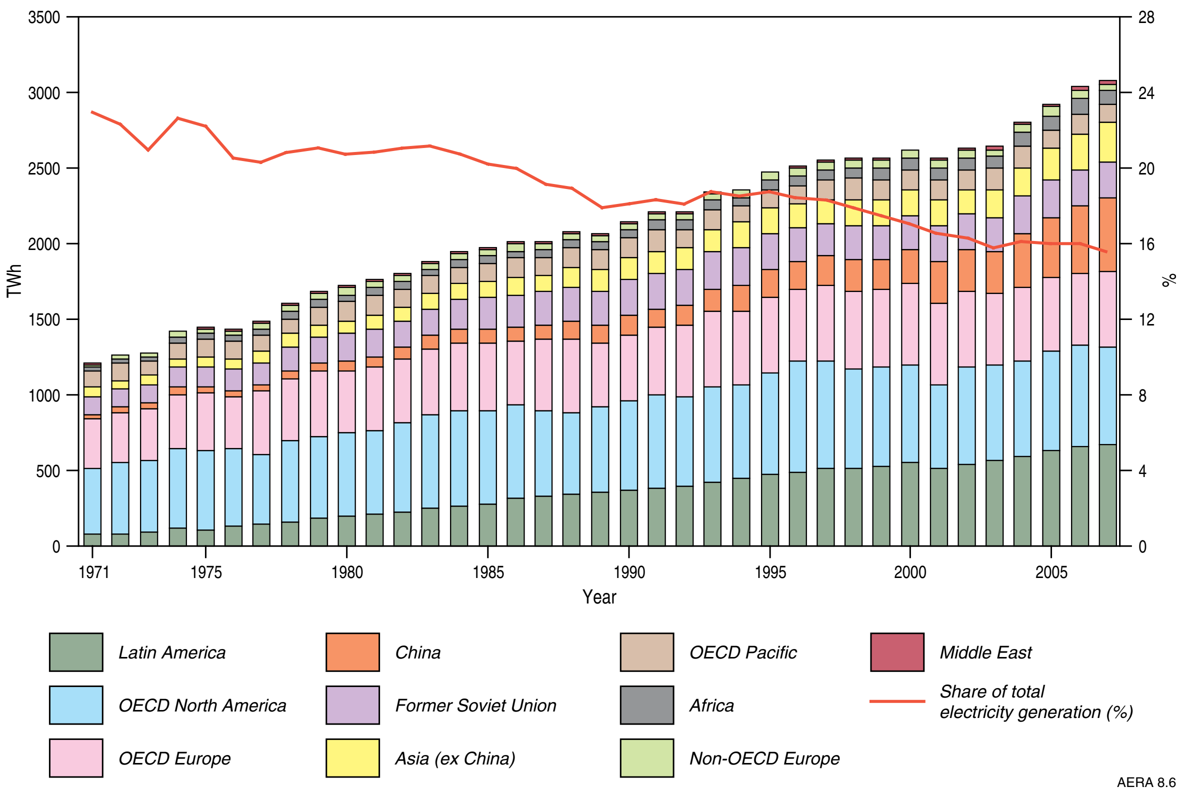

Figure 8.6 World hydro generation and share of total electricity generation

Source: IEA 2009a

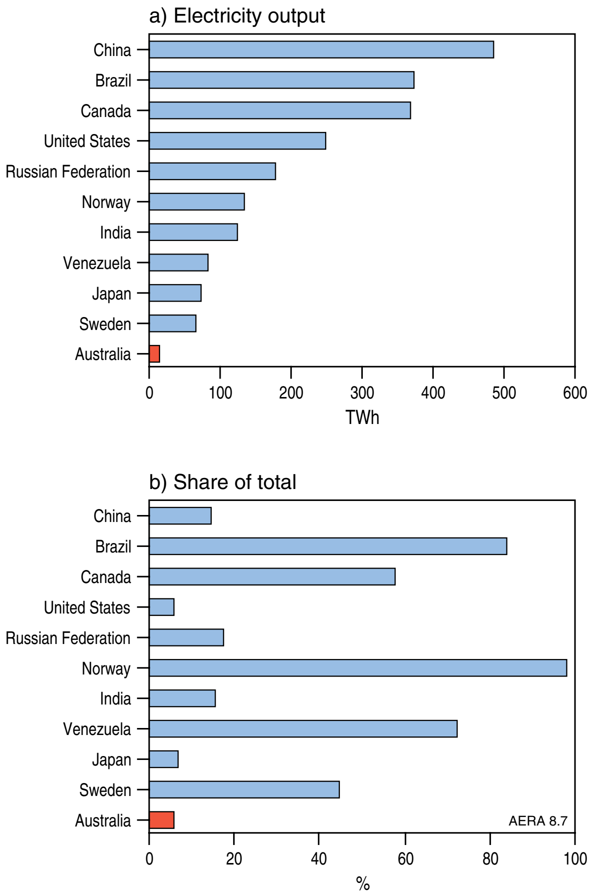

Figure 8.7 World electricity generation from hydro, major countries, 2007

Source: IEA 2009a

electricity generation in some of these countries including, most notably, Norway (98 per cent), Brazil (84 per cent), Venezuela (72 per cent), Canada (58 per cent) and Sweden (44 per cent) (figure 8.7b).

Hydroelectricity meets over 90 per cent of domestic electricity requirements in a number of other countries including: the Democratic Republic of the Congo, Ethiopia, Lesotho, Malawi, Mozambique, Namibia and Zambia in Africa; Bhutan, Kyrgyzstan, Laos, Nepal and Tajikistan in Asia; Albania and Norway in Europe; and Paraguay in South America (Hydropower and Dams 2009).

Outlook for the world hydroelectricity market

In the IEA reference case projections, world hydroelectricity generation is projected to increase to 4680 TWh in 2030, at an average annual rate of 1.8 per cent (table 8.2). Hydroelectricity generation is projected to grow in the OECD at an average annual rate of 0.7 per cent and in non-OECD countries by an average annual rate of 2.5 per cent.

The growth in hydroelectricity generation in the OECD is expected to come from utilisation of remaining undeveloped hydro energy resources. Growth is also expected to occur in small (including mini and micro) and medium scale hydroelectricity plants. Improvements in technology may also improve the reliability and efficiency and, hence, output of existing hydroelectricity plants, as would refurbishment of ageing infrastructure.

In non-OECD countries, growth is expected to be underpinned by the cost competitiveness of hydroelectricity compared with other means of electricity generation. Much of the growth is expected to be in small scale hydroelectricity, although there are plans in many African countries to build large scale hydroelectricity generation capacity. Growth is also expected to occur in Asia, particularly China.

