WORLD NUCLEAR ASSOCIATION

WNA submission to “the inquiry into the prerequisites for nuclear energy in Australia”

This WNA submission reflects the views of industry experts but does not necessarily represent the views of any of the WNA’s individual member organisations.

To The Standing Committee on Environment and Energy

The World Nuclear Association is grateful for the opportunity to make a submission to this inquiry into what it would take to make nuclear energy a viable option for Australia.

We believe it is only natural that a technologically sophisticated country like Australia should seek to make use of nuclear energy as it attempts to address its energy, environmental and economic challenges. While it may seem like a big step, in fact Australia is already a nuclear nation in many ways. It is home to one of the most advanced nuclear research and medical facilities in the world at Lucas Heights and is also one of the world's largest suppliers of uranium. Several new nuclear technologies have also been developed with the assistance of Australian scientists. The country has a long and proud nuclear history and is well placed from a technical, regulatory and social standpoint to start a nuclear power program.

We are pleased to see that the Committee will take note of the important work carried out by the 2016 South Australian Nuclear Fuel Cycle Royal Commission and the 2006 Switkowski nuclear energy review. However, the international climate and energy dialogue has evolved significantly in the intervening years. There have been several recent authoritative intergovernmental reports published which we would like to bring to the Committee's attention.

Firstly, the IPCC *Global Warming of 1.5 °C* report, published late in 2018, considered the impacts of global warming of 1.5 degrees above pre-industrial levels and presented pathways by which greenhouse gas emissions could be reduced to keep warming below that threshold[1]. While there are substantial differences between models and across the IPCC pathways, on average nuclear generation increases by around 2.5 times by 2050 from today's level in the 89 mitigation scenarios considered, and by 5 times in the scenarios with increased electricity consumption.

Next, the IEA's recently-published report *Nuclear Power in a Clean Energy System*, clearly articulates the current, and growing, importance of nuclear energy for meeting climate goals. The report states that "*nuclear power today makes a significant contribution to electricity generation, providing 10% of global electricity supply in 2018. In advanced economies, nuclear power accounts for 18% of generation and is the largest low-carbon source of electricity*[2]." It further mentions that "*A range of technologies, including nuclear power, will be needed for clean energy transitions around the world*". While achieving a clean energy transition without nuclear is conceivable it would require an extraordinary – and essentially impractical – effort. By contrast, adding nuclear power "*can contribute to easing the technical difficulties of integrating renewables and lowering the cost of transforming the electricity system.*"

Detailed energy modelling conducted by the OECD NEA led it to similar conclusions[3]. The agency found that while a diverse range of low carbon technologies is needed for a generalised country to achieve decarbonisation of the electricity system, a mix relying primarily on nuclear energy is most cost effective. "*Based on the cost assumptions used in the main scenarios, this study shows that a mix relying primarily on nuclear energy is the most cost-effective option to achieve the decarbonisation target of 50 gCO2 per kWh.*" In fact, even it is assumed that variable renewable technologies become much cheaper than today, 40 – 60% of electricity would still be supplied by dispatchable low carbon technologies – like nuclear and fossil fuels with carbon capture and storage – in the cost-optimised case.

From the above it is clear that any advanced economy which is serious about addressing climate change should be developing nuclear energy if it wishes to increase the speed – and reduce the costs – of deep

[1] IPCC, 2018, *Special Report Global Warming of 1.5C*
[2] IEA, 2019, *Nuclear Power in a Clean Energy System*
[3] OECD NEA, 2019, *The Costs of Decarbonisation: System Costs with High Shares of Nuclear and Renewables*

decarbonisation. Nuclear energy is a complementary partner to renewables and helps to ensure a reliable and resilient electricity supply, which is the backbone of any modern society.

In an Australian context, the near-term retirement of a significant portion of the country's baseload coal generators poses serious challenges[4]. Australia has in the past enjoyed some of the lowest electricity costs in the developed world, but the sudden spike in wholesale electricity prices which accompanied the close of Hazelwood power station in 2017 is an event likely to be repeated as other large baseload stations close. To address this, Australian policy makers should be able to consider all low emission and affordable power sources, including nuclear energy.

Low-carbon energy technologies have also evolved in the last few years. While much is made of the rapid price declines in wind and solar, nuclear technology has also progressed considerably. The IAEA notes that currently there are more than 50 small modular reactor (SMR) designs under development for different applications, and that three demonstration projects are in advanced stages of construction and expected to be operational within a few years[5]. *"SMRs show the promise of significant cost reduction through modularization and factory construction which should further improve the construction schedule and reduce costs. In the area of wider applicability SMR designs and sizes are better suited for partial or dedicated use in non-electrical applications such as providing heat for industrial processes, hydrogen production or sea-water desalination."* Some SMR designs will be available in the 2020s while a wide range of designs will become commercially available during the 2030s.

