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NUCLEAR POWER STATION

Introduction

Recent information on nuclear power costs is available from reliable sources. A Summary Report[1] by PB Power, provides the finding of a study commissioned by the Royal Academy of Engineering into the 'Costs of Generating Electricity'.

The following major parameters have been identified by PB Power for nuclear power stations:

	Low	High
Capital Cost	£1,000/kW	£1,200/kW
Fuel Price	£4.60/MWh	£4.60/MWh

The estimated 'levelised' cost of generation provided by PB Power is 2.80p/kWh[2].

The cost breakdown for nuclear power shows that capital costs are the dominant proportion of total costs.

Brief Description of Nuclear Power Plant

A nuclear power plant would have many of the same items of equipment as a coal fired plant. A coal fired unit consists of a boiler, turbine and alternator, with the heat from combusting coal supplying steam to drive the turbine.

A nuclear unit uses enriched uranium in a reactor to provide steam to drive the turbine which is coupled to the alternator for electricity production.

In a coal fired unit the steam is continuously recycled by condensing it back to water and reheating it in the boiler for conversion to steam again. The process for nuclear is essentially the same, except for the higher safety standards that apply.

The steam cycle is a closed loop, for both coal fired and nuclear stations, requiring little additional water.

However, both coal fired and nuclear stations are large users of cooling water to condense and recycle the steam.

[1] PB Power, Summary Report, 'Powering the Nation – A Review of the Costs of Generating Electricity', March 2006. The full report is available from PB Power for £250.
[2] 7c/kWh, compared with 3.5c/kWh for current best practice coal fired power in Australia.

Cooling Water Consumption

The amount of cooling water consumed in producing electricity from coal or nuclear power stations is independent of the fuel used, except for the efficiency of the process.

Nuclear power stations, even of the latest designs, require more cooling water than the latest coal fired stations because they have lower thermodynamic efficiencies. The efficiencies are lower because the steam in a nuclear plant is designed and operated at lower temperature and pressure than for the latest generation of coal fired plants.

The lower temperature and pressure inherent in the nuclear plant design results in less efficient use of the heat from the nuclear reaction, and hence more cooling water is needed per unit of electricity production than coal.

A paper on Georgia, USA, water resources[3] states in Table 2 that Water Consumption Rates* for Electric Generation Sources are as follows:

Technology	Gallons per kilowatt hour
Coal	0.49
Nuclear	0.62

*Through evaporative loss, not including water that is recaptured and treated for further use.

In comparison, Stanwell Power Station's water consumption in 2004-05 was 19.4Gl (19,400Ml).[4] The station has nominal capacity of 1400MW and produced 9882GWh[5] (9,882,000MWh) during the same period. This amounts to 1.96kl/MWh. By comparison the Georgia figure of 0.49gals(US)/kWh equates to 1.85kl/MWh, which compares closely with the Stanwell figure, given the geographic differences and the unspecified efficiency of the Georgia plants.

Hence, a nuclear station of nominal 1400MW, 10,000GWh/a sent out production would be expected to use about 1.26 times the water usage of the equivalent coal fired power station, or about 25Gl/a[6]. The water source would need to be assured in at least a one in one hundred year drought.

[3] Sara Barszak and Rita Kilpatrick, 'Energy Impacts on Georgia's Water Resources', Proceedings of the 2003 Georgia Water Resources Conference, held 23-24 April, 2003 at the University of Georgia. Kathryn J. Hatcher, editor, Institute of Ecology, The University of Georgia, Athens, Georgia.
[4] Stanwell Power Station – Environmental Performance, Stanwell Annual Report 2005
[5] The capacity factor of the base load Stanwell station is 88% for the year, after converting the 1400MW generated to 1284MW sent out.
[6] The firm yield of Wivehoe plus Somerset Dams is listed by the Queensland Government as 373,000Ml/a, but expected to reduce due to drought.

Alternative Cooling Water Options

The alternative cooling water options for a nuclear station, as for a coal fired station, include:

- Seaboard once-through cooling
- Direct once-through river cooling
- Evaporative cooling (forced or natural draft)
- Dry cooling.

