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Water requirements of nuclear power stations

Introduction

Currently the Government is undertaking a feasibility study into the possibility of establishing a nuclear power industry in Australia.[1]

Among the concerns raised about the development of a nuclear power industry in Australia is the amount of water consumed by nuclear power plants compared with other power stations.

Water's role in power production

Electricity power stations can use large quantities of water. They can use river, lake, dam, or sea water and as such are located close to large and reliable water sources.

The water is needed to turn the turbines that drive the generators. To do this the water is turned into high pressure steam by a boiler or nuclear reactor.

This steam is then cooled so that the water can be pumped through the system again.

The amount water a power station uses and consumes depends on the cooling technology.

The distinction between 'use' and 'consume' is important. Some power stations *use* large quantities of water, but most of this water is returned to the source and can be used again by other consumers or for environmental purposes. All power stations do *consume* some of the water they *use*. This is generally water that is lost as evaporation.

Cooling systems

'Closed cycle' — the steam is cooled in towers or ponds and the water that is not lost to evaporation is recycled through the plant again.

'Once-through' — the steam is cooled by more water that is pumped from an outside source in pipes through a condenser.[2]

Of the two systems, the closed cycle uses about two to three per cent of the water volumes used by the once-through system.[3] However, as can be seen from the statistics in Table 1, the two systems consume about the same amount.

Some power plants also use dry cooling systems and hybrid wet/dry systems. However, these are far less common than the wet systems mentioned above [4] as they are more expensive to build and less efficient.[5],[6]

Nuclear compared with other sources of fuel

Nuclear power plants need more cooling water than fossil-fired power stations. This is because the steam in nuclear power stations is designed to operate at lower temperatures and pressures, which means they are less efficient at using the heat from the reactor and thus require more water for cooling.[7]

A study on water and sustainability for power production in the US by the Electric Power Research Institute (EPRI) compared the water needs and consumption rates of existing power stations by type of fuel and cooling technology.[8]

Table 1: Cooling Water Withdrawal and Consumption (Evaporation to the Atmosphere)
Rates for Common Thermal Power Plant and Cooling System Types (converted from US gallons to litres)

Plant and Cooling System Type	Water Withdrawal (litres/MWh)			Typical Water Consumption (litres/MWh)		
Fossil/biomass/waste-fueled steam, once-through cooling	75 708	to	189 270	~1 136		
Fossil/biomass/waste-fueled steam, pond cooling	1 136	to	2 271	1 136	to	1 817
Fossil/biomass/waste-fueled steam, cooling towers	1 893	to	2 271	~1 817		
Nuclear steam, once-through cooling	94 635	to	227 124	~1 514		
Nuclear steam, pond cooling	1 893	to	4 164	1 514	to	2 725
Nuclear steam, cooling towers	3 028	to	4 164	~2 725		
Natural gas/oil combined-cycle, once-through cooling	28 391	to	75 708	~ 379		
Natural gas/oil combined-cycle, cooling towers	~ 871			~ 681		
Natural gas/oil combined-cycle, dry cooling	~ 0			~ 0		
Coal/petroleum residuum–fueled combined-cycle, cooling towers	*~1			~757		

* includes gasification process water

Source: Water & Sustainability (Volume 3):U.S. Water Consumption for Power Production—The Next Half Century, Topical Report March 2002, EPRI, Concord. Viewed 1 November 2006. http://www.epriweb.com/public/000000000001006786.pdf

The EPRI analysis showed that existing nuclear power stations used and consumed significantly more water per megawatt hour than electricity generation powered by fossil fuels, see Table 1.[9]

From Table 1 it can be seen that nuclear 'once-through' systems use about 20 to 25 per cent more water and nuclear 'closed systems' can use up to 83 per cent more water. Furthermore actual water consumption rates are higher.

The data shows that for once-through systems nuclear consumes about 33 per cent and closed systems 50 per cent more than fossil fuel power stations.

Annual water requirements by energy source

Assuming that a power station ran 24 hours a day and based on the lower end of the estimates in Table 1, annual usage and consumption per megawatt would be as follows.

Table 2. Once-through

	Water withdrawal ML/MW	Consumption ML/MW
Fossil/biomass/waste	663	10
Nuclear	829	13

Table 3. Pond cooling

	Water withdrawal ML/MW	Consumption ML/MW
Fossil/biomass/waste	10	10
Nuclear	17	13

Table 4. Tower cooling

	Water withdrawal ML/MW	Consumption ML/MW
Fossil/biomass/waste	17	16
Nuclear	27	24

Hypothetical requirements for future Australian power stations

There are several new nuclear power station proposals in the USA. These projects propose to use the latest in nuclear power plant technology.

A recent Australian Nuclear Science and Technology Organisation (ANSTO) report did a cost benefit analysis of establishing one of these stations in Australia. The plant referred to in this report was an Advanced Pressurized Water Reactor (AP1000) developed by Westinghouse.[10] This plant would have an operating output of between 1 115 and 1 150 megawatts depending on the cooling technique employed.

A report by the US Department of Energy published estimates of the likely cooling water requirements of this sort of plant. These were stated to be between 450 000 to 750 00 US gallons per minute.[11] This equates to an annual average usage rate of between 779 and 1 338 megalitres per megawatt which is consistent with the above analysis for existing nuclear power plants.

Conclusion

Per megawatt existing nuclear power stations *use* and *consume* more water than power stations using other fuel sources. Depending on the cooling technology utilised, the water requirements for a nuclear power station can vary between 20 to 83 per cent more than for other power stations.

Glossary

Megawatt (MW) — One million watts
Megalitre (ML) — One million litres
~ — Approximate

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1. R*eview of uranium mining processing and, nuclear energy in Australia*, Media Release, Prime Minister, 6 June 2006, http://www.pm.gov.au/news/media_releases/media_Release1965.html, viewed 31 October 2006.
2. Power Scorecard, Pace University, Pace Law School Energy Project, http://www.powerscorecard.org/issue_detail.cfm?issue_id=5, viewed 30 October 2006.
3. *Comparison of Alternate Cooling Technologies for California Power Plants: Economic, Environmental and Other Tradeoffs*, Public Energy Research Program: Final Report, California Energy Commission, Public, February 2002, p. 1–7, http://www.energy.ca.gov/reports/2002-07-09_500-02-079F.PDF, Viewed 31 October 2006.
4. ibid, p. 3–6.
5. ibid, p. 2–9.
6. The efficiency of all cooling systems is affected by climate.
7. Dr Ian Rose, *Nuclear Power Station*, Roam Consulting, 26 October 2006. http://www.thepremier.qld.gov.au/library/pdf/NuclearPowerStation261006.pdf, Viewed 1 November 2006.
8. It should be noted that power plants in the future may be more efficient and probably use less water.
9. Water & Sustainability (Volume 3):U.S. Water Consumption for Power Production—The Next Half Century, Topical Report March 2002, EPRI, Concord, http://www.epriweb.com/public/000000000001006786.pdf, Viewed 1 November 2006.
10. Professor John H. Gittus*, Introducing nuclear power to Australia: an economic comparison. A report prepared for the Australian Nuclear Science and Technology Organisation*, ANSTO, May 2006, http://www.ansto.gov.au/ansto/nuclear_options_paper.pdf, Viewed 30 October 2006.
11. Study of potential sites for the deployment of new nuclear power plants in the United States, prepared by Dominion Energy Inc. for US Dept. of Energy, September 2002, pp. 7–8, http://www.ne.doe.gov/np2010/espStudy/espStudyDominion.pdf, Viewed 30 October 2006.

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