The implementation of global climate change policies is likely to encourage the development of hydroelectricity as a renewable, low emissions energy source. In the IEA's 450 climate change policy scenario, the share of hydro in world electricity generation is projected to increase to 18.9 per cent in 2030, compared with 13.6 per cent in its reference case. For the OECD regions, under this scenario, the share of hydro in total electricity generation is projected to increase to 13.5 per cent in 2030 compared with 11.2 per cent in the reference case.

Table 8.2 IEA reference case projections for world hydroelectricity generation

	unit	2007	2030
OECD	TWh	1258	1478
Share of total	%	12.2	11.2
Average annual growth, 2007–2030	%	-	0.7
Non-OECD	TWh	1820	3202
Share of total	%	19.9	15.2
Average annual growth, 2007–2030	%	-	2.5
World	TWh	3078	4680
Share of total	%	15.6	13.6
Average annual growth, 2007–2030	%	-	1.8

Source: IEA 2009b

8.3 Australia's hydro energy resources and market

8.3.1 Hydro energy resources

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 (figure 8.8). There is also high variability in rainfall, evaporation rates and temperatures between years, resulting in Australia having very limited and variable surface water resources. Of Australia's gross theoretical hydro energy resource of 265 TWh per year, only around 60 TWh is considered to be technically feasible (Hydropower and Dams 2009). Australia's economically feasible capacity is estimated at 30 TWh per year of which more than 60 per cent has already been harnessed (Hydropower and Dams 2009).

The first hydroelectric plant in Australia was built in Launceston in 1895. Australia currently has 108 operating hydroelectric power stations with total installed capacity of 7806 MW. These coincide with the areas of highest rainfall and elevation and are mostly in New South Wales (55 per cent) and Tasmania (29 per cent) (figure 8.9). The Snowy Mountains Hydro-electric Scheme, with a capacity of 3800 MW, accounts for around half of Australia's total hydroelectricity generation capacity but considerably less of actual production. There are also hydroelectricity schemes in north-east Victoria, Queensland, Western Australia, and a mini-hydroelectricity project in South Australia. Pumped storage accounts for about 1490 MW.

