Australian nuclear energy proposals, water availability and acquisition options

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Australian nuclear energy proposals, water availability and acquisition options

1. Executive Summary

In a dry and warming continent, the water footprint of any major new industry is a vital consideration.

On 19 June 2024, the Federal Opposition Leader, the Hon Peter Dutton MP, in a joint statement with the Hon David Littleproud MP, Leader of the National Party, and the Hon Ted O'Brien MP, Shadow Energy Minister, announced "*that a future Federal Coalition Government will introduce zero-emissions nuclear energy in Australia…*" The statement[i] went on to outline sites for the proposed nuclear reactors, all of them at sites where coal-fired power plants have been closed or are scheduled to close in coming decades. Six of the seven sites are inland, and one, Port Augusta, is on the coast. The Coalition released modelling from Frontier Economics[ii] that assumed 13 GW of nuclear generation capacity would be built across the seven sites, which currently host 8 GW of coal-fired power capacity.

This paper examines the water use of nuclear power stations and the assertion that there will be sufficient available water at the seven proposed sites for sustainable operation of nuclear power stations at high operating capacities for the 80 years proposed by the Coalition. It assesses catchment hydrology at each of the proposed sites, the current water allocation regime and applicable water markets, and the likely sources of water for nuclear power. Where there are apparent potential constraints to water availability over the next 80 years, it discusses the opportunity costs of allocating very high security water for nuclear power – i.e. potential impacts on other water users including irrigation industries, town water supplies, industrial users and the environment.

Around the world, most operating nuclear power stations are sited on the coast, on large lakes or river systems, and/or in cold wet regions. Nuclear reactors require large volumes of high security water to be constantly available for energy production and cooling. In wet, cold places, the quantum and temperature of available water for cooling is not a constraint. Few nuclear power stations are located inland in hot, dry regions, or on small rivers with occasional low flows. Australian rivers are known for being small and sluggish by world standards, but especially for having extreme variability in annual streamflow[iii]. International experience in places where rivers are the source of cooling water like southern France, Texas, Tennessee and Alabama, is that nuclear power generation sometimes needs to be curtailed or shut down during extended periods of very hot weather and/or low flows.

The Federal Coalition proposed[i] in 2024 that up to 14,000MW of electricity generation could be supplied by seven new nuclear power plants. This analysis examines water availability at each of those seven sites, assuming a total of 13,860MW of power generation apportioned across the sites with similar shares to their current and recent coal-fired generation capacity. Of the 13,860MW capacity envisaged, current water availability appears to be insufficient for 6,930MW or 50% of the proposed new nuclear generation capacity. A further 5,500MW (39.7%) is in the orange zone, whereby water resources are likely to be constraining during extended hot/dry periods under the most likely climate change scenarios over the 80-year projected life of nuclear power stations. In these circumstances, international experience in other warm inland regions is that nuclear power generation needs to be curtailed when cooling water is limited by low river flows or warming waters. Just over 10% (1430MW) of the total 13,860MW of new generation proposed here is assessed as not being constrained by the availability of sufficient cooling water over the 80-year life of a facility. This is depicted in Figure 1 below.

Figure 1. Water constraints across 13,860MW of proposed nuclear power generation in Australia

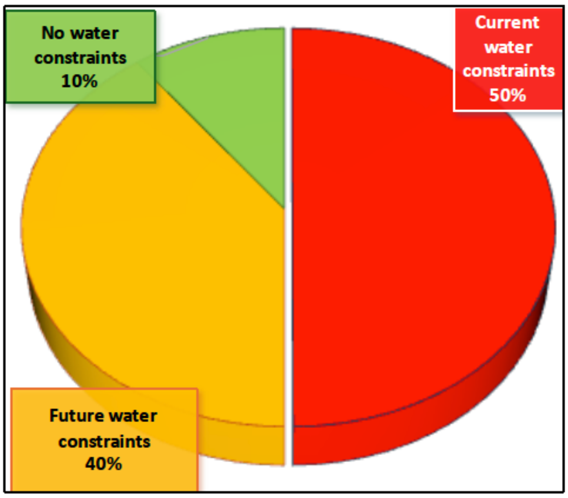


Table 1 below sets out the anticipated size of nuclear reactor required at each site to generate a total approximating the 'up to 14GW' proposed by the Coalition. It presents the estimated requirement for cooling water at each site and the likely source of that water.

Rows are shaded green for sites where water availability is not constraining; orange where it will likely be constraining in long hot/dry periods over an 80-year timeframe; and red where there are already obvious water constraints for new nuclear power stations of the type and capacity envisaged.

As summarised in Figure 1 and Table 1, across the seven sites proposed by the Coalition, five sites comprising 90% of the proposed nuclear generation are water-constrained, either now or over the projected 80-year life of a nuclear power station. At these sites, it is highly likely that nuclear generation would need to be curtailed during hot, dry conditions, and/or new cooling water sources would need to be found by diverting water from other uses – industrial, agricultural, residential and environmental – or by increased use of desalination plants and pipelines at great expense.

This paper analyses the available water resources at each of the seven proposed nuclear sites, and the anticipated water requirements of the planned nuclear reactors, to assess whether there is sufficient available water for cooling nuclear power stations over 80 years from the 2030s to the 2110s. It identified likely impacts on other water users if these nuclear reactors are built.

It concludes that:

- Only at **Port Augusta** in South Australia is there sufficient available water now and projected over coming decades to provide adequate cooling water for a proposed nuclear power station of the capacity suggested by the Coalition.
- At **Tarong** in Queensland, there is sufficient available water for cooling an 1100MW reactor, but not for 2200MW.
- At **Liddell** in NSW, the amount of water required for a new nuclear power station of the size and type proposed would be so significant (especially in dry seasons) as to have major impacts on other water users, including agriculture, industry, urban residents and the environment. Up to 39 gigalitres of water would need to be secured each year through buying back water from farmers and industrial users in the Hunter Valley. The risks of power output being curtailed during hot, dry periods are likely to rise with climate change over coming decades.
- At **Callide** in Queensland, the amount of water required for a new nuclear power station of the size and type proposed would be so significant (especially in dry seasons) as to have major impacts on other water users, including agriculture, industry, urban residents and the environment. An additional 5 gigalitres of high security water would need to be acquired every year through buying back water from farmers and industrial and urban users in the relatively small and variable Callide and Awoonga-Callide schemes.
- At **Loy Yang** in Victoria, **Mt Piper** in NSW and **Muja** in Western Australia, existing water availability is already so constrained that new nuclear power stations of the capacities proposed would lack sufficient cooling water to provide reliable power now, let alone for 80 years into the future, even if the majority of existing irrigation water entitlements were acquired.

Table 1. Summary of projected water use and constraints for proposed nuclear sites

Location	Reactor size & type	Current annual water use by coal-fired power production	Annual water use needed for nuclear power production	Additional water allocation required	Water allocation regime	Socio-economic implications	Environmental implications
Liddell	AP1000 x 4 4400 MW	61 GL/year (Liddell plus Bayswater)	Up to 100 GL/year	Up to 39 GL/year	Hunter Regulated River Water Sharing Plan	May require recovery of General Security water entitlements by irrigation buyback and/or closure of additional Hunter Valley coal mines	Potential increase in thermal pollution at Lake Liddell
Mt Piper	AP1000 x 1 1100 MW	14 GL/year	25 GL/year	Up to 25 GL/year	Dependent upon Springvale coal mine lifespan. May require reverting to Coxs River/Fish River supply.	If Springvale coal mine dewatering ceases, then 25 GL increase. Implications for higher Sydney desalination plant use to offset Coxs River supply, or Macquarie River irrigation water entitlement purchase	Reduced flow in upper Hawkesbury-Nepean and/or upper Macquarie, especially if mine dewatering ceases
Loy Yang	AP1000 x 5 5500 MW	Up to 102 GL/year (Loy Yang A & B; Yallourn W and Hazelwood)	Up to 125 GL/year	Up to 125 GL/year (Existing water allocations are committed to open cut pit remediation for 30 years)	Surface Water and Groundwater Bulk Entitlements and subsidiary water entitlements.	Up to 125 GL/year required during 30 year period of open cut pit lake filling. Most realistic option would be to acquire~50% of entitlements in the Latrobe and Macalister irrigation districts. Compulsory acquisition probably needed. Climate projections for reduced rainfall/runoff in the Latrobe, if correct, may require future closure of entire irrigation system to keep nuclear power station operating over 80-year lifespan	Increased utilisation of water entitlements in the Latrobe-Thomson reduces environmental flows to Gippsland Lakes Ramsar site. Increased difficulty in rehabilitating large open cut pits unless additional water entitlements are acquired.
Tarong	AP1000 x 1 1100 MW	30 GL/year	25 GL/year	Nil	Boyne River and Tarong Scheme, augmented by Western Corridor Recycled Water Scheme in drought conditions	No significant water-related issues provided nameplate capacity is reduced to 1100 MW	No significant additional environmental impacts provided nameplate capacity reduced to 1100 MW

Callide	AP1000 x 1 1100 MW	20 GL/year Awoonga-Callide Scheme plus Callide local water sources including groundwater (variable, max 5 GL/year estimated)	25 GL/year	5 GL/year from either Awoonga-Callide Scheme or Callide Scheme	Awoonga-Callide Scheme augmented by water recycling including groundwater seepage recovery from Callide Dam	Modest (15%) additional water demand – could be sourced from irrigation water recovery in local Callide Scheme or industrial water use savings in the Awoonga-Callide Scheme. Doable, but not trivial (see Callide discussion).	No significant water related environmental concerns
Port Augusta	AP300 x 1 330 MW		Seawater cooling, once-through	Nil	Not applicable	Nil freshwater-related	Renewed thermal pollution risks in upper Spencer Gulf, but lower than that caused by historical coal power generation
Muja	AP300 x 1 330 MW	10 GL/year (Muja and Collie A power stations, from mine dewatering)	7.5 GL/year	7.5 GL/year. Mine dewatering expected to cease as soon as coal fired power stations close.	Groundwater pumping most likely. Significant decline in rainfall has caused major declines in surface water runoff and groundwater recharge, reducing water security for all users.	Southwest WA is already experiencing major water shortages due to declining rainfall. Full retirement of coal-fired power station water demand by 2040 is not sufficient to reverse this situation. Continuous water supply for power station cooling (of any type) over 80 years is likely incompatible with other water demands (e.g. potable water supply) over that period.	Threats to groundwater-dependent ecosystems.
TOTAL	**13,860 MW**		**~307.5 GL/year**				

Assumptions

The numbers in Table 1 and throughout this report are based on assumptions that on the whole are generous for the nuclear energy proposition. It is assumed that:

1. "Off-the-shelf" technology is used as the Coalition has publicly stated: Westinghouse AP-1000 Pressurised Water Reactors. Water use is assumed to be 25GL/year at 90% capacity factor for each 1100 MW AP-1000 unit, based on the design brief for the newly-commissioned AP-1000 units at Vogtle on the Savannah River in Georgia USA, which has natural draft cooling towers.
2. Notwithstanding that they are not yet operational anywhere in the world, small modular reactors similar to the Westinghouse AP300 SMRs will exist and can be deployed from the 2030s, with water consumption pro-rata matching AP1000 x 0.3, or around 7 GL/year.
3. Deduced from the modelling conducted by Frontier Economics and from statements released by the Coalition, 13,860 MW of nuclear capacity (operating at 90%) would be constructed at the seven sites, replacing the existing 8,000 MW of coal-fired power production at these sites. Note that this breakdown assumes only 1100 MW of new nuclear at Tarong (lower than previous coal-fired outputs), because of water limitations. Were a bigger unit to be constructed at Tarong, it would be shaded red in Table 1 above on the basis of water constraints.
4. Recirculating wet-tower freshwater cooling systems would be used at all sites except for Port Augusta, which would use a once-through system drawing sea water from Spencer Gulf.
5. On-going water requirements for decommissioning and decommissioned coal mines associated with the coal-fired power stations are noted where reliable figures are available, but this has not been possible at all locations.
6. The water requirements for Emergency Core Cooling Systems (ECCS), an additional requirement for nuclear power stations in the event of meltdown or any major problems with primary cooling, are not explicitly quantified here.

Given these assumptions, the numbers in this table are at the lower end of the probable range of water requirements for nuclear power in Australia.

The impacts of water consumption for nuclear power on other water users need to be planned for, well ahead of any infrastructure investment. Water consumption for energy production should be more prominent in current debates.

In all proposed locations, there are generic risks associated with nuclear power (including cost over-runs, construction time blow-outs, regulatory complexity, workforce constraints, security and waste disposal) that also need to be considered, but are not analysed here.