Once through seaboard and river cooling relies on very large volumes of water, whereby the water temperature of the cooling water is raised several degrees but evaporation is not employed for cooling. Seaboard cooling is used for nuclear plants that have suitable sites. San Onofre nuclear plant in California is an example. An equivalent seaboard coal fired generating plant is Gladstone Power Station, which employs once through cooling by seawater. The number of seaboard nuclear sites in areas close to a major transmission grid in Eastern Australia is likely to be limited. One of the benefits of seawater cooling is the lower cooling water ambient temperatures than inland sites for a given latitude.

Direct once-through river cooling can only be used for thermal stations with substantial reliable river flows. This has been used in Europe, North America and New Zealand (coal fired) but is increasingly difficult due to lack of reliability of water and the environmental effects of raising the water temperature downstream from the cooling water discharge. It is not an option for Australian conditions.

Evaporative cooling is the most common method of cooling for large thermal stations in Australia. It employs evaporative cooling to reject the waste heat from the thermal power station (coal or gas). Cooling towers have generally comprised the large hyperbolic shaped natural draft cooling towers that dominate many power station sites, particularly Tarong, Stanwell and Callide ‘B’.

More recently, low profile forced draft cooling towers which rely on fans have been adopted for recent coal fired stations such as Callide ‘C’.

Whether natural or forced draft, the evaporative cooling consumes, (i.e. evaporates), large amounts of water, approximately 20Gl per annum in the case of Stanwell.

The Millmerran and Kogan Creek power stations in Queensland provide the latest examples of cooling technology in areas with limited water. South Africa pioneered ‘dry cooled’ coal fired stations over many years and this technology is now accepted. Dry cooling operates without evaporation by passing the steam from the turbines through a set of finned pipes immediately beside the turbine and cooling the water by having large volumes of air driven by fans to condense the steam in the pipes.

Dry cooling has the disadvantages of higher capital cost, due to the very large system of pipes and fans, and lower efficiency resulting from the higher turbine back pressure. For coal fired stations, the resulting CO_2 emissions are therefore higher than those of an equivalent evaporative or ‘wet cooled’ station of otherwise equivalent design.

The preferred option for ongoing coal or nuclear power stations would therefore be one based on evaporative cooling from a reliable fresh water source, such as stored water from a large reservoir. This combines the lowest capital costs with the highest achievable efficiencies. However, the number of such stored water sites is increasingly limited, owing to lack of stored water and other water uses.

Power Station Size

The latest generation of PWR nuclear plants are designed for unit sizes of greater than 1000MW. This is substantially larger than the 750MW Kogan Creek power station, which will be the largest unit in Australia when completed in 2007. However, Kogan Creek is only slightly larger than the ten 660MW units in New South Wales, which are being uprated to 700MW presently.

Hence Kogan Creek does not represent a quantum increase in unit size on the Australian NEM grid. The problems with moving to, say, a 1000MW unit size are that a trip of such a unit from full load would increase the possibility of load shedding unless extra spinning reserved was carried by other generating units on the grid.

Hence the reasonable maximum size of a nuclear unit in Queensland in the next ten years would be 750MW to 800MW, unless additional advantages accrued to moving to a larger size, such as adopting a standard design. Since the NEM is a single grid, similar considerations would apply to any location in another state such as New South Wales or Victoria. South Australia would tend to be disadvantaged in this regard by its lower load base and correspondingly weaker interconnections with Victoria.

In a location such as North Queensland, the preference would be towards a nominal 2 × 500MW station rather than a single larger unit. Prior to the development of Kogan Creek, Queensland previously accepted a 450-500MW unit size as the norm, with Callide 'C' (2 × 450MW), Tarong North (1 × 450MW) and Millmerran (2 × 450MW) and logically this size would match well with many locations in Queensland from an operational perspective.

The chosen unit size would be established following detailed technical and economic evaluations.

Grid Connection

The grid connection requirements for a nuclear station of nominally 1000MW (either two units of 500MW, a unit of 750MW, or a larger unit) would require a strong grid connection to provide the inherent stability to ride through transmission faults and unit trips on the system.

The Queensland grid has a strong backbone of multiple 275kV circuits between Central and Southern Queensland. The North Queensland grid is being upgraded by Powerlink from a minimum of 2 × 275kV circuits to a minimum of 4 × 275kV circuits from Central Queensland to Townsville by 2010.