The Snowy Mountains Hydro-electric Scheme 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, 145 km of inter-connected trans-mountain tunnels and 80 km of aqueducts. The Snowy Mountains Hydro-electric Scheme provides around 70 per cent of all renewable energy that is available to the eastern mainland grid of Australia, as well as providing peak load power (Snowy Hydro 2007).

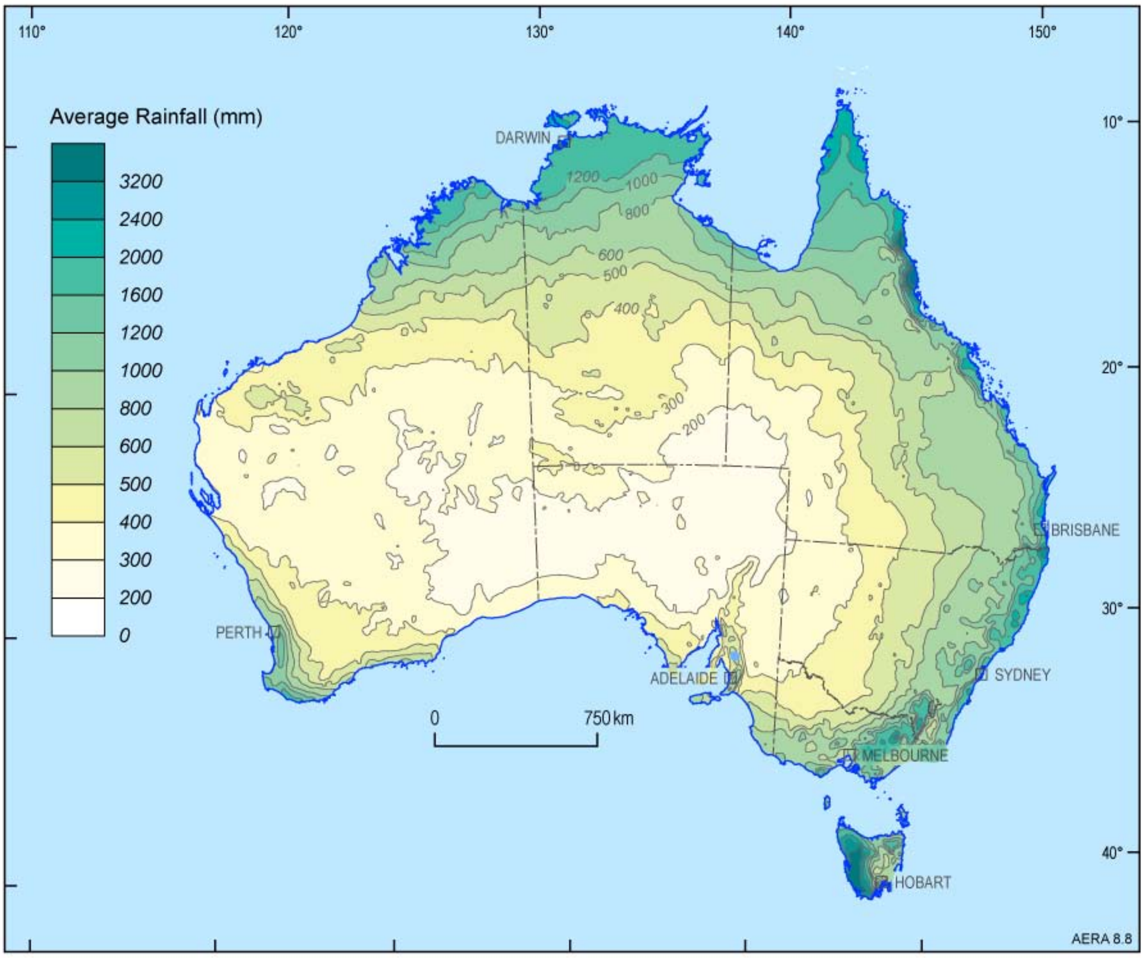

Figure 8.8 Average annual rainfall across Australia

Source: Bureau of Meteorology

The hydroelectricity generation system in Tasmania comprises an integrated scheme of 28 power stations, numerous lakes and over 50 large dams. Hydro Tasmania, the owner of the majority of these hydroelectricity plants, supplies both base load and peak power to the National Electricity Market (NEM), firstly to Tasmania and then the Australian network through Basslink, the undersea interconnector which runs under Bass Strait.