2. Introduction

On 19 June 2024, the Federal Opposition Leader, the Hon Peter Dutton MP, in a joint statement with the Hon David Littleproud MP, Leader of the National Party, and the Hon Ted O'Brien MP, Shadow Energy Minister, announced *"that a future Federal Coalition Government will introduce zero-emissions nuclear energy in Australia…"* The statement[i] went on to outline sites for the proposed nuclear reactors:

"And today, we announce seven locations, located at a power station that has closed or is scheduled to close, where we propose to build zero-emissions nuclear power plants:

- *Liddell Power Station, New South Wales*
- *Mount Piper Power Station, New South Wales*
- *Loy Yang Power Stations, Victoria*
- *Tarong Power Station, Queensland*
- *Callide Power Station, Queensland*
- *Northern Power Station, South Australia (SMR only)*
- *Muja Power Station, Western Australia (SMR only)*

Each of these locations offer important technical attributes needed for a zero-emissions nuclear plant, including cooling water capacity and transmission infrastructure…"

This paper examines the water use of nuclear power stations and the assertion that there will be sufficient available water at the seven proposed sites for sustainable operation of nuclear power stations at high operating capacities for the 80 years proposed by the Coalition. It assesses catchment hydrology at each of the proposed sites, the current water allocation regime and applicable water markets, and the likely sources of water for nuclear power. Where there are apparent potential constraints to water availability over the next 80 years, it discusses the opportunity costs of allocating very high security water for nuclear power – i.e. potential impacts on other water users including irrigation industries, town water supplies and the environment.

The key focus of this analysis is the likely quantum of high security water required for the Commonwealth to operate nuclear power facilities at 90% capacity for 80 years, as proposed by the Coalition and modelled by Frontier Economics.

There is an obvious policy complication that is not explored here, which is that water allocation regimes under the Australian Constitution are the province of State Governments, not the Commonwealth. The powers to allocate (and reallocate) water are state-based legal powers. Any attempt to substantially change water allocations to secure the highest security water for nuclear power generation would require either some new Commonwealth-State agreement, or the Commonwealth attempting to take over state powers, which could result in constitutional challenges (and consequent delays).

3. Water, Energy, Food – converging insecurities

The author has been working at the interface of, writing[iv] and presenting about the 'converging insecurities' of water security, energy security, food security and environmental policy and management for many years. These all interact with and compound each other in multiple ways, and all are amplified by global heating and associated increasing frequency and intensity of extreme weather.

Yet in policy development, public administration and on-ground management, we still tend to deal with each of these issues in isolation, in different ministries with diverse delivery mechanisms. Rather than holistic thinking informing integrated approaches that minimise negative trade-offs and capture potential synergies, the integration ends up happening by default as each new development gets approved in isolation and squeezed into a region or catchment. Regional communities, industries and ecosystems end up paying the costs of competition between water, energy and food production, and missing out on potential benefits had synergies been identified in planning stages and captured in implementation.

Many of the interactions between water, energy, food production and the environment are obvious, but we still tend to deal with them separately.

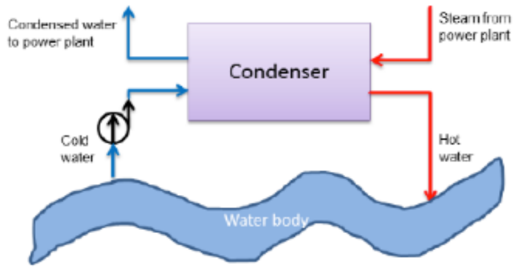
In Australia, food production is by far the biggest user of land and water, using around 70% of diverted freshwater. Declining per capita freshwater availability is a key driver of global food insecurity[v]. Each litre of water weighs one kilogram. A kilolitre weighs one tonne. A megalitre (ML) weighs one thousand tonnes. Unless you are using gravity, moving water around uses lots of energy. Pumping water, water treatment and provision of clean healthy water is one of the biggest users of energy in cities. Extraction and refining of coal, oil and gas uses large amounts of water, and unconventional (shale and coal seam) gas production also generates long-term risks for groundwater aquifers[vi]. First-generation biofuels, such as ethanol from corn production, use very large amounts of land and water per unit of energy produced, with obvious trade-offs for food production. Desalination to produce potable water is energy-intensive. Energy production, food production and food waste are all significant sources of greenhouse gas pollution, especially methane, which is much more potent than CO2 in trapping heat in the atmosphere over the timeframe within which most emissions reduction needs to occur.[vii]

This analysis is based on the premise that Australia needs to take an integrated, holistic approach across water, energy and food, with a full understanding of tensions, trade-offs and potential synergies between them, especially when considering multi-decadal infrastructure investments of hundreds of billions of dollars. As one component of such an analysis, the long-term hydrological implications of nuclear power generation are examined at each of the seven sites identified in the Coalition proposal.

4. Water use by nuclear power stations

Nuclear power plants use water for cooling in two ways: to convey heat from the reactor core to the steam turbines; and to remove and dump surplus heat from this steam circuit.[viii] Thermal power stations, whether coal-fired, gas-fired or nuclear, use three main types of cooling systems, depicted in Figures 2-4 below.

Figure 2. Direct or once-through wet cooling[ix]

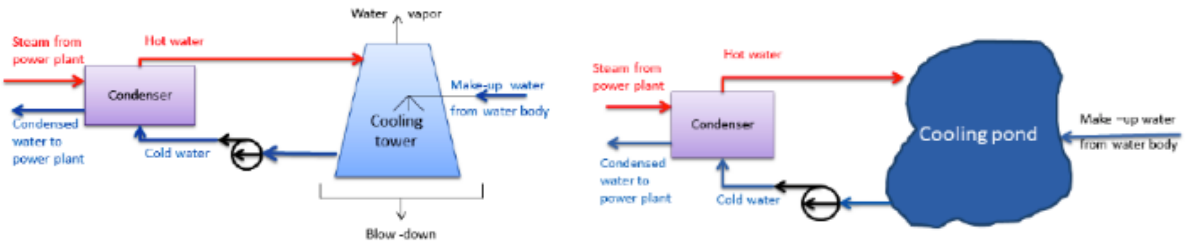


According to the World Nuclear Association[viii], the simplest method of cooling a thermal power station is to site it beside a large body of (preferably cold) water and run a large amount of water through the condensers in a single pass and return it to the sea, lake or river a few degrees warmer. While such plants require access to large volumes of water, the net amount consumed in the cooling process is less than for recirculating systems using cooling towers or cooling ponds as in Figure 3 below.

The efficiency of any thermal power plant is proportional to the temperature difference between the internal heat source and the external water source, which is why most thermal power plants, fossil and nuclear, have higher net outputs in winter than summer.

Water temperature is a crucial point in contemplating nuclear power for Australia, especially at inland sites. International experience in places like Southern France, Texas, Tennessee and Alabama, is that nuclear power generation sometimes needs to be curtailed or shut down during extended periods of very hot weather and/or low flows where rivers are the source of cooling water[viii]. If the intake water temperature is too high, river flows are too low, or the discharge water temperature is so high as to threaten aquatic life in receiving waters, then licence conditions can restrict the operation of nuclear power plants. Australia's larger rivers have a coefficient of variation of annual flows (CVR) almost four times the world average.[iii]

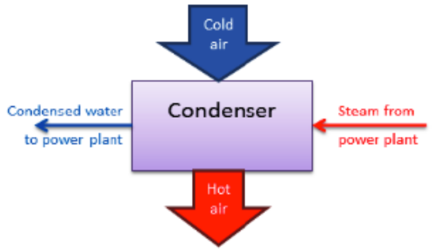
Figure 3. Recirculating or indirect wet cooling[ix]



Where power plants lack access to abundant water, recirculating cooling systems are used. These pass the steam through condensers and then use cooling towers, where passing air through water droplets cools the water. At some sites, a large on-site pond or canal may be sufficient for cooling the water. The cooling tower evaporates up to 5% of the flow, which must be replaced continually from the adjacent water source. The net water consumption of these systems is higher than for once-through systems.[viii]

According to the World Nuclear Association: *"Cooling towers with recirculating water reduce the overall efficiency of a power plant by 2-5% compared with once-through use of water from sea, lake or large stream, the amount depending on local conditions. A 2009 US DOE study says they are about 40% more expensive than a direct, once-through cooling system."*[viii]

Figure 4. Dry cooling[ix]



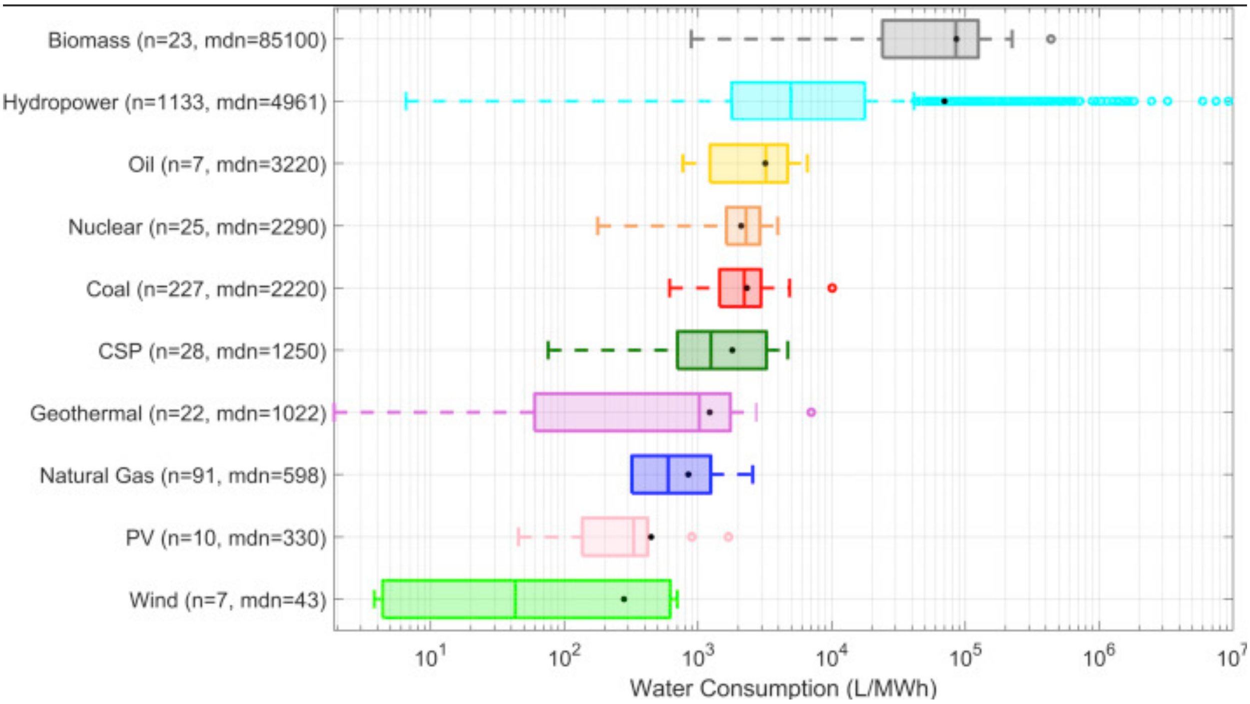
Relatively few power plants are cooled by air, using *"cooling towers with a closed circuit, or high forced draft air flow through a finned assembly like a car radiator"*[viii] According to the World Nuclear Association, such power plants use less than 10% of the water of a wet-cooled plant, with about 1-1.5% of the power generated required to run the large cooling fans. The only nuclear facility where it is in routine use is for the "*very small reactors at Bilibino in the Arctic permafrost region of Siberia*"[viii]

According to the World Nuclear Association: *"Hardly any US generating capacity uses dry cooling, and in the UK it has been ruled out as impractical and unreliable (in hot weather) for new nuclear plants. A 2009 US DOE study says they are three to four times more expensive than a recirculating wet cooling system. All US new plant licence applications have rejected dry cooling as infeasible for the site or unacceptable because of lost electrical generating efficiency and significantly higher capital and operating costs. For large units there are also safety implications relating to removal of decay heat after an emergency shutdown with loss of power."*[viii]

For this analysis, and noting the stated preference of the Coalition for 'off the shelf' proven technologies, it is assumed that dry cooling systems for nuclear power in Australia are not feasible. If the UK is seen as too hot for such systems, then use of such systems in Australia would be highly problematic. Given that there are water constraints for all six inland sites proposed by the Coalition, it is assumed that recirculating wet cooling systems using cooling towers would be the preferred technology. For Port Augusta, a once-through cooling system using sea water from the Spencer Gulf is assumed.

So how much water does a recirculating wet cooling system use? Figure 5 below summarises a global meta-analysis of water use across all power generation technologies. A key point from this analysis is that there is a considerable range of water consumption per unit of power output, within as well as between technologies.