Innovation is also improving currently available gigawatt-scale nuclear reactors, making them cheaper and easier to construct (for example through using advanced concrete solutions, additive manufacturing technologies, better project management and contract structuring) as well as improving operational performance (examples including accident tolerant fuels and robotics). We would encourage Australia to keep an open mind with respect to nuclear technology selection at this stage. Gigawatt-scale nuclear reactors should not be ruled out in any comprehensive plan.

More and more countries are embarking on nuclear energy programmes based on gigawatt-scale nuclear reactors. The list includes Bangladesh[6], Belarus[7], Egypt[8], Turkey[9], UAE[10], and Uzbekistan[11]. It is striking that with the exception of UAE, these are all countries with lower GDP per capita than Australia, and all score lower on the human development index. Introducing nuclear energy into Australia would create important development opportunities, boosting regional economic growth and supporting science, engineering and key trades. Today, about two-thirds of the world's population lives in countries which benefit from the reliable, affordable and clean electricity that is generated from nuclear energy.

Whether or not Australia decides to join the list of embarking nuclear newcomer countries as a result of the several inquiries now taking place, we hope to see the Committee recommend the revision of the federal Environment Protection and Biodiversity Conservation Act of 1999 and Australian Radiation Protection and Nuclear Safety Act of 1998, both of which currently prohibit nuclear power plants and certain other nuclear fuel cycle facilities from being constructed in Australia. The prohibitions are outdated and simply have no place in a modern, data-driven society striving for a sustainable future.

[4] Minerals Council of Australia, November 2018, *Submission to the Department of Environment and Energy's Underwriting New Generation Investments consultation paper*, p. 3
[5] IAEA 2018, *Advanced in Small Modular Reactor Technology Developments*
[6] World Nuclear News, 1 Feb 2019, *Construction progress at Bangladesh plant*
[7] World Nuclear News, 8 April 2019, *Commissioning starts at first Belarus unit*
[8] World Nuclear News, 10 April 2019, *Site approval for Egyptian nuclear power plant*
[9] World Nuclear News, 14 March 2019, *Basemat of Turkey's Akkuyu 1 completed*
[10] World Nuclear News, 8 July 2019 *First Barakah operators receive regulatory certification*
[11] World Nuclear News, 12 July 2019 Uzbekistan adds second plant to nuclear power goal

In the submission below we broadly address the Committee's terms of reference, drawing upon international experience. We are happy to help address more specific questions as the inquiry progresses and/or to put the Committee in touch with relevant industry experts.

London, 13 September 2019

[redacted]

Agneta Rising, Director General World Nuclear Association.

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A. Waste management, transport and storage

Civil nuclear wastes of all kinds have been managed and transported safely for more than five decades.

Final disposal facilities are already in operation for low- and intermediate-level wastes while the international consensus is for high-level waste (HLW) to be disposed of in deep geological repositories. Finland is expected to start operating the world's first geological disposal facility for civil HLW in 2023[i].

Most HLW is used reactor fuel which can be recycled (reprocessed), increasing fuel resources and reducing the amount of waste for disposal. Nuclear fuel is energy dense – approximately a million times more so than coal. Consequently, the amount of fuel required – and thus the amount of used fuel created – is relatively small. About 367,600 tonnes of used nuclear fuel has been produced from over 50 years of reactor operation[ii]. By contrast about 40 million tonnes of electronic waste is produced worldwide annually[iii]. Unlike some other toxic wastes, such as heavy metals, the principal hazard associated with nuclear waste – radioactivity – diminishes with time. After 40 years, the radioactivity of used fuel has fallen to one-thousandth of its initial level[iv].

Transport of nuclear goods takes place routinely. Around 20 million shipments of radioactive material – the most part for medical purposes – take place every year[v]. There has never been an instance of radioactive release causing harm to people, property or the environment during a shipment of nuclear materials. Packages carrying highly radioactive material are designed to withstand severe accident conditions. They must withstand high force impacts while maintaining containment, shielding and fire resistance[vi].