8.3.2 Hydroelectricity market

Australia has developed much of its large scale hydro energy potential. Electricity generation from hydro has declined in recent years because of an extended period of drought in eastern Australia, where most hydroelectricity capacity is located. Hydro energy is becoming less significant in Australia's fuel mix for electricity generation, as growth in generation capacity is being outpaced by other fuels.

Primary energy consumption

As hydro energy resources are used to produce electricity, which is used in either grid or off-grid applications, hydro energy production is equivalent to hydro energy consumption. Hydro accounted for 0.8 per cent of Australia's primary energy consumption in 2007–08. Hydroelectricity generation declined at an average annual rate of 4.2 per cent between 1999–2000 and 2007–08, the result of a prolonged period of drought.

Electricity generation

In 2007–08, Australia's hydroelectricity generation was 12.1 TWh or 4.5 per cent of total electricity generation (figure 8.10). Over the period 1977–78 to 2007–08, hydroelectricity generation has tended to fluctuate, reflecting periods of below or above average rainfall. However, the share of hydro in total electricity generation has steadily declined over this period reflecting the higher growth of alternative forms of electricity generation.

Tasmania has always been the largest generator of hydroelectricity in Australia, accounting for 57 per cent of total generation in 2007–08 (figure 8.11). New South Wales is the second largest, accounting for 22 per cent of total electricity generation in 2007–08 (sourced mostly from the Snowy Mountains Hydro-electric Scheme). Victoria, Queensland and Western Australia account for the remainder.