Figure 5. Comparison of water use across all generation technologies[x]

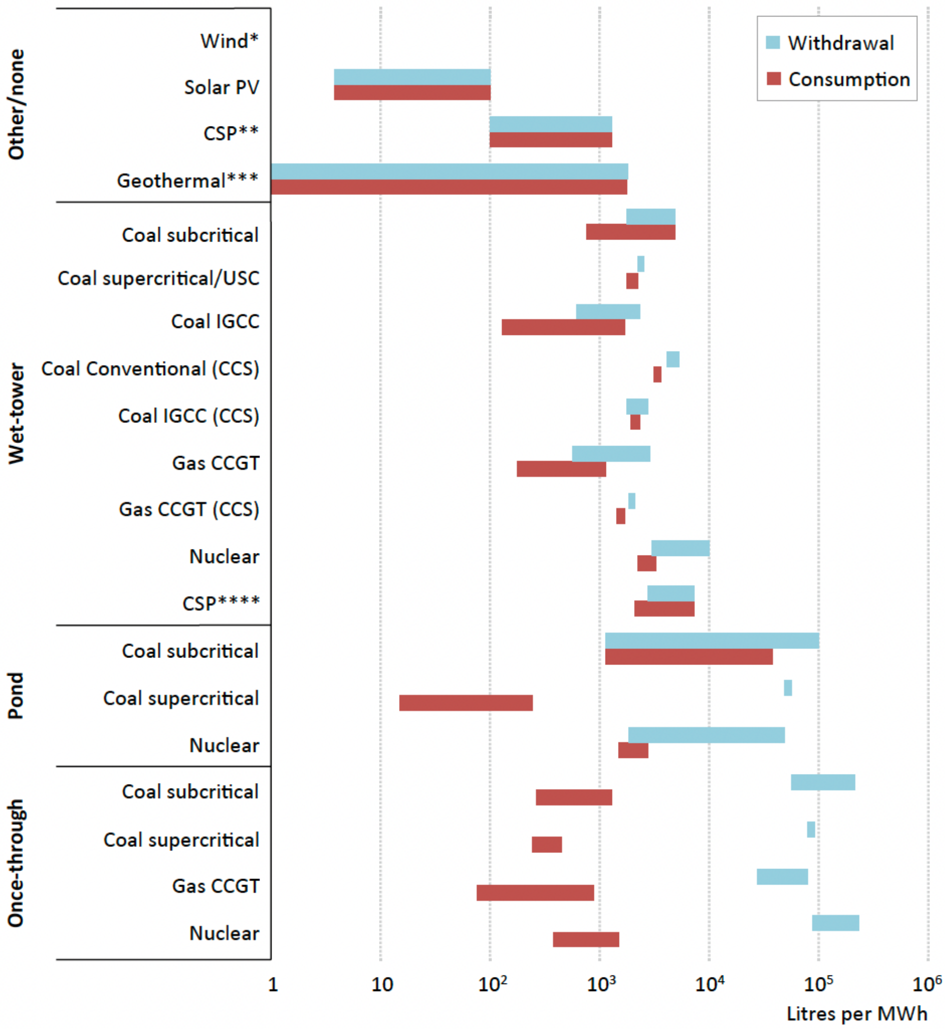


Note that the horizontal axis in this chart is a logarithmic scale, and that this represents a full life-cycle analysis of each technology, not just the operational water consumption. The sample sizes here for solar photo-voltaic (PV) and wind are small, and their operational water use is much less – generally considered to range from zero to negligible, as in the chart in Figure 6 below, from the International Energy Agency[xi].

Figure 6 makes the useful distinction between operational water withdrawals versus water consumed, for the different types of cooling systems. Again, the horizontal axis is a log scale of Litres per Megawatt hour. A key question for our purposes is the water use comparison between nuclear and coal, for both recirculating wet tower and once-through cooling systems. Figure 6 shows that for both wet-tower and once-through systems, the water consumption figures for coal and nuclear are comparable, per MWh of power produced – between 2,000 and 5,000 L/MWh for wet-tower systems and around 1,000 L/MWh for once-through systems – noting that the latter require access to and the ability to withdraw much larger volumes of water.

For this analysis, the reference case is the newly-commissioned units 3 and 4 at the Vogtle site on the Savannah River in Georgia, USA. The design brief for these Westinghouse AP-1000 units (one of the example technologies cited by the Coalition) estimates water consumption of 25.7 GL per year at 90% capacity factor. This equates to 2960L/MWh, within the range noted in Figure 6. The Savannah River gets as warm as 27 degrees C in summer, making it a useful comparator with Australian river systems.

Figure 6. Intensity of water use across the power sector[xi]



The intensity of water use varies widely across the power sector

* The amount of water used during operation is minimal and does not register on this chart. ** Includes trough and tower technologies using dry and hybrid cooling systems. *** Includes binary, flash and enhanced geothermal system technologies using tower, dry and hybrid cooling. **** Includes trough, tower and Fresnel technologies.

Notes: Solar PV= solar photovoltaics; CSP = concentrating solar power; USC = ultra-supercritical; IGCC = integrated gasification combined-cycle; CCGT = combined-cycle gas turbine; CCS = carbon capture and storage. Ranges shown are for the operational phase of electricity generation, which includes cleaning, cooling and other process related needs; water used for the production of input fuels is excluded. Ranges are based on estimates summarised from the sources below. Ranges for supercritical coal are also used for ultra-supercritical coal technologies. This chart is a representative sample of technologies; see *www.worldenergyoutlook.org/resources/water-energynexus/* for a more detailed list including the numerical averages of each technology.

Sources: Meldrum (2013); Macknick (2011); Sprang (2014); NETL (2011); US DOE (2006); IEA analysis.

5. Acquiring and securing water for seven nuclear power sites in Australia

This chapter explores the likely water requirements for nuclear power generation in more detail, at each of the seven sites proposed by the Coalition. To arrive at a likely size for the nuclear power station at each location, we have worked backwards from the total generation capacity of up to 14,000MWh announced by the Coalition, and their suggested capacity factor of 90%, apportioning the nuclear power roughly the same as the previous proportion of coal-fired power generated at each site.

There are inherent difficulties in estimating water supply availability over the 80 years from the mid-2030s to say 2115; the time period over which the Coalition proposes these power stations will operate.

In south-western Western Australia (site of the proposed Muja reactor), there has been a clear drying trend over the last 40 years, with declines in annual rainfall and even steeper declines in runoff, streamflow and groundwater recharge[xii]. The Indian Ocean Climate Initiative (a collaboration between CSIRO, the Bureau of Meteorology and the Government of Western Australia) concluded that *"even with the most optimistic greenhouse gas emission scenarios, SWWA is projected to be drier and warmer later this century with potentially much less water available for storage or for use by agriculture, ecosystems and industry."*[xii]

In south-eastern Australia (relevant to Liddell, Mt Piper and Loy Yang), the most authoritative analysis of likely future climatic conditions and the implications for rainfall, runoff and streamflow was undertaken by the South-East Australian Climate Initiative (SEACI), a collaboration between CSIRO, the Bureau of Meteorology, the Murray-Darling Basin Commission, the Victorian Department of Sustainability and Environment, and the Commonwealth Department of Climate Change and Energy Efficiency.[xiii] That research concluded that there have already been long-term reductions in cool season rainfall and streamflow, the traditional 'filling season' for water supply systems in southeastern Australia. While there remains a high degree of uncertainty about future rainfall and streamflow scenarios, the best estimates suggest that 1 degree C of global warming would see a 0 to 9% decline in annual rainfall (median 4%) and a 2 to 22% (median 12%) decline in runoff. Warming of 2 degrees would see an approximate doubling in impact.[xiii] Obviously, a long-term decline in runoff of 25% would have huge implications for water security for all users and the environment.

5.1. Liddell

Summary

Four AP1000 reactors operating at 90% capacity would require about 100GL of cooling water per year. This is an additional 39GL per year, but still just within the 106GL of entitlements. In future drought sequences there is a risk that additional water would need to be acquired, most likely from buybacks from the Hunter Valley irrigation system or Hunter Valley coal mines.

Background

Liddell Power Station (2000 MW, AGL Energy), shut down and decommissioned in 2023, is located near Muswellbrook in the Hunter Valley. It is located within 10 km of the AGL Energy Bayswater (2640 MW) coal-fired power station (currently scheduled to close between 2030-2033) and both power stations burn thermal coal from common mine sites.

Both Liddell and Bayswater power stations rely on Lake Liddell as a cooling water pond, with water supplied from the Hunter River system. In 2014, in assessing the acquisition of Macquarie Generation (the previous owner of both Liddell and Bayswater power stations) AGL due diligence[xiv] identified annual water consumption of 61 GL against 106 GL of water entitlements, with large "onsite" water storage volume (including Lake Liddell 148 GL and Plashett Reservoir 65 GL both owned by AGL Macquarie) equivalent to three years' worth of use, further buffering water supply risk. The study also noted that generation was unimpeded by water supply from 2000 to 2007 during the Millennium Drought.

In addition to water entitlements under the Water Sharing Plans for the Hunter Regulated River and Hunter Unregulated and Alluvial Water Sources, AGL Macquarie acquired the Barnard River Scheme, a system constructed during drought conditions in the mid-1980s to transfer up to 20 GL per annum of water from the Barnard River, a tributary of the Manning River, to the Oaky Creek, a tributary of the upper Hunter. This scheme was designed to boost water availability for Bayswater Power Station[xv] in drought conditions, and has been used only once since construction.

Water Availability for Future Nuclear Power Station Cooling

Given the relatively abundant water entitlements from the Hunter River system (regulated surface water supplies under the Hunter Regulated Water Sharing Plan allow a Long Term Average Annual Extraction Limit (LTAAEL) of 217 GL/annum), combined with relatively large balancing storages in Lake Liddell, Plashett Reservoir and for the catchment more broadly, and potential access to the Barnard Scheme, water supplies would appear to be less constraining at this site than for other sites identified.

However, there remains an issue with respect to the higher capacity factor for nuclear versus coal. The AGL (now AGL Macquarie) 2014 analysis did not explicitly consider increases in capacity factor (nuclear was not envisaged), and Liddell itself, as one of the oldest coal generators in the country, had a low capacity factor, associated with high outage rates.

Assuming a near matching total capacity (Liddell plus Bayswater 4640 MW Nameplate Capacity) for a new nuclear power station (the equivalent of 4 Westinghouse AP1000 units @ 1100 MW, 4400 MW total) and increasing capacity factor from 59% (CSIRO Gencost - a generous allowance for Liddell) to 90%, this would proportionately increase cooling water consumption by 64%, to up to 100 GL per annum. This significantly reduces the buffer available against the total water entitlement volume of 106 GL, which in dry conditions would require balancing storages to be relied upon more than previously, with increasing risk of generation curtailment in long drought sequences due to reduced water availability. If additional water entitlements were required to boost reliability of supply to a nuclear power station, the presence of a large irrigation sector in the Hunter Valley plus a significant share of General Security water entitlements held by numerous other coal mines provides opportunity for water entitlements to be recovered using either irrigation efficiency programs or water entitlement purchase (buyback) from either irrigators or coal mines.

Thermal pollution

Lake Liddell was closed permanently for public recreational use in 2016 following the discovery of the ‘brain eating’ amoeba *Naegleria fowleri* in the lake[xvi]. Usually fatal to those infected, this amoeba commonly occurs in warm water bodies. The closure of Liddell coal-fired power station in 2023, and the pending closure of Bayswater, are viewed as opportunities to reduce the risk of *N. fowleri* in Lake Liddell as these hot water discharges cease and the lake cools down to natural temperatures. However, it is likely that the replacement of Liddell and Bayswater generation with a nuclear facility of similar scale would be required to utilise Lake Liddell for cooling in a similar fashion, and hence the lake would need to remain permanently closed. In fact, should the increase in water use associated with increased power station capacity factor require greater reliance on Lake Liddell as a balancing storage in long droughts, the temperature can be expected to increase in Lake Liddell due to reduced volume in storage, with consequent risks to generation from reduced cooling efficiency, and likely on-going prevalence of *N. fowleri* in the lake.

5.2. Mt Piper

Summary

One AP1000 reactor operating at 90% capacity would require around 25 GL per year. Current water use is around 14 GL/year, which is mostly supplied by dewatering Springvale coal mine. Upon the scheduled closure of that mine, an additional 25 GL of water would need to be secured. Options include irrigation buybacks from the Macquarie system, or greater withdrawals from the Coxs River system, necessitating water conservation measures and/or greater reliance on desalination in the Sydney Basin.

Background

Mount Piper Power Station (1400 MW, EnergyAustralia) is located 25 km from Lithgow and about 160 km from Sydney, in the Central Tablelands of NSW. It is located about 7 km from the site of the Wallerawang Power Station (1000 MW, EnergyAustralia) that was decommissioned in 2014, and demolished in 2021. Coal supplied to both Mount Piper and Wallerawang power stations has been sourced from nearby coal mines including Centennial's Angus Place (underground - mothballed) and Springvale (underground) coal mines, and from Lidsdale Siding rail facility. Cooling water for Mount Piper is currently provided from Springvale mine dewatering operations, reducing previous dependence on water sources from the Coxs River (Lyell Dam and Thompsons Creek Dam), a tributary of the Hawkesbury-Nepean upstream of Warragamba Dam which supplies drinking water to Sydney. It also draws from the Fish River Water Supply Scheme as shown in Figure 7, which is located in the upper Macquarie River catchment, and is the only water supply scheme to transfer water east from the Murray-Darling Basin to the Sydney Basin.