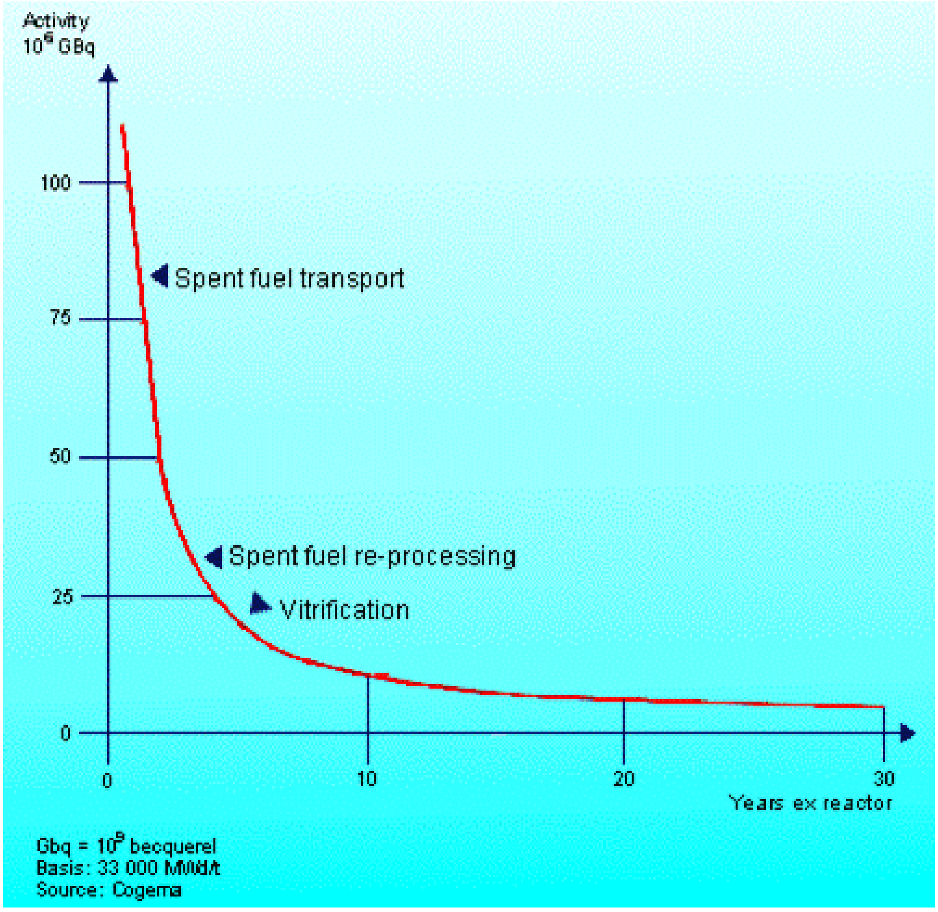

Figure 1 Illustrative decay in radioactivity of fission products – one tonne of spent PWR fuel.

B. Health and safety

Nuclear energy is objectively very safe. Nuclear energy has caused the least number of direct fatalities per unit of production of all the energy sources indicated in Figure 2. Nuclear plants do not emit harmful substances during normal operation and help keep the air clean and protect public health. By preventing air pollution from other energy sources (fossil fuels and biofuels) nuclear energy has averted about 2 million pollution-related deaths and, by 2050, may have prevented a further 7 million[vii].