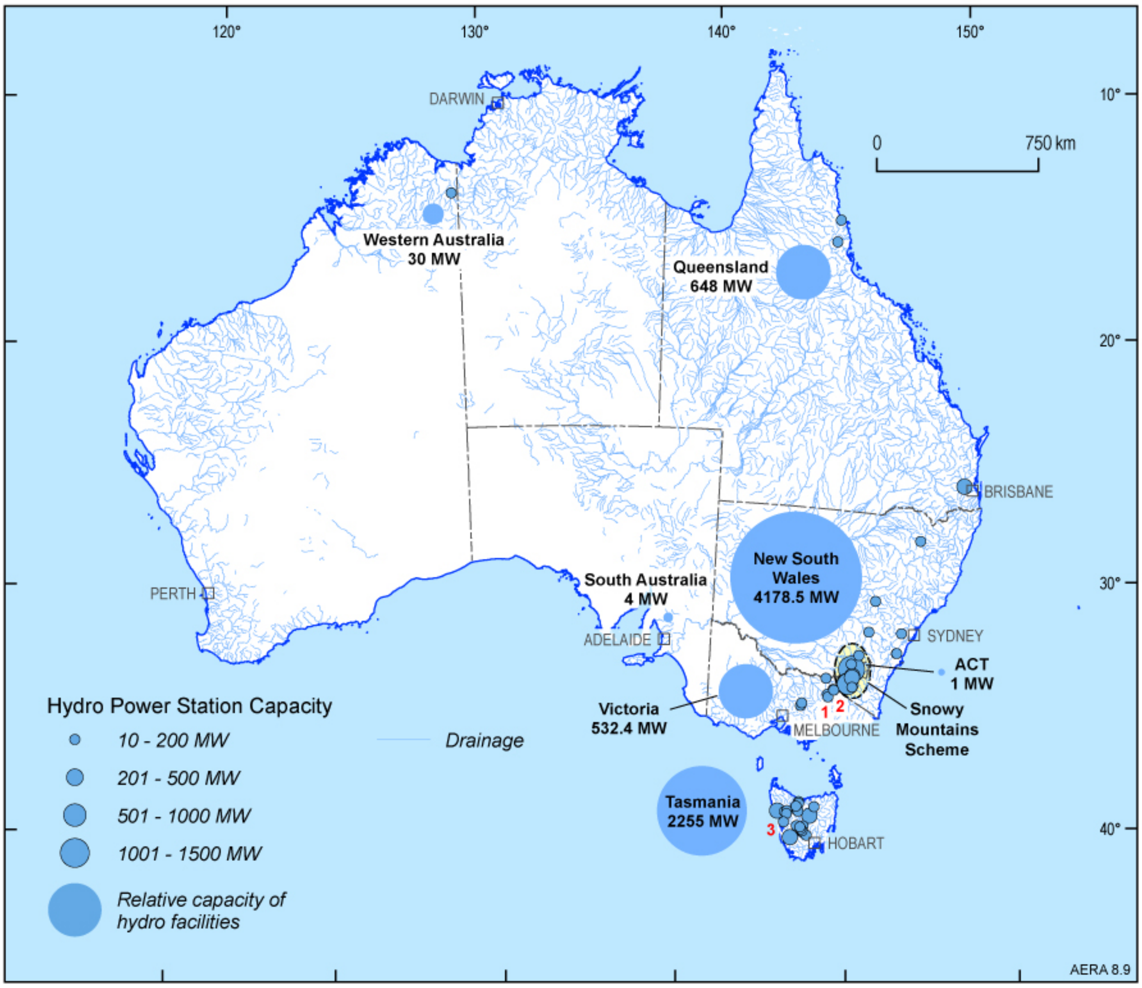

Figure 8.9 Major Australian operating hydro electric facilities with capacity of greater than 10 MW. Numbers indicate sites referred to in section 8.4.2

Source: Geoscience Australia

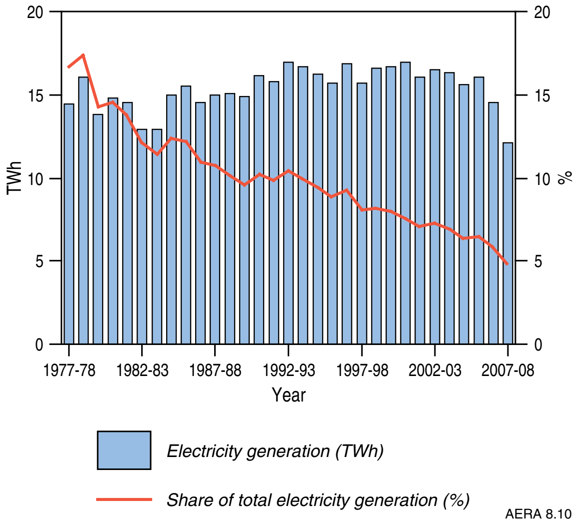

Figure 8.10 Australia's hydro generation and share of total electricity generation