A 2009 environmental assessment undertaken by Sinclair Knight Merz (SKM) for a proposed expansion of Mount Piper Power Station[xvii] (not implemented) quotes water usage for Mount Piper at 1.53 ML/GWh generated and for Wallerawang of 1.69 ML/GWh. From the same report, the water use for Mount Piper and Wallerawang were estimated at 14,150 ML and 8,750 ML respectively for the previous 5 years of generation (Wallerawang was still operating at the time) or a total of just under 23 GL per annum. This seems a reasonable estimate in comparison to the water entitlement volumes also described as Coxs River 23 GL; Fish River up to 8.184 GL (both subject to allocation availability); and "Mine Water" of up to 5.5 GL (prior to Springvale mine's dewatering recycling scheme upgrade), and given the smaller size and relatively low capacity factor achieved at Wallerawang (the older of the two sites). Reduced diversions since Wallerawang's closure over 10 years ago and since Mount Piper's change to use water sourced from Springvale coal mine dewatering have effectively helped to boost supply to Sydney and to other users reliant upon the Fish River scheme.

Coal Mine Closure Risks to Water Supplies

A potential consequence of closing Mount Piper Power Station is the potential closure of nearby coal mines, including Springvale. Coal supplies were trucked and supplied via conveyor belt short distances from Springvale and Angus Place collieries to both Wallerawang and Mount Piper power stations, and the Lidsdale Siding was used to dispatch coal for export, in addition to local use. In 2019, EnergyAustralia was required to operate Mount Piper Power Station in "Coal Conservation Mode" for several months owing to a lack of coal supply and quality concerns at Springvale mine[xviii]. Owing to security of coal supply and concerns about Springvale coal quality, Lidsdale Siding was modified by EnergyAustralia and Centennial to also receive coal from Centennial's other western NSW mine sites, to overcome the issue of temporary generation curtailment at the power station due to limited coal supply.

Given the expected lifespan of a nuclear power station of around 80 years, even with an earliest possible commissioning date of 2035, cooling water for a nuclear power station would need to be reliably provided until 2115. The lifespan of Springvale colliery becomes a key determinant for secure cooling water supply at this site, as does the future economics of continuing to export coal from Springvale. The reliability of cooling water for any Mount Piper Nuclear Power Station is thus dependent on continued export of thermal coal from Springvale to international markets.

The timing of future closure of Springvale is critical. Should Springvale close in conjunction with the closure of Mount Piper Power Station (currently scheduled for 2040) – then the cooling water needs of a replacement nuclear power plant would need to be supplied from other sources from the outset.

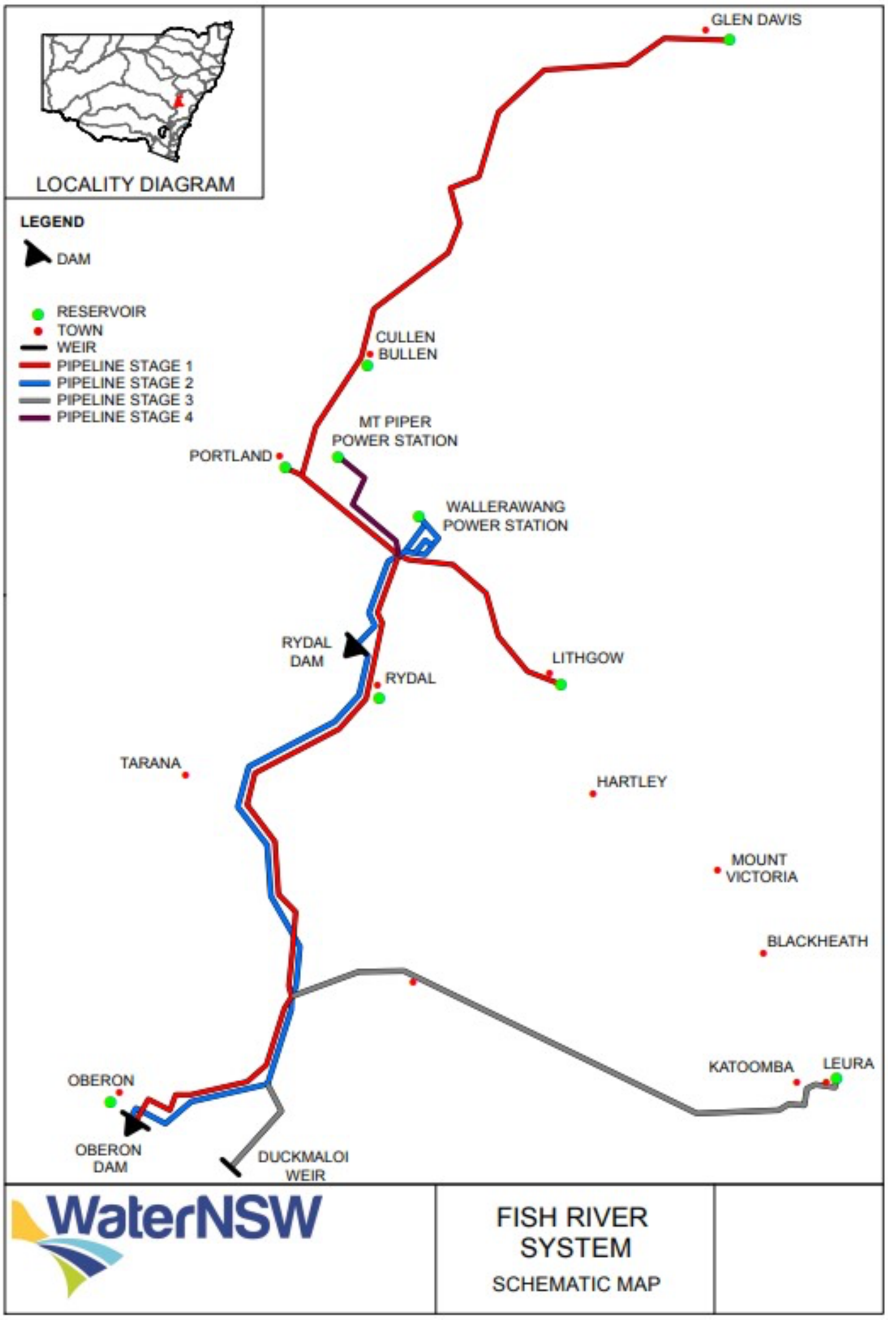
Regardless, should Springvale cease operating (and hence dewatering) at any time over the lifespan of the nuclear power station, alternative water supplies would need to be secured.

Reverting to Coxs River and/or Fish River supply

The Coxs River system, part of the Hawkesbury-Nepean, forms part of the water supply catchment for Sydney. According to the NSW Department of Planning and Environment Greater Sydney Water Strategy:

"Sydney's growing population and economy mean that, without action, we are almost certain to face a growing gap between our demand for drinking water and the available supply. Our forecast sustainable supply level is up to 540 gigalitres (GL) per year (a bit less than the volume of water in Sydney Harbour) and modelling suggests this may be about 40 to 70 GL/year less than we need under a moderate growth scenario…"[xix].

Figure 7 Fish River Water Supply Scheme Configuration



Sydney water supplies are fully developed. In the absence of other options, increased water take from the Sydney water catchment will increase the challenge in providing sufficient water to meet the needs of a population expected to grow from 4.7 million to 8 million by 2060[xx], increasing the need for water restrictions and/or desalination, in particular during drought periods.

Alternatively, cooling water could once again be sourced from the Fish River Water Supply Scheme (Fig 7), which was previously used to augment water supplies to Wallerawang and Mount Piper Power Stations. Reducing reliance on Fish River and Coxs River was a key driver for the Mount Piper Power Station to use recycled water from Springvale mine dewatering. In addition to local concerns for water supply security (including for the town of Oberon from Oberon Dam), increased take in the upper Macquarie catchment would need to comply with the

Sustainable Diversion Limit (SDL) under the Murray-Darling Basin Plan for the Macquarie River. This would potentially require a reduction in other water use in that system, such as for irrigation. It is difficult to see how water could be secured from the Macquarie system without using water buybacks to avoid breaching the SDL, given that irrigation efficiency programs have already been implemented in the Macquarie.

It may be feasible to continue using some groundwater supplies to assist in meeting cooling water needs for a proposed Mount Piper Nuclear Power Station. However, the high rate of extraction necessary to de-water an underground mine is unlikely to be sustainable long-term in the absence of concessions granted for mine dewatering compared to sustainable groundwater use, particularly given that there are existing concerns over the drying out of endangered upland peat swamps in the nearby Gardens of Stone State Conservation Area. In any case, groundwater supplies beyond those obtained from mine dewatering (longwall mining can increase permeability of disturbed sediments post mining) have previously been considered in environmental assessments undertaken for a proposed Mount Piper Power Station expansion, and were discounted as being of small yield[xxi].

Nuclear Power Plant Capacity

While Mount Piper and Wallerawang combined capacity of 2400 MW aligns closely to a two-unit AP1000 configuration (2200 MW nameplate capacity), this is not considered feasible given the local constraints on cooling water supply and uncertainty associated with the likely cessation of Springvale mine dewatering. It would be a challenge to source and sustain water supplies at this location for even a single AP1000 (1100 MW) nuclear power station. At 1100 MW with 90% capacity factor, compared to 1400 MW and 59% (Gencost), cooling water demand at Mount Piper (excluding Wallerawang) can be expected to increase by about 20%. The most likely options to secure this water would be buybacks from the Macquarie River irrigation system, and/or greater withdrawals from the Coxs River system, offset (expensively) by greater use of desalination for Sydney water supply.

5.3. Loy Yang

Summary

Five AP1000 reactors operating at 90% capacity would require around 125 GL per year. This is about double what the three coal-fired facilities are using now. Moreover, there are also very substantial on-going water requirements for minesite rehabilitation until at least 2065. Options to secure additional cooling water for nuclear power generation include purchasing water entitlements from the Macalister Irrigation District, increased groundwater extraction, reducing inter-basin transfers to Melbourne, or cutting environmental flows to Gippsland Lakes (breaching Australia's obligations under the RAMSAR Convention). Given recent and projected declines in streamflow in this region, even deploying these options could not guarantee adequate water supplies to operate a 5500 MW facility at 90% capacity for 80 years while remediating old coal sites.

Background

Victoria's Latrobe Valley has been a source of large-scale electricity generation using coal for over a century. In addition to the Loy Yang A (2210 MW, AGL Energy) and Loy Yang B (1070 MW, Alinta Energy) power stations, nearby facilities include the Yallourn W power station (1480 MW, Energy Australia, scheduled for closure in 2028) and the site of the previous Hazelwood power station (1600 MW), decommissioned in 2017.

Given the concentration of large power stations within close proximity, the Latrobe Valley's electricity transmission network has the capacity to support ongoing large-scale energy generation, and it is assumed that the largest nuclear facility of the seven proposed would be located at this site in order to approach the total generation target of 14,000 MW.

Latrobe Basin Water Supplies

The Yallourn Power Station and Loy Yang A and B power stations draw surface water from Yallourn Weir/Lake Narracan, supplemented with supplies from the 198 GL Blue Rock Dam as shown in Figure 8.