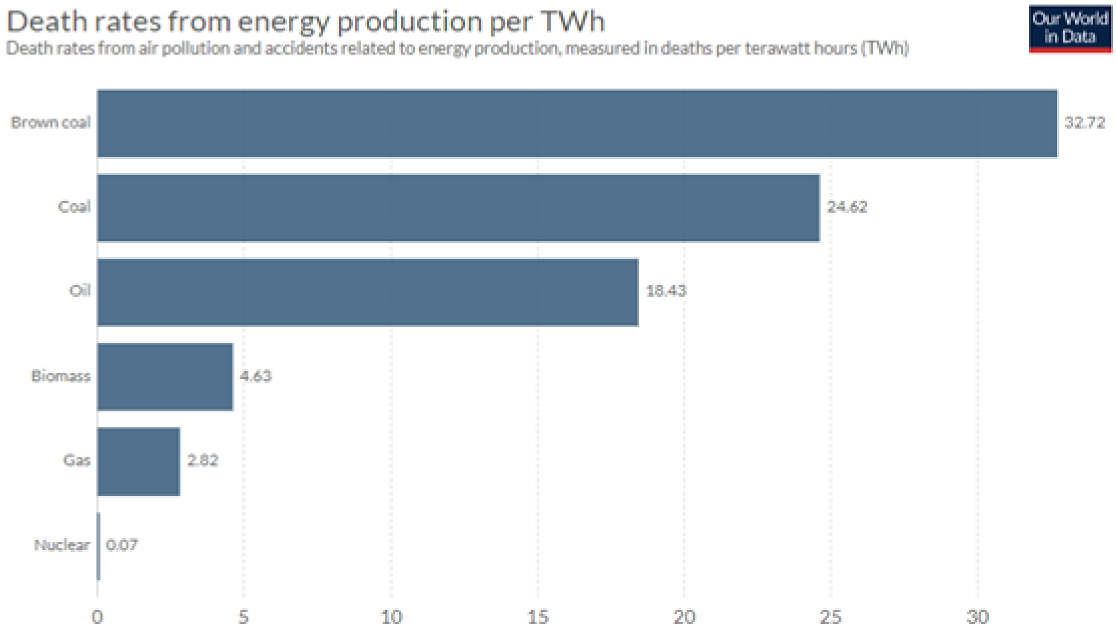

Figure 2 Death rates from energy production per terawatt-hour. Figure includes deaths resulting from accidents in energy production and deaths related to air pollution impacts. Deaths related to air pollution are dominant, typically accounting for greater than 99% of the total. Source: Our World in Data[viii])

Nuclear accidents are very rare and with the experience gained should be even less likely to occur in the future. Their health impacts have proven not to be as great as previously feared. In the history of nuclear energy only the Chernobyl nuclear accident has led to radiation-related fatalities. The official fatality numbers from that accident, as reported by the United Nations Scientific Committee on the Effects of Atomic Radiation, are small[ix]:

- 28 early responders died within three months.
- 19 early responders died over the following seven years from causes which may have included radiation.

In terms of long term radiation impacts some of the cases of thyroid cancer which subsequently occurred in the region can also be attributed to the accident. However thyroid cancer is a highly treatable disease with a greater than 90% survival rate. Gerry Thomas, one of the world's most prominent radiation and molecular pathology experts recently predicted that only about 160 of the cases developing as a result of the accident will prove fatal[x].

In fact, the major health impacts of the Chernobyl and Fukushima nuclear accidents were not caused by radiation exposure, but instead were due to psychological and socio-economic factors, resulting from misconceptions and fears about radiation[xi,xii]. In other words they could have mostly been avoided if better information was available at the time, trust in regulators/experts had been maintained and if emergency response measures had not been overly precautionary.

The global nuclear industry has a strong safety culture. This means that protecting peoples' health and wellbeing is considered first in everything it does. Every nuclear reactor plant in the world is represented in the World

Association of Nuclear Operators (WANO), where operators cooperate to share safety information, exchange international best practice and carry out peer reviews.

C. Environmental impacts

Nuclear energy boasts a very small environmental footprint.

The whole lifecycle CO_2 emissions of nuclear energy are among the lowest of all forms of electricity generation, similar to onshore wind. The IPCC reports a median figure for nuclear lifecycle emissions of 16 grams of CO_2 per kilowatt hour. For wind the figure is 12 grams and for solar PV it is 46 grams[xiii]. Moreover, including nuclear in the mix helps countries to achieve deep decarbonisation faster[xiv]. As shown in Figure 3, the historic rate at which nuclear energy has been added by certain countries/regions outstrips some of the most frequently cited buildouts of variable renewables over similar time periods. The case of France is particularly notable, as it managed to almost entirely decarbonise its electricity supply over the course of 20 years as a result of its nuclear energy programme.

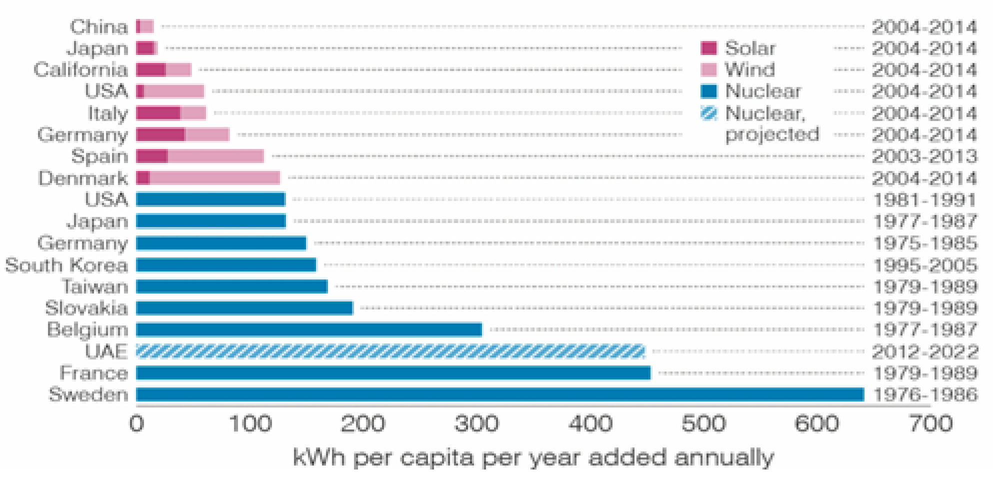

Figure 3 Historic rate of low-carbon electricity additions from different technologies. Source Cao et al (ref xiv)