Source: ABARE 2009a

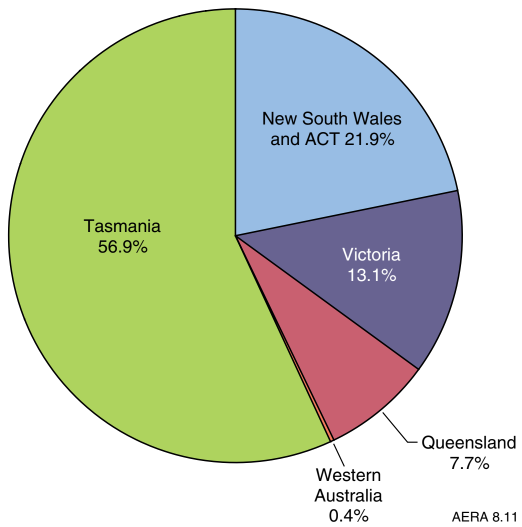

Figure 8.11 Australia's hydro consumption by state, 2007–08

Source: ABARE 2009a

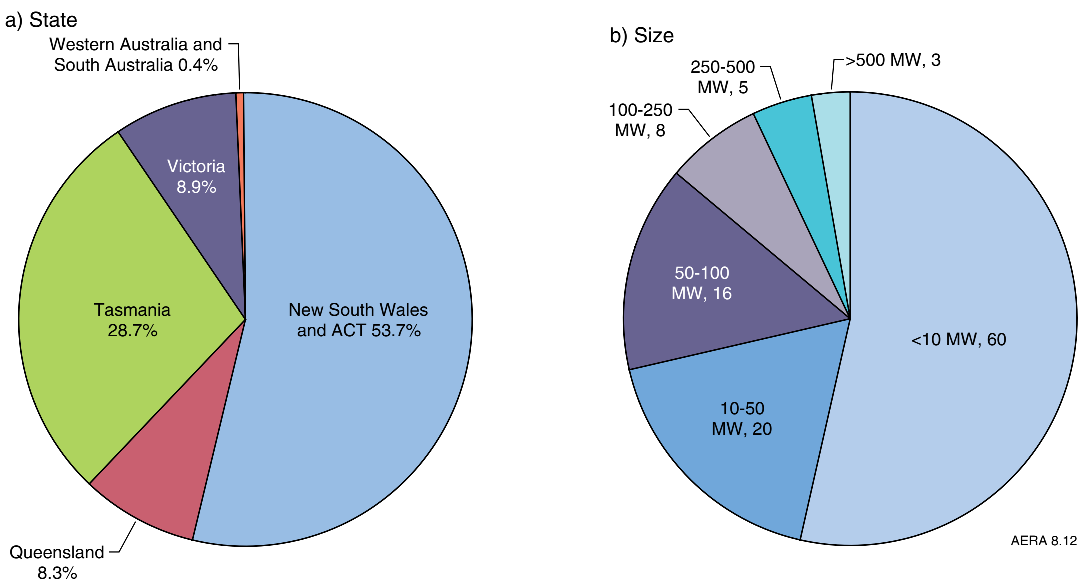

Figure 8.12 Installed hydro capacity by state and size, 2009

Source: Geoscience Australia

Installed electricity generation capacity

Australia has only 3 hydroelectricity plants with a capacity of 500 MW or more, all of which are located in the Snowy Mountains Hydro-electric Scheme (figure 8.12). The largest hydroelectricity plant in Australia has a capacity of 1500 MW, which is mid-sized by international standards. More than 75 per cent of Australia's installed hydroelectricity capacity is contained in 16 hydroelectricity plants with a capacity of 100 MW or more. At the other end of the scale, there are some 60 small and mini-hydroelectricity plants (less than 10 MW capacity) with a combined capacity of just over 150 MW.

However, installed hydroelectricity generation capacity does not directly reflect actual electricity generation. The smaller installed capacity in Tasmania produces more than double the output of the Snowy Mountains Hydro-electric Scheme. Tasmania is the only state that uses hydroelectricity as the main means of electricity generation.

8.4 Outlook to 2030 for Australia's hydro energy resources and market

Although benefiting from the Renewable Energy Target and increased demand for renewable energy, growth in Australia's hydroelectricity generation is expected to be limited and outpaced by other renewables, especially wind energy. Future growth in hydroelectricity generation capacity is likely to come mainly from the installation of small scale plants. Water availability will be a key constraint on the future expansion of hydroelectricity in Australia.

8.4.1 Key factors influencing the outlook

Opportunities for further hydroelectricity generation in Australia are offered by refurbishment and efficiency improvements at existing hydroelectricity plants, and continued growth of small-scale hydroelectricity plants connected to the grid. Hydroelectricity generation is a low-emissions technology, but future growth will be constrained by water availability and competition for scarce water resources.

Hydroelectricity is a mature renewable electricity generation technology with limited scope for further large scale development in Australia

Most of Australia's best large scale hydro energy sites have already been developed or, in some cases, are not available for future development because of environmental considerations. There is some potential for additional hydro energy generation using the major rivers of northern Australia but this is limited by the region's remoteness from infrastructure and markets and the seasonal flows of the rivers.

Upgrading and refurbishing ageing hydro infrastructure in Australia will result in capacity and efficiency gains

Many of Australia's hydroelectric power stations are now more than 50 years old and will require refurbishment in the near future. This will involve significant expenditure on infrastructure, including the replacement and repair of equipment. The refurbishment of plants will increase the efficiency and decrease the environmental impacts of hydroelectricity. Further technology developments will be focused on efficiency improvements and cost reductions in both new and existing plants (box 8.2).

The Snowy Hydro Scheme is currently undergoing a maintenance and refurbishment process, at a cost of approximately A$300 million (in real terms) over seven years (Snowy Hydro 2009). The modernisation will include the replacement of ageing and high maintenance equipment, increasing the efficiency and capacity of turbines, and ensuring the continued reliable operation of the component systems of the scheme.

Refurbishment of the power station at Lake Margaret, Tasmania – one of Australia's oldest hydroelectricity facilities (commissioned in 1914) – commenced in 2008. The main objective of the project was to repair the original wooden pipeline, which had deteriorated

BOX 8.2 HYDROELECTRICITY COSTS

Hydroelectricity generation costs

The most significant cost in developing a hydro resource is the construction of the necessary infrastructure. Infrastructure costs include the dams as well as the power plant itself. Building the plant on an existing dam will significantly reduce capital outlays. Costs incurred in the development phase of a hydro facility include (Forouzbakhsh et. al. 2007):

- **Civil costs** – construction of the components of the project including dams, headponds, and access roads.
- **Electro mechanical equipment costs** – the machinery of the facility, including turbines, generators and control systems.
- **Power transmission line costs** – installation of the transmission lines.