Figure 8. Latrobe River System

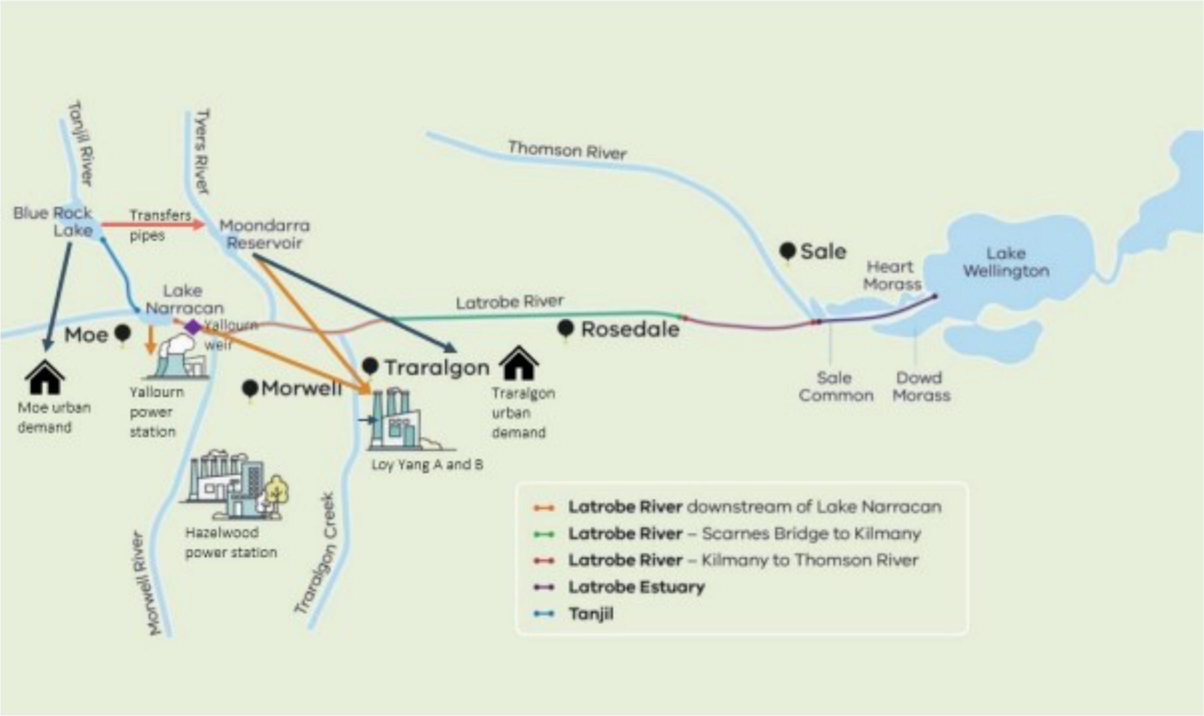
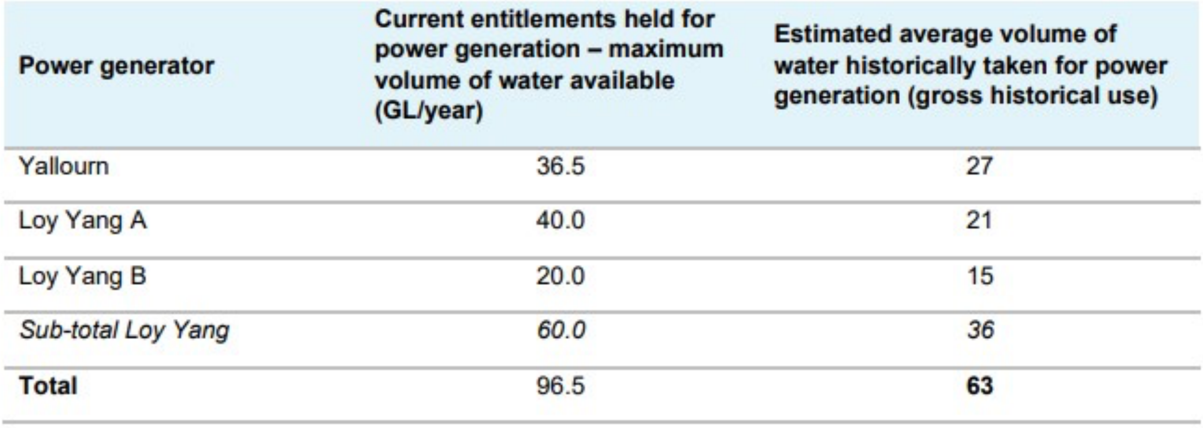


Table 2 below shows that the combined entitlement volume available for Yallourn and Loy Yang is 96.5 GL, of which an average of 63 GL has been used.

Table 2 – Annual diversion limit volumes and average historical use for power generation[xxii]



Power generator	**Current entitlements held for power generation – maximum volume of water available (GL/year)**	**Estimated average volume of water historically taken for power generation (gross historical use)**
Yallourn	36.5	27
Loy Yang A	40.0	21
Loy Yang B	20.0	15
Sub-total Loy Yang	*60.0*	*36*
Total	96.5	**63**

When in operation, Hazelwood Power Station was supplied with water under Gippsland Water's Bulk Entitlement from Moondarra Reservoir (62 GL/annum total averaged over 2 years for all users not just Hazelwood) and also supplemented with water from Blue Rock Reservoir under Gippsland Water's 20 GL maximum annual volume Bulk Entitlement (averaged over 3 years, and also for all users not just

Hazelwood). When operating, Hazelwood was estimated to use around 27 GL/annum, of which around 15 GL/annum was from surface water sources.

Surface water supplies in the Latrobe river system are considered to be fully allocated.[xxiii] Historically, power generation has been the largest water user in the Latrobe water supply system, and has consumed approximately 10% of inflows to the system. In addition to surface water, the Latrobe Valley Regional Groundwater and Land Level Monitoring Report for 2018-19 (GHD 2019)[xxiv] identified that of a licenced volume of ~45 GL/annum, around 24 GL/annum of groundwater was extracted for mine stabilisation across the three open cut pit sites. This water appears to have also been used to augment surface water sources for coal-fired power station cooling.[xxv] Summing across these water sources for the three sites, the total cooling water use (surface water plus groundwater) is estimated at around 102 GL/annum.

Nuclear Power Station Water Supply Risks

Given the history of large-scale coal-fired power generation in the area, surely there must be enough water for replacement nuclear power generation with comparable nameplate capacity?

There are three fundamental problems with this assumption.

Firstly, the expected increase in capacity factor from around 59% (CSIRO GenCost) to 90% for nuclear represents a significant proportional increase in cooling water demand. Table 2 shows that Loy Yang and Yallourn have used only 63 GL on average from a 96.5 GL Entitlement. Growing use to fully uptake the licensed volume would reduce reliable yield to the system as a whole, affecting other water users and the environment. For a previous water use of 102 GL/annum total for 6440 MW at 59% capacity factor, water use can be expected to increase proportionately to 125 GL/annum for a 5-unit AP1000 configuration nuclear power plant at 90% capacity. Such an increase would require full take-up of surface water licensed volumes previously under-utilised (33.5 GL) permissible under the Latrobe region water sharing arrangements.

At its core, water resource management in constrained Australian surface water hydrology involves trading off supply reliability against yield. A growth in use of this scale in a relatively small system would consequently reduce reliability of water allocations to all water users and the environment. To the extent that the reliability of water entitlements needed for nuclear power station cooling water supply would also be reduced, there would be a need to acquire additional water entitlements to compensate.

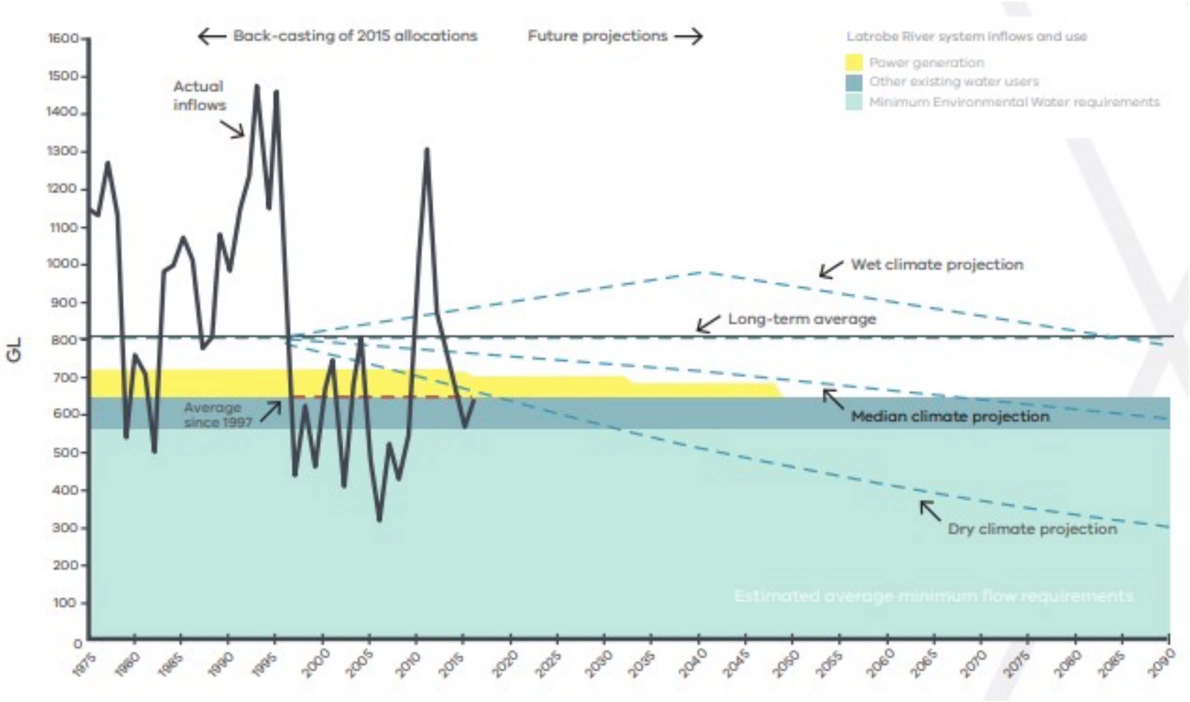
Secondly, recent and scheduled coal mine closures require mine site rehabilitation. Planning for this process has been underway for over a decade, and was updated in 2023 to reflect the announced earlier closure of the two remaining coal-fired power stations. While the final volume of water required to fill Yallourn and Loy Yang pits will be determined by the volume of coal mined at each site (that reduces with earlier closure date) the water supply requirements to support rehabilitation are enormous in any case. The Hazelwood pit alone (now closed) measures approximately 6 km long by 3.5 km wide, and up to 135 m deep. For the three major open cut pits associated with the three power stations (Loy Yang, Yallourn and Hazelwood) the rehabilitation proposed is largely based around filling each pit with fresh water to form three new large lakes with an indicative capacity of around 2,800 GL (over five times the volume of Sydney Harbour) to fill completely, and a minimum of 1,641 GL to fill sufficiently to achieve “weight balance” (to secure geological stability in the long term)[xxvi].

The 2020 Latrobe Valley Regional Rehabilitation Strategy found that these open cut pit lakes would take decades to fill, and that mine site rehabilitation should investigate alternative water supplies such as desalination and/or water recycling in lieu of Latrobe river system allocations to fill these enormous pits. The 2023 amendment proposes a 30-year timeframe to fill the open cut pit lakes, or no later than 2065, **using the existing water licences** with water taken predominately during periods of unregulated flow in wet years to minimise the impact on other water sectors. Once filled, the LVRRS estimated an ongoing 7-9 GL/annum water allocation would be required to counter evaporative losses from the lakes.

Finally, reductions in river flows over recent decades in the Latrobe river system compound the difficulty of maintaining current supplies to all users (and filling open-cut pit lakes), let alone seeking additional water allocations for additional cooling water demand. The Latrobe Valley Regional Water Study undertaken in 2017 found that *"surface water availability in the Latrobe River system has decreased significantly in the past 20 years, from a long term average of about 800 gigalitres a year to about 600 gigalitres a year since 1997".*

Figure 9, from the Latrobe Valley Regional Rehabilitation Strategy, shows historical inflows and future projections. Average inflows since 1997 align with future median climate projections in around 2070 – a real concern for water supplies in the region. The reduction in power generation water demand (yellow shading) does not include volumes required to fill pits for mine remediation – those volumes need to be added to the demands shown in this chart unless water is supplied from outside the Latrobe system. Under a potentially drier future climate scenario *"surface water availability could be less than needed to supply all environmental and consumptive demands and mine rehabilitation"*. This study was based on reduced water demands associated with the expected closure of the two remaining coal fired power stations (and a commensurate reduction in cooling water supply) and did not consider ongoing cooling water supply to a large nuclear power station.

Figure 9. Water Availability in the Latrobe River system: Latrobe River inflows compared with minimum environmental water requirements and consumptive uses, including power generation

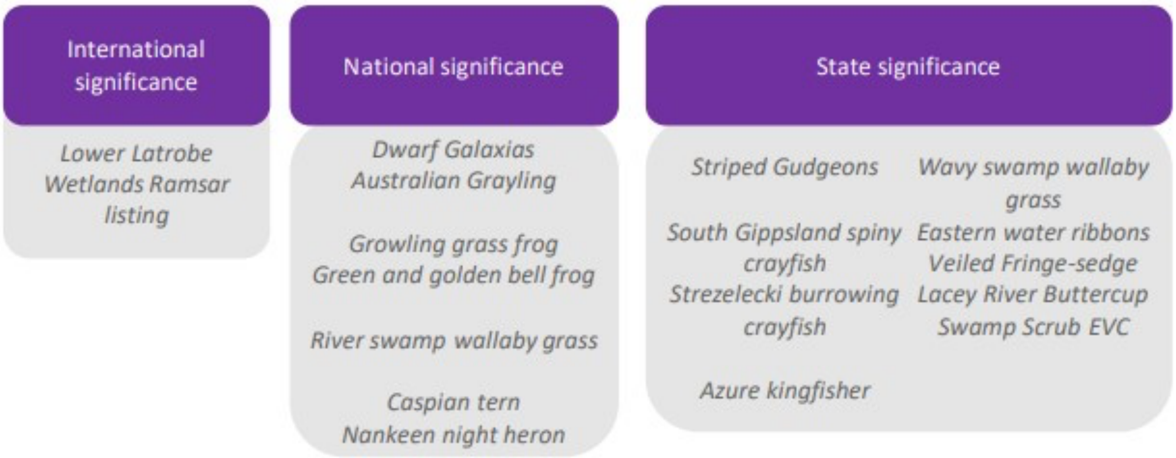


Environmental Flow Requirements

The minimum environmental flow requirements in the Latrobe river system are considerable. The West Gippsland CMA's *Latrobe environmental water requirements investigation*[xxvii] cites:

Figure 10. Water-dependent values of the Latrobe river system

The Latrobe system, comprising the Latrobe River, its tributaries and the Lower Latrobe Wetlands, supports plant and animal species of high conservation significance. The Latrobe River also provides an *essential source of freshwater to the Ramsar-listed Gippsland Lakes site, of which the Lower Latrobe Wetlands are an important component.*



International significance	National significance	State significance	
Lower Latrobe Wetlands Ramsar listing	*Dwarf Galaxias* *Australian Grayling*	*Striped Gudgeons*	*Wavy swamp wallaby grass*
	Growling grass frog *Green and golden bell frog*	*South Gippsland spiny crayfish* *Strezelecki burrowing crayfish*	*Eastern water ribbons* *Veiled Fringe-sedge* *Lacey River Buttercup* *Swamp Scrub EVC*
	River swamp wallaby grass	*Azure kingfisher*	
	Caspian tern *Nankeen night heron*		

Squeezing the environment's share of water even further to supply cooling water for a large nuclear power plant, in a catchment that has already experienced high water resource development impact on the environment, increases the likelihood of degrading the ecological character of the Gippsland Lakes Ramsar site. This would place the Australian Government in breach of its international obligations under the Ramsar Convention, as well as threatening a range of species of National and State significance.