Advanced nuclear technologies under development will help to decarbonise not only electricity but also heat, transport and industry. China[xv] and Finland[xvi], for example, are both actively exploring the potential of advanced reactor concepts for district heating.

Nuclear plants leave more space for nature. They require far less fuel than their coal or gas equivalents, requiring less extraction and transport infrastructure. They also take up only a small fraction of the space needed for wind and solar farms. A 3.2 GW nuclear power plant on 430 acres produces the same amount of electricity as 130,000 acres of solar panels or 250,000 acres of onshore wind farms[xvii].

Nuclear developers and operators often take proactive measures to protect the natural environment, such as setting up conservation programmes. Many construct wildlife habitats or set aside areas for the protection of local species[xviii].

Like coal-fired plants, nuclear plants require a lot of water for cooling, but over 99% of it is returned to the environment just a few degrees warmer. A nuclear power plant with once-through cooling will extract 175 litres of water to create one kilowatt-hour of electricity, but overall consumption is about 0.4 litres per kilowatt-hour[xix]. This process, which is essentially the same as for other thermal power plants, may potentially harm local aquatic species but the impacts are minimized through careful siting and appropriate regulation.

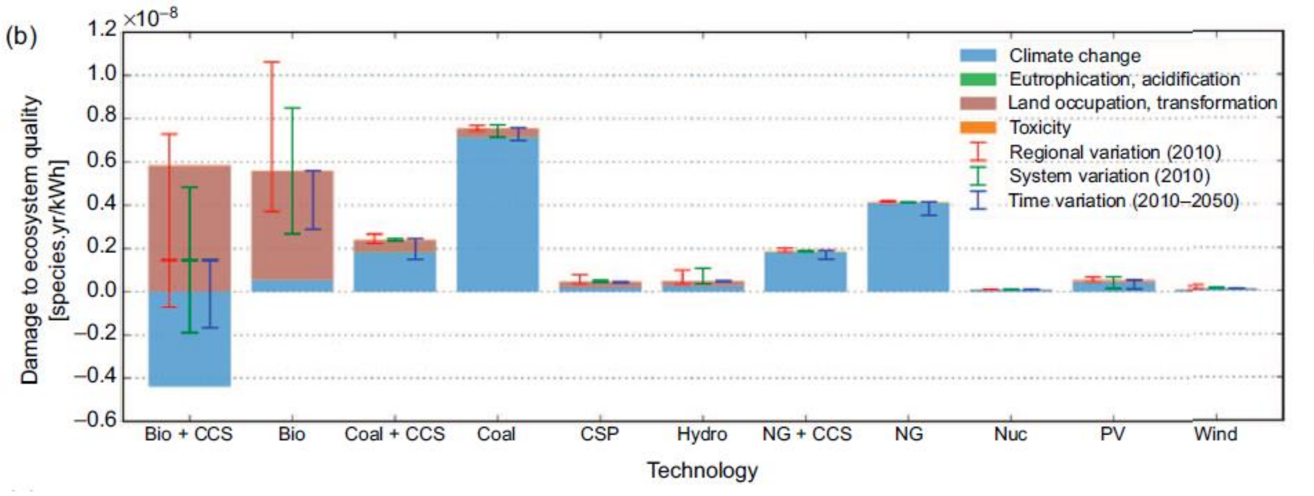

Figure 4: Results of an environmental life cycle assessment comparing different energy sources. Source: Gibon et al[xx]

Nuclear power plants are highly resilient to weather events and are suitable for deployment in a wide range of areas. Plants that have reduced output due to hot weather in Europe and the United States have done so primarily for environmental, not technical, reasons. It is possible to reduce the scale of these outages, and alternatives to once-through cooling such as cooling towers or use of ponds or channels are available if needed. In general the level of nuclear output lost to these incidents is much smaller than that lost by other low-carbon technologies[xxi]

D. Energy affordability and reliability

Most existing nuclear power plants