Indirect costs include engineering, design, supervision, administration and inflation impacts on costs during the construction period. Construction of small and medium plants can take between 1 to 6 years, while for large scale plants it can take up to 30 years (for example, the Snowy Hydro Scheme took 25 years to build).

The costs of building Australian hydroelectricity generation plants have been varied. The Snowy Hydro scheme, Australia's largest hydroelectricity scheme, was constructed over a period of 25 years at a cost of A$820 million (Snowy Hydro 2007). Australia's most recent major hydroelectric development, the Bogong project (site 1, figure 8.9), commenced construction in 2006 and was commissioned in late 2009 at a cost of around $234 million. The project – which includes the 140 MW Bogong power station, a 6.9 km tunnel, head works and a 220 kV transmission line – will provide fast peaking power. In comparison, the Ord River hydroelectricity scheme, which was built on the existing dam which created Lake Argyle in Western Australia, was constructed at a cost of A$75 million (Pacific Hydro 2009). While this plant is relatively small

(30 MW), it demonstrates the potential reduction in construction costs where an existing dam can be used.

While hydroelectricity has high construction and infrastructure costs, it has a low cost of operation compared to most other means of electricity generation. In the OECD, capital costs of hydroelectric plants are estimated at US$2400 per kW, and operating costs are estimated at between US$0.03 and US$0.04 per kWh (IEA 2008). For non-OECD countries, capital costs are often below US$1000 per kW. The operating costs of small hydroelectricity facilities are estimated at between US$0.02 and US$0.06 per kWh. Operating and capital costs depend on the size and type (for example, run-of-river) of plant, and whether it includes pumped storage capabilities. Most hydroelectric plants have a lifetime of over 50 years, during which minimal maintenance or refurbishment is required, so the relatively high capital costs are amortised over a long period.

(Hydro Tasmania 2008). The project involved additional maintenance on the dam, minor upgrade of the machines, as well as replacement of a transformer. This upgrade, completed in late 2009, cost about $14.7 million to gain 8.4 MW of capacity at a capital spend rate of $1.75 million per MW, considerably less than the costs of new plant. Work has commenced on the redevelopment of the Lower Margaret Power Station (Hydro Tasmania 2009).

Small scale hydro developments are likely to be an important source of future growth in Australia

With the exception of the Bogong project (see Proposed development projects in section 8.4.2), most hydroelectricity plants installed in Australia in recent years have been mini hydro schemes. These plants have the advantage of lower water requirements and a smaller environmental impact than larger schemes, especially those with large storage dams.

Although most of Australia's most favourable hydroelectricity sites have been developed, mini hydroelectricity plants are potentially viable on smaller rivers and streams where large dams are not technically feasible or environmentally acceptable. They can also be retro-fitted to existing water storages. At present mini hydro plants account for only around 2 per cent of installed hydro capacity. Research, development and demonstration activity is likely to increase the cost competitiveness of small scale hydro schemes in the future (box 8.3).

Surface water availability and competition for scarce water resources will be a key constraint to future hydro developments in Australia

Australia has a high variability of rainfall across the continent (figure 8.8). This means that annual inflows to storages can vary by up to 50 per cent and seasonal variations can be extreme. Ongoing drought in much of south eastern Australia has seen a substantial decline in water levels in the major storages in New South Wales (notably the Snowy Mountains scheme), Victoria and Tasmania and declining capacity factors for hydroelectricity stations. Water levels in storages across Australia have declined to an average of below 50 per cent of capacity (National Water Commission 2007). Cloud seeding has been used in the Snowy Mountains and in Tasmania to augment water supplies.

Climate change models suggest the outlook for south eastern Australia is for drier conditions with reduced rainfall and higher evaporation, and a higher frequency of large storms (BOM 2009; IPPC 2007; Bates et al. 2008). Reduced precipitation and increased evaporation are projected to intensify by 2030, leading to water security problems in southern and eastern Australia in particular (Hennessy et al. 2007). The climate change projections further exacerbate the problem of Australia's dry climate with low and variable rainfall, low run off and unreliable water flows and mean that there is only limited potential for further major hydro development in mainland Australia. Some of this potential is located in the rivers in northern Australia, but this is limited by the inconsistency of water flows in this region (periods of low rainfall along with periods of flooding).