Alternative Water Supply Options

Relatively large volumes of groundwater (around 24 GL/annum) have been extracted to dewater the three open cut mine sites in the recent past. To the extent that that volume is less than the maximum permitted groundwater licensed volume of 45 GL/annum, the cooling water demands of a large nuclear power station could utilise full uptake of groundwater licences – an increase of 21 GL per annum. However, this amount of groundwater extraction is untested and may not be sustainable in the short term, let alone over the 80-year lifespan of a nuclear facility. Regardless, this source is inadequate to meet the additional cooling water demand for a 5500MW nuclear facility. While the LVRRS found that groundwater extraction will need to continue until such time as the open cut pits are stabilised by filling with water sufficient to achieve weight balance, the rate of groundwater extraction needed to maintain stability can be expected to gradually decrease as water levels in the open-cut pit lakes rise. Hence groundwater sources are not expected to remain a sustainable source of cooling water for the life of a nuclear power station.

Other options to secure water supplies for the new (additional) water demand associated with a nuclear power station include water efficiency programs and water purchase. The irrigation sector has been the dominant source of such programs in Federal and State programs implemented in the Murray-Darling Basin to recover large quantities of water for the environment over the last 25 years.

Urban water supplies are typically less than 10% of total water consumption in the Murray Darling Basin (including large demands for Adelaide). Previous programs – including the Water Efficiency Labelling Scheme (WELS) at national scale, and programs such as Strengthening Basin Communities in the MDB have contributed relatively small volumes to water recovery in that system. While these programs have achieved excellent local benefits (including securing alternative sources of water for some regional towns), the volumes recovered are dwarfed by irrigation water efficiency programs and by outright water entitlement purchase (buyback).

Irrigation is the largest demand in the combined Latrobe-Thomson system (although power generation is the largest demand in the Latrobe River upstream of the Thomson). This includes the Macalister Irrigation District, located on the lower Thomson River and Macalister River (a tributary of the Thomson

River), near the town of Maffra. The Thomson itself is a major tributary that joins the Latrobe just upstream of Lake Wellington as shown in Figure 8. Importantly, the Thomson joins upstream of the largest wetland complexes, and additional water recovered from the Macalister Irrigation District could potentially be used to augment environmental water demands in the Sale Common, Heart Morass, Dowd Morass, and in Lake Wellington, hence offsetting additional water demands for nuclear power generation in the Latrobe system upstream.

Urban water supply transfers from Thomson Reservoir to the Upper Yarra River for Melbourne are also a large water demand in the Latrobe-Thomson River system. While there may be potential to reduce inter-basin transfers to Melbourne and use the Wonthaggi Desalination Plant to make up for a supply shortfall, this would entail much higher costs. Calls from the irrigation sector to increase utilisation of the Adelaide Desalination Plant to offset water recovery for the environment from irrigation in the Murray-Darling Basin have been dismissed in the past 10 to 15 years on economic grounds. In any case, increased desalinisation may be needed to augment Melbourne supply, should recent climatic trends observed in the Latrobe system continue, such that inflows to Thomson Dam are also reduced.

Based on the need to find additional large quantities of water for mine site remediation in the Latrobe Valley over the next 30-40 years, fully committed water allocations, and the recent reductions in water yield that are forecast to worsen under median (and especially under dry) climate change projections, the establishment of a large-scale nuclear reactor at Loy Yang contains an irreducible risk of frequent and significant generation curtailment, and/or significant reductions in water security for other users including towns, irrigation and the environment.

5.4. Tarong

Summary

One AP1000 reactor (1100MW) operating at 90% capacity would require around 25 GL per year. This is about the same as what the existing coal-fired facilities are using now, and for which there is sufficient available water now and into the future. Two units (2200MW) would be unsustainable given available water resources, even with buy-backs of most accessible irrigation water entitlements.

Background

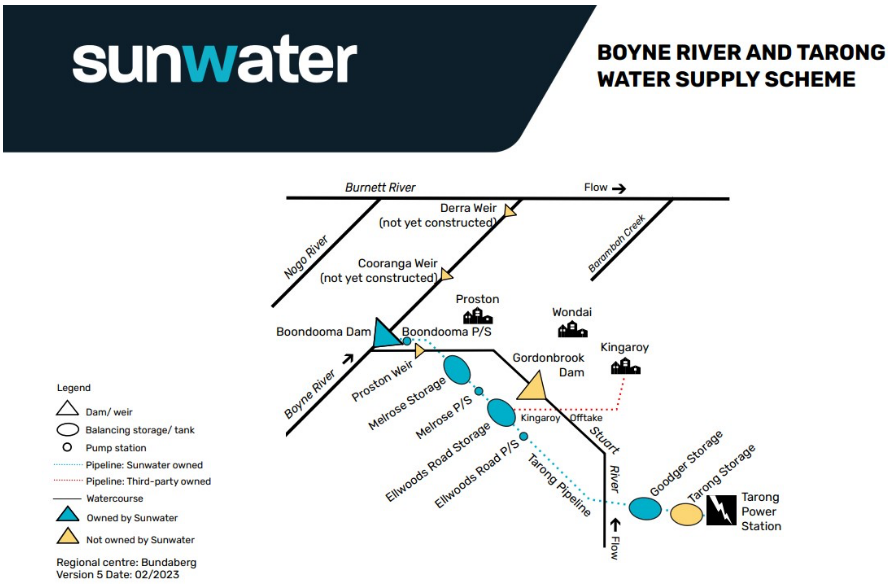
The Tarong and Tarong North coal-fired power stations, owned by Stanwell, are located about 27 km south of Kingaroy in Queensland. The two stations have a nameplate capacity combined of 1843 MW (1400 MW and 443 MW respectively[xxviii]), and are supplied with coal via the Meandu Coal Mine, located about 2 km from the power stations. Both stations are supplied with cooling water from the Boyne River and Tarong Scheme, managed by SunWater. Water is pumped from the 204 GL capacity Boondooma Dam, on the Boyne River just downstream of the Stuart River confluence, via a 95km pipeline to the two power stations[xxix]. Several small reservoirs located at the power station site are used as holding ponds and for cooling water recycling.

The Tarong power stations also have a link to water sourced from Wivenhoe, the main water storage used to supply potable water to Brisbane, when the Boyne River and Tarong Scheme supplies are inadequate. However, in preference to obtaining water from Wivenhoe – that can also experience low water levels at the same time – recycled water has been obtained from the Western Corridor Water Recycling Scheme (refer below). Obtaining water from Wivenhoe would compromise Brisbane water supply, requiring increased use of the Gold Coast water desalinisation plant, with implications for cost in addition to reliability of urban water supply. Hence Wivenhoe is not considered a realistic option to augment Tarong Power Station water needs.

Boyne River and Tarong Water Supply Scheme

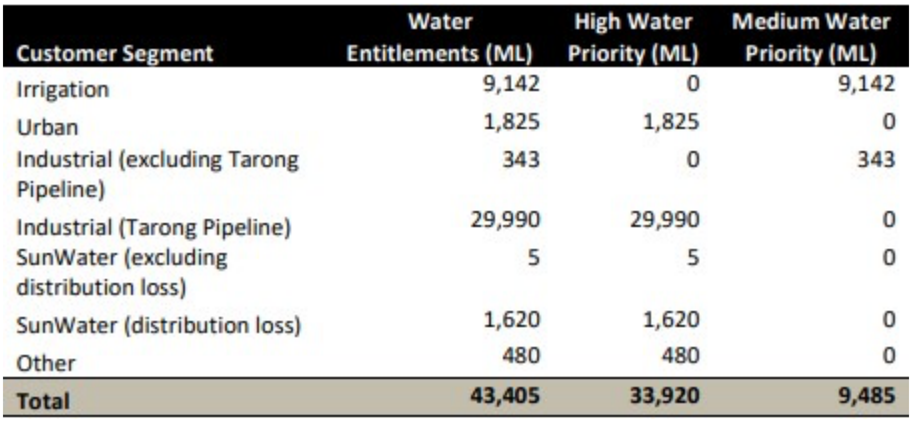
The Boyne River and Tarong scheme was constructed in the early 1980s to provide Tarong Power Station with cooling water. The scheme also provides town water supply to Kingaroy, population 10,545 (2021 census) and Wondai, population 1,975 and water to irrigators along the Boyne River that is used for a range of crops including mangoes, avocadoes, mandarins, grapes, pecans and blueberries.

Figure 11. Boyne River and Tarong Water Supply Scheme Configuration[xxx]



A breakdown of issued water entitlements is shown in Table 3 below. The existing High Priority water entitlements for Tarong and Tarong North power stations are listed as Industrial (Tarong Pipeline) and represent 69% of all issued entitlements by volume, and 88% of all High Water Priority entitlements. Medium Water Priority entitlements are considered very unreliable, with an average yield of 73% entitlement volume. This is already considered inadequate to satisfy irrigation demand[xxxi], let alone the cooling system for a nuclear plant operating at 90% capacity.

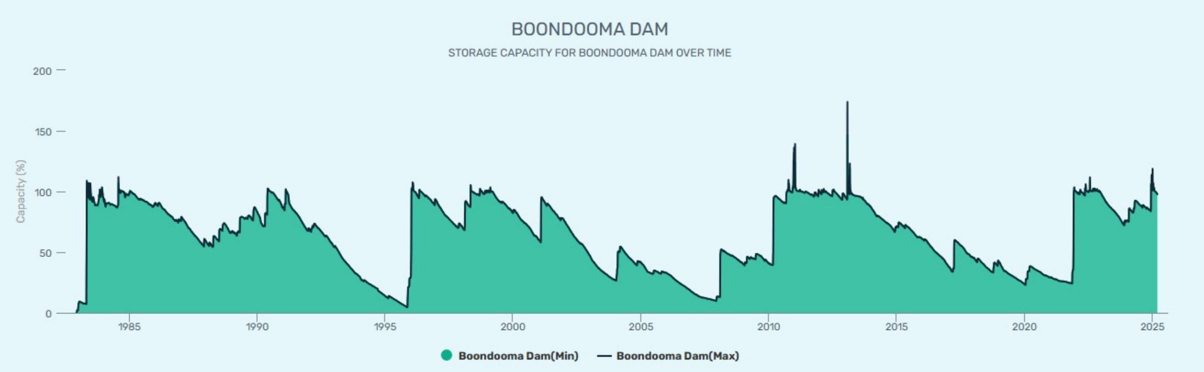
Table 3 - Boyne River and Tarong Water Entitlements[xxxii]



Customer Segment	Water Entitlements (ML)	High Water Priority (ML)	Medium Water Priority (ML)
Irrigation	9,142	0	9,142
Urban	1,825	1,825	0
Industrial (excluding Tarong Pipeline)	343	0	343
Industrial (Tarong Pipeline)	29,990	29,990	0
SunWater (excluding distribution loss)	5	5	0
SunWater (distribution loss)	1,620	1,620	0
Other	480	480	0
Total	**43,405**	**33,920**	**9,485**

Figure 12 below shows the historical water levels for Boondooma Dam since it was commissioned in the early 1980s. It illustrates several periods during which water storage has been very low. Low inflows to Boondooma Dam occurred over multiple years in the mid 1990s, in the mid-2000s corresponding to the worst years of the Millennium Drought, and again from 2014-2021. In response to concerns about power generation being potentially curtailed due to unreliable cooling water supply, recycled water has been used to augment cooling water supplies to both Tarong and Tarong North power Stations (and to the gas fired Swanbank Power Station) via the Western Corridor Recycled Water Scheme (WCRWS), operated by SEQWater. While the WCRWS was mothballed in response to wet conditions in 2013, the scheme was recommissioned from 2018-2020. In 2020/21, the WCRWS supplied 1,493ML to Tarong Power Station, at a peak supply rate of 30.3 ML/d[xxxiii]

Figure 12. Boondooma Dam Storage Level 1982-2025[xxxiv]



Nuclear Power Station Commentary

The combined capacity of Tarong and Tarong North power stations of 1843 MW is the largest coal-fired power generation facility in Queensland (although Gladstone power station and Callide power station both exceed Tarong when Tarong North is excluded). A single unit AP1000 at 1100 MW is considerably less than the current rated capacity and would not fully utilise available capacity in the high voltage transmission network at this site. Given that there are cooling water supply constraints at other sites, we have investigated the option to install two Westinghouse AP1000 sized reactors at Tarong, at 2200 MW nameplate capacity (1100 MW each unit).