The strong points for connection of a nuclear power station in Queensland would be any of Ross (Townsville), Strathmore (Collinsville), Nebo (Mackay), Broadsound and Bouldercombe (Rockhampton). Other points further south would be appropriate from a grid perspective but may be problematic from a water supply perspective.

Operating Mode

The operating mode of the station would be as a base load unit, with a nominal availability[7] of at least 90%, and a nominal capacity factor[8] approaching that. This would be a direct substitute for the equivalent amount of coal fired generation which would otherwise need to be installed on the Queensland grid within the next decade to meet projected load growth.

Since the nuclear station would have relatively low marginal costs, i.e. the cost of fuel alone, it would tend to be bid at low or zero price into the market and be a price taker. It would probably be underpinned by long term power contracts rather than operate as a merchant plant exposed to spot price risk.

The higher capital cost would be offset by its zero CO_2 emission environmental benefits.

Waste Storage

Waste storage in the short term would be provided on site in a special pool. Permanent waste disposal would be a long term consideration.

Construction Time

The lead time for nuclear power stations is necessarily long to develop plans, designs and construction.

It is anticipated that the minimum time to achieve operations would be ten years from commencement of plant, with approximately five years for planning, permitting and detailed design, and a further five years for construction.

This is not inconsistent with the Kogan Creek 750MW project, which commenced the detailed planning phase in about 1997.

Visual Attributes

A nuclear power station would comprise a reactor building, turbine hall, cooling system with forced or natural draft cooling towers, switchyard and workshops/administration.

There would be no chimney stack, and, if forced draft cooling is adopted, no high profile natural draft cooling towers.

[7] Percentage of time unit is able to be operated at full output.
[8] Percentage of time unit is producing at full load output.

Major Suppliers

There are several major suppliers of latest generation nuclear power designs, including Toshiba, which has recently acquired Westinghouse nuclear group and British Nuclear Fuels. Areva is another major supplier.

There are also several established utilities with extensive nuclear capability and know how including EDF (France) and Canadian utilities.

Detailed consideration of alternative technologies would be needed as a next step.

Resources

Nuclear power development is a specialised area, requiring 'end to end' knowledge and skills for successful development. Although there may be individuals in Australia collectively with many of those skills, it would be essential that the first project is developed in conjunction with a corporation or group of corporations that could deliver a turnkey project.

China is developing nuclear power plants and the first such project was entirely designed and developed by EDF. Subsequent projects have been progressively developed with additional Chinese content, typically 70/30, 30/70 and so forth.

There is no reason why Australia would not have the necessary skill base that could be trained to fully take over the operations of a nuclear power station. However, the design and manufacture of the 'main plant' would likely remain in European, Japanese or North American industry.

Since the 'balance of plant' will comprise civil engineering works and electrical engineering facilities such as switchyards, a significant proportion of the total value of the nuclear power station could come from Australian manufacturers and suppliers.

Nuclear Fuel

It is not necessary for Australia to develop a fuel processing facility to convert mined uranium into nuclear fuel. This activity is understood to be a 'commodity' business with several suppliers of the appropriate centrifuge technology used for uranium enrichment. There are also several countries which can supply enriched uranium.

Brazil has recently sought to develop it own uranium enrichment industry using locally developed technology in order to break into this part of the business. However, the benefits of such an approach are understood to be somewhat unclear.

However, there is no reason why Australia should not have a uranium enrichment industry in due course, probably using an established supplier of facilities.

Staff Levels

Maintenance and operations should be broadly equivalent to those for a major coal fired station. It is understood that the trend is towards minimising the number of on site staff and maximising the use of contract staff for periodic maintenance.

Operating Lifetime

The operating lifetime would be of the order of 50 years, after which time the units would be decommissioned, although the site could continue operating with new units.

Half life refits are a major issue that would have to be considered in the initial design, particularly as control systems become obsolete more quickly than main plant components.

Queensland Uranium Resources

According to the Australian Government Geoscience Australia website, Australia has 40% of the world's total identified resources of uranium recoverable at low cost.

Queensland, along with South Australia, the Northern Territory, and Western Australia have uranium deposits. The contribution of Queensland to the national resources is significant.

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