Competition for water resources will also affect the availability of water for hydroelectricity generation. Demand for water for urban and agricultural uses is projected to increase. It is likely that these uses for scarce water resources will take precedence over hydroelectricity generation. Generators face increasing demands to balance their needs against the need for greater water security for cities and major inland towns. The maintenance of environmental flows to ensure the environmental sustainability of river systems below dams is also an important future consideration which may further constrain growth of hydroelectricity generation.

Water policies may also play a role in the future development of hydroelectricity in Australia. Policies that limit the availability of water to hydroelectricity generators, restrict the flow of water into dams, require generators to let water out of dams, or prioritise the use of water for agriculture could change the viability of many hydroelectric generators, and limit future growth. The extended drought in much of Australia has led to water restrictions being put into place in most capital cities, and regulation of the Murray-Darling basin river systems has strengthened.

BOX 8.3 TECHNOLOGY DEVELOPMENTS IN HYDROELECTRICITY

Research is being undertaken to improve efficiency, reduce costs, and to improve the reliability of hydroelectricity generation. There are different research needs for small and large scale hydro (table 8.3). Small hydropower plants, including micro and pico plants, are increasingly seen as a viable source of power because of their lower development costs and water requirements, and their lower environmental footprint. Small scale hydropower plants require special technologies to increase the efficiency of electricity generation and thereby minimise both the operating costs and environmental impacts of hydroelectricity generation (ESHA 2006).

The environmental impacts of hydroelectricity are also being investigated, and ways to mitigate these impacts developed. This includes the development of new and improved turbines designed to minimise the impact on fish and other aquatic life and to increase dissolved oxygen in the water. The introduction of greaseless bearings in the turbines would reduce the risk of petroleum products entering the water, and is also currently being investigated (EERE 2005).

Table 8.3 Technology improvements for hydropower

Large hydro	Small hydro
Equipment Low-head technologies, including in-stream flow Communicate advances in equipment, devices and materials	**Equipment** Turbines with less impact on fish populations Low-head turbines In-stream flow technologies
Operation and maintenance Increasing use of maintenance-free and remote operation technologies	**Operation and maintenance** Develop package plants requiring only limited operation and maintenance
	Hybrid systems Wind-hydro systems Hydrogen-assisted hydro systems

Source: IEA 2008

8.4.2 Outlook for hydroelectricity market

Hydroelectricity is projected to continue to be an important source of renewable energy in Australia over the outlook period.

In ABARE's latest long-term energy projections that include the Renewable Energy Target, a 5 per cent emissions reduction target and other government policies (ABARE 2010), hydroelectricity generation is projected to increase only slightly between 2007–08 and 2029–30, representing an average annual growth rate of 0.2 per cent. In 2029–30, hydro is projected to account for 3.5 per cent of Australia's total electricity generation, and 0.6 per cent of primary energy consumption (figure 8.13). The potential for return of hydroelectricity output to pre-2006 levels will be strongly influenced by climate and by water availability.

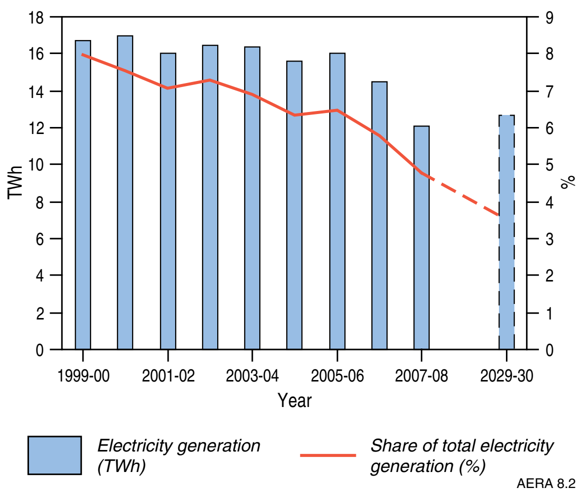

Figure 8.13 Australia's hydroelectricity generation to 2029–30

Source: ABARE 2009a, 2010

Proposed development projects

Based on Hydropower and Dams (2009), there are several current hydro project developments in Australia:

- A 20 MW hydro plant is currently under construction at the Dartmouth regulating dam in Victoria (Site 2, figure 8.9).
- The next stage of redevelopment of the 8.4 MW Lake Margaret power station in Tasmania has been approved by the board of Hydro Tasmania (Site 3, figure 8.9).
- Hydro Tasmania Consulting has been awarded a contract to supply and construct six mini hydro plants for Melbourne Water with a total capacity of 7 MW, producing up to 40 GWh per year.

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