A new 2-unit AP1000 nuclear power station would require water supply to be increased to around 50,000 ML/annum, an additional water demand of around 20,000 ML/annum.

Boyne River and Tarong Scheme Capacity to Supply

As shown in Table 3, a range of other water entitlements in the Boyne River and Tarong Scheme may be targeted for buy-backs to help secure the water requirements of a new 2200MW nuclear power station. High Water Priority entitlements used for urban supply to Kingaroy and Wondai are discounted. It is assumed that the 1,620 ML SunWater distribution losses associated with regulating river water flow to supply irrigation water to the Boyne River downstream of Boondooma Dam would also not be a feasible source. While these losses would not need to be incurred in theory (should all irrigation water be redirected to the nuclear power station via the pipeline system) the significant environmental impact does not seem warranted (or likely to be approved) for such a small volume.

Experience in the Murray-Darling Basin to secure Water for the Environment has shown that, in systems where water entitlements are already fully or over-allocated, there are two main mechanisms to source water to meet new large-scale demands: the dividends from infrastructure improvements that improve irrigation efficiency; and outright irrigation water entitlement purchase. However, with only 9,485 ML of Medium Water Priority entitlements (comprising all irrigation and other industrial water use) and assuming the quoted reliability factor of 73% applies, it would be necessary to purchase water rather than rely on increasing irrigation efficiency. Even if **all** of these entitlements were acquired, this would secure only 6,924 ML long-term average yield.

The water supply demand of a new nuclear power station, sized at 2200MW, clearly exceeds the supply capacity of the Boyne River and Tarong Water Supply Scheme.

If the Western Corridor Recycled Water Scheme was operated at its previous peak capacity of 30.3 ML/d continuously, an additional 11,060 ML/annum could be supplied, with the advantage that the infrastructure required already exists. However, this combined with all Medium Water Priority water allocations, would still fall short of required supply.

To meet the additional water demands associated with nuclear power generation at this scale, it would be necessary to divert water from other water supply systems. This could include increasing the WCRWS to include additional sources of recycled water, or sourcing water from elsewhere in the Burnett river system such as from the Barker-Barambah Scheme. However, given the small scale of existing water supply schemes in the region, it is likely that water would need to be sourced from multiple schemes in combination, with new pumps and pipelines required to get water to the Tarong site.

In the absence of practical and cost-effective solutions to the additional water demand at Tarong, water supply is the key limitation on the size of a future nuclear power plant at this site. A single 1100 MW unit (at 90% capacity factor) is the maximum size that the Tarong site can support, with similar cooling water consumption to that of the two existing coal fired plants (25,000 ML/year for a single 1100 MW unit compared with 29,990 ML/year volume available under the current High Water Priority licence). Tarong is shaded green in Table 1 assuming a single 1100MW unit. If two such units were constructed, it would be shaded red, indicating insufficient water for reliable generation of the specified output.

Other Considerations

Water needed to manage the rehabilitated Meandu coal mine adjacent to Tarong Power Station has not been estimated. The Meandu rehabilitation plan cites remediation options including partially refilling the open cut progressively with fly ash tailings and for a future water supply storage – it is possible that the cooling water reservoir capacity at the site could be augmented using the remaining cavity for this purpose. While the volume required to fill a new cooling reservoir is a once-off volume, the annual evaporation from a new reservoir would also contribute to ongoing water demand at the site.

5.5. Callide

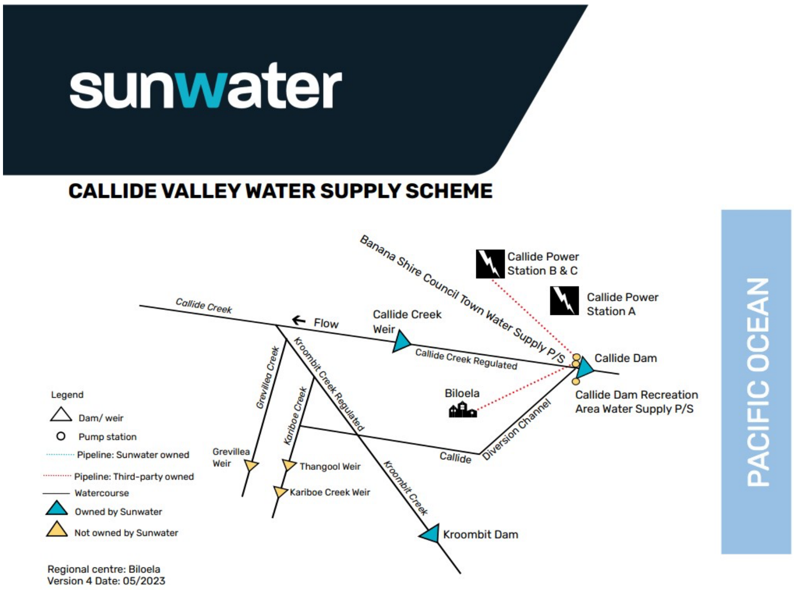
Summary

One AP1000 reactor operating at 90% capacity would require around 25 GL per year. This is about 15% more than the existing coal-fired facilities are using now. That additional water could be sourced from buybacks from irrigators in the Callide Scheme or (at greater cost) from industrial water users in the Awoonga-Callide Scheme. Any long-term reductions in streamflow would compromise the ability to operate at 90% capacity for 80 years, in the absence of securing new sources of cooling water.

Background

Callide Power Station (1544 MW, CS Energy) is located 84 km southwest of Gladstone near Biloela Queensland. Coal is supplied from the adjacent Callide Mine (Batchfire Resources). Cooling water is supplied to the power station from Lake Callide, formed by Callide Dam located about 3 km south of the power station, under the Callide Valley Water Supply Scheme managed by Sunwater, shown in Figure 13.

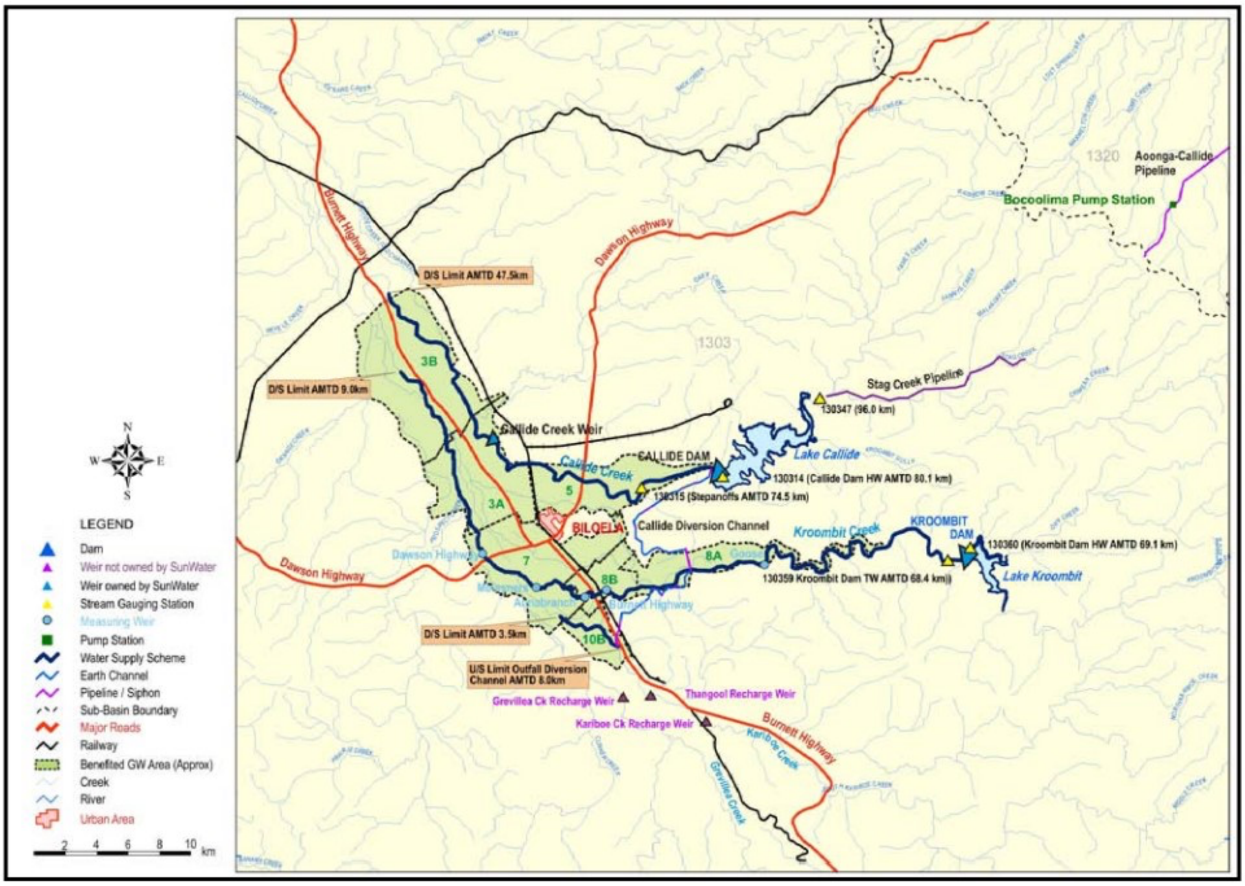
Figure 13. Callide Valley Water Supply Scheme



The Callide Valley scheme also supplies town water to Biloela and recharges groundwater aquifers used to supply irrigators along Callide Creek and Kroombit Creek, via the Callide Creek Weir and Kroombit Dam, shown in greater detail in Figure 14. Irrigation water is used for summer and winter cereals, cotton, lucerne, dairy and beef.

Also shown in Figure 14 is the last section of the Awoonga-Callide Pipeline, and the Stag Creek Pipeline. Water supplies to the Callide Power Station are augmented via transfers from the Awoonga Callide Water Scheme, which includes the 777 GL Awoonga Dam near Gladstone, owned by the Gladstone Area Water Board, and the Stag Creek and Awoonga-Callide Pipelines, owned and operated by Sunwater, featuring 3 pumping stations and 54 km of pipeline from Awoonga Dam to the top of the Great Dividing Range, and a further 15 km of gravity fed pipeline to Lake Callide. The Awoonga-Callide Scheme provides greater reliability of cooling water supply to the power station when supplies in the Callide system itself are low due to drought conditions.

Figure 14. Callide Valley WSS Locality Map[xxxv]



Nuclear Power Station Commentary

This investigation assumes that a single AP1000 (or equivalent) nuclear power station, at 1100 MW with 90% capacity factor (990 MW rated capacity), would replace Callide's 1544 MW current nameplate capacity. This comparison is favourable when considering that the CSIRO GenCost capacity factor for coal of 59% shows an estimated rated capacity of 911 MW for the coal-fired power station. The cooling water requirements for a single unit AP1000 represent a modest increase (15%) in cooling water demand at this site. The connection to the Awoonga-Callide Scheme offers additional security, and there are irrigation water entitlements that could be acquired within the Callide Scheme itself if required.

Nevertheless, Callide is shaded orange in Table 1, because the Callide scheme is a small system, and the additional water required represents over 10% of the scheme's long-term average yield. Because it has variable allocations, to get a reliable additional 5GL/year over 80 years would require considerably more entitlement volume. Awoonga-Callide has better reliability, but it has more urban and industrial users, so that water would be more expensive.

5.6. Port Augusta

Port Augusta, located on the coast at the northern tip of the Spencer Gulf, previously featured two coal fired power stations – the Northern Power Station (Alinta, 520 MW) retired in 2016, and Playford B (Alinta, 240 MW) mothballed in 2012 and decommissioned in 2016. Both of these power stations drew seawater for pass-through cooling, with the discharge water plume approximately 6-7 degrees warmer than the original ocean temperature.

Port Augusta has been identified as a candidate site for a Small Modular Reactor, which by definition would appear to be smaller than the previous total coal generation capacity (for comparison the Westinghouse AP300 SMR is one of the largest SMR design proposals, and is rated at 330 MW).

Port Augusta municipality receives fresh water from the River Murray via the 360 km Morgan-Whyalla Pipeline. It is unlikely that further supplies of fresh water could be supplied within the existing capacity of this pipeline. Hence, like the previous coal-fired power stations, a SMR can be expected to also draw cooling water from Spencer Gulf, avoiding any concerns for freshwater supplies at this location.

5.7. Muja

Muja Power Station (Synergy/WA Government) is one of several coal-fired power stations in southwest Western Australia that utilise coal mined from nearby Collie. Muja nameplate capacity peaked at over 1000 MW before the decommissioning of Stage A and B in 2017 and Stage C Unit 5 in 2022. The currently commissioned Muja nameplate capacity is 654 MW, with the closure of the 200 MW Stage C Unit 6 scheduled for 1 April 2025.

Other power stations utilising Collie coal include Bluewaters at 434 MW (Kansai Electric and Sumitomo Corporation) and Collie Power Station at 350 MW (Synergy/WA Government), and the Worsley Alumina Power Station (which has been progressively converted to gas-fired).

Muja and Collie power stations are scheduled for final closure by 2027 and 2029 respectively, with no confirmed closure date for Bluewaters Power Station.

Like Port Augusta, a Small Modular Reactor has been proposed for the Muja site. By definition, a SMR would have less capacity than the (currently commissioned) nameplate capacity for Muja, Collie and Bluewaters combined, and would have less capacity than the capacity foregone via closure of Muja and Collie by 2029. To generate similar amount of nuclear power at this site as the previous level of coal-fired generation would appear to require several SMRs or a more conventional large-scale nuclear power station.

Cooling Water Supplies

Current water sources used for cooling across the multiple coal-fired power stations located near Collie include surface water from Harris Dam, groundwater, and water obtained from dewatering coal mines.

Comparing to the case for Mount Piper described above, water obtained from coal mine dewatering for a nuclear power station at Muja with a design life of around 80 years is an even higher risk proposition, given that an overwhelming majority of coal extracted from the Collie coalfields has been used for power generation within Western Australia[xxxvi] and hence coal mining can be expected to cease before the commissioning of a nuclear power station at Muja. This places greater emphasis on surface water and groundwater sources for any future nuclear power station.

Climate Change and Water Resources in Southwest Western Australia

Over recent decades, southwest Western Australia has experienced a serious decline in rainfall, and hence runoff and groundwater recharge – even more dramatic than in the eastern states. Rainfall has declined by 20% since the 1970s, and as a result of drier soils, surface water runoff has declined by over 80%[xxxvii].

While the impending closure of coal-fired power stations represents a reduced demand for cooling water, the continued availability of cooling water supplies for even a small modular reactor needs careful planning in this region. While there has been no announcement of the capacity of the SMR planned for Muja, it is likely that a detailed investigation of long-term secure cooling water supply would show that cooling water availability could limit design capacity of such a SMR, or force regular curtailment of generation. The key question for the Muja Small Modular Reactor is: “how small is small?”. A Westinghouse AP300 (an example described by Coalition sources) is in the larger size range generally described as “Small” Modular Reactors. As there are no currently operating AP300 units from which to compare water use, this paper assumes a pro-rata amount compared to operating AP1000 units in the US; e.g. an approximate water demand for a single AP300 of 7.5 GL/annum (330/1100 MW x 25 GL/annum). It would be a formidable challenge to maintain sufficient cooling water supply over the 80-year design life of even a ‘small’ 330MW nuclear power station in inland Southwest WA, given the on-going trends in declining rainfall, runoff and groundwater recharge. Attempts to secure such water would inevitably be at the expense of the water security of other water users, including potable water supplies.

Summary

This chapter is summarised in Table 1 overleaf, which sets out for each site how much water would be required for nuclear power generation and how such water might be secured.

Table 1. Summary of projected water use and constraints for proposed nuclear sites

Location	Reactor size & type	Current annual water use by coal-fired power production	Annual water use needed for nuclear power production	Additional water allocation required	Water allocation regime	Socio-economic implications	Environmental implications
Liddell	AP1000 x 4 4400 MW	61 GL/year (Liddell plus Bayswater)	Up to 100 GL/year	Up to 39 GL/year	Hunter Regulated River Water Sharing Plan	May require recovery of General Security water entitlements by irrigation buyback and/or closure of additional Hunter Valley coal mines	Potential increase in thermal pollution at Lake Liddell
Mt Piper	AP1000 x 1 1100 MW	14 GL/year	25 GL/year	Up to 25 GL/year	Dependent upon Springvale coal mine lifespan. May require reverting to Coxs River/Fish River supply.	If Springvale coal mine dewatering ceases, then 25 GL increase. Implications for higher Sydney desalination plant use to offset Coxs River supply, or Macquarie River irrigation water entitlement purchase	Reduced flow in upper Hawkesbury-Nepean and/or upper Macquarie, especially if mine dewatering ceases
Loy Yang	AP1000 x 5 5500 MW	Up to 102 GL/year (Loy Yang A & B; Yallourn W and Hazelwood)	Up to 125 GL/year	Up to 125 GL/year (Existing water allocations are committed to open cut pit remediation for 30 years)	Surface Water and Groundwater Bulk Entitlements and subsidiary water entitlements.	Up to 125 GL/year required during 30 year period of open cut pit lake filling. Most realistic option would be to acquire~50% of entitlements in the Latrobe and Macalister irrigation districts. Compulsory acquisition probably needed. Climate projections for reduced rainfall/runoff in the Latrobe, if correct, may require future closure of entire irrigation system to keep nuclear power station operating over 80-year lifespan	Increased utilisation of water entitlements in the Latrobe-Thomson reduces environmental flows to Gippsland Lakes Ramsar site. Increased difficulty in rehabilitating large open cut pits unless additional water entitlements are acquired.
Tarong	AP1000 x 1 1100 MW	30 GL/year	25 GL/year	Nil	Boyne River and Tarong Scheme, augmented by Western Corridor Recycled Water Scheme in drought conditions	No significant water-related issues provided nameplate capacity is reduced to 1100 MW	No significant additional environmental impacts provided nameplate capacity reduced to 1100 MW

Callide	AP1000 x 1 1100 MW	20 GL/year Awoonga-Callide Scheme plus Callide local water sources including groundwater (variable, max 5 GL/year estimated)	25 GL/year	5 GL/year from either Awoonga-Callide Scheme or Callide Scheme	Awoonga-Callide Scheme augmented by water recycling including groundwater seepage recovery from Callide Dam	Modest (15%) additional water demand – could be sourced from irrigation water recovery in local Callide Scheme or industrial water use savings in the Awoonga-Callide Scheme. Doable, but not trivial (see Callide discussion).	No significant water related environmental concerns
Port Augusta	AP300 x 1 330 MW		Seawater cooling, once-through	NIl	Not applicable	Nil freshwater-related	Renewed thermal pollution risks in upper Spencer Gulf, but lower than that caused by historical coal power generation
Muja	AP300 x 1 330 MW	10 GL/year (Muja and Collie A power stations, from mine dewatering)	7.5 GL/year	7.5 GL/year. Mine dewatering expected to cease as soon as coal fired power stations close.	Groundwater pumping most likely. Significant decline in rainfall has caused major declines in surface water runoff and groundwater recharge, reducing water security for all users.	Southwest WA is already experiencing major water shortages due to declining rainfall. Full retirement of coal-fired power station water demand by 2040 is not sufficient to reverse this situation. Continuous water supply for power station cooling (of any type) over 80 years is likely incompatible with other water demands (e.g. potable water supply) over that period.	Threats to groundwater-dependent ecosystems.
TOTAL	**13,860 MW**		**~307.5 GL/year**				

Assumptions

The numbers in Table 1 and throughout this report are based on assumptions that on the whole are generous for the nuclear energy proposition. It is assumed that:

1. “Off-the-shelf” technology is used as the Coalition has publicly stated: Westinghouse AP-1000 Pressurised Water Reactors. Water use is assumed to be 25GL/year at 90% capacity factor for each 1100 MW AP-1000 unit, based on the design brief for the newly-commissioned AP-1000 units at Vogtle on the Savannah River in Georgia USA, which has natural draft cooling towers.
2. Notwithstanding that they are not yet operational anywhere in the world, small modular reactors similar to the Westinghouse AP300 SMRs will exist and can be deployed from the 2030s, with water consumption pro-rata matching AP1000 x 0.3, or around 7 GL/year.
3. Deduced from the modelling conducted by Frontier Economics and from statements released by the Coalition, 13,860 MW of nuclear capacity (operating at 90%) would be constructed at the seven sites, replacing the existing 8,000 MW of coal-fired power production at these sites. Note that this breakdown assumes only 1100 MW of new nuclear at Tarong (lower than previous coal-fired outputs), because of water limitations. Were a bigger unit to be constructed at Tarong, it would be shaded red in Table 1 above on the basis of water constraints.
4. Recirculating wet-tower freshwater cooling systems would be used at all sites except for Port Augusta, which would use a once-through system drawing sea water from Spencer Gulf.
5. On-going water requirements for decommissioning and decommissioned coal mines associated with the coal-fired power stations are noted where reliable figures are available, but this has not been possible at all locations.
6. The water requirements for Emergency Core Cooling Systems (ECCS), an additional requirement for nuclear power stations in the event of meltdown or any major problems with primary cooling, are not explicitly quantified here.

Given these assumptions, the numbers in this table are at the lower end of the probable range of water requirements for nuclear power in Australia.

6. Conclusion

In a dry and warming continent, the water footprint of any major new industry is a vital consideration.

Around the world, most operating nuclear power stations are sited on the coast, on large lakes or river systems, and/or in cold wet regions. In such places, the quantum of available water for cooling is not a constraint. Very few nuclear power stations are located inland in hot, dry regions, or on small rivers with occasional low flows. Australian rivers are known for being small and sluggish by world standards, but especially for having extreme variability in annual streamflow[iii].

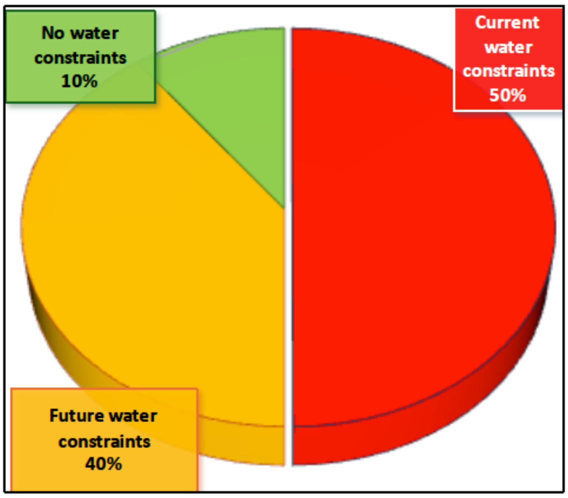
The Federal Coalition proposed in 2024 that up to 14,000MW of electricity generation could be supplied by seven new nuclear power plants. This study examined the water availability at each of those seven sites, assuming a total of 13,860MW of power generation apportioned across the sites with similar shares to their current and recent coal-fired generation capacity.

Of the 13,860MW capacity envisaged, current water availability appears to be already insufficient for 6,930MW or 50% of the proposed new nuclear generation capacity, as depicted in Figure 15 below.

A further 5,500MW (39.7%) is in the orange zone, whereby water resources are likely to be constraining during extended hot/dry periods under the most likely climate change scenarios over the 80-year projected life of nuclear power stations. In these circumstances, international experience in other warm inland regions is that nuclear power generation needs to be curtailed when cooling water is limited by low river flows or warming waters.

Assuming that Tarong would be limited to just 1100MW of nuclear power, just over 10% (1430MW) of the total 13,860MW of new generation proposed here is in the green zone, assessed as not being constrained by the availability of sufficient cooling water over the 80-year life of a facility.

Figure 15. Water constraints across 13,860MW of proposed nuclear power generation in Australia



This study analysed the available water resources at each of the seven nuclear sites, and the anticipated water requirements of the planned nuclear reactors, to assess whether there is sufficient available water for cooling nuclear power stations over 80 years from the 2030s to the 2110s. It identified likely impacts on other water users if these nuclear reactors are built.

It concluded that:

- Only at **Port Augusta** in South Australia is there sufficient available water now and projected over coming decades to provide adequate cooling water for a proposed nuclear power station of the capacity suggested by the Coalition.
- At **Tarong** in Queensland, there is sufficient available water for cooling an 1100MW reactor, but not for 2200MW.
- At **Liddell** in NSW, the amount of water required for a new nuclear power station of the size and type proposed would be so significant (especially in dry seasons) as to have major impacts on other water users, including agriculture, industry, urban residents and the environment. Up to 39 gigalitres of water would need to be secured each year through buying back water from farmers and industrial users in the Hunter Valley. The risks of power output being curtailed during hot, dry periods are likely to become progressively higher with climate change over coming decades.
- At **Callide** in Queensland, the amount of water required for a new nuclear power station of the size and type proposed would be so significant (especially in dry seasons) as to have major impacts on other water users, including agriculture, industry, urban residents and the environment. An additional 5 gigalitres/year of high security water would need to be acquired through buying back water from farmers and industrial users in the relatively small and variable Callide and Awoonga Callide schemes.
- At **Loy Yang** in Victoria, **Mt Piper** in NSW and **Muja** in Western Australia, existing water availability is already so constrained that new nuclear power stations of the capacities proposed would lack sufficient cooling water to provide reliable power now, let alone for 80 years into the future, even if the majority of existing irrigation water entitlements were acquired.

The water footprint of proposed inland nuclear power needs to be much more prominent in current debates.

In all proposed locations, there are generic risks associated with nuclear power (including cost over-runs, construction time blow-outs, regulatory complexity, workforce constraints, security and waste disposal) that also need to be considered, but are not analysed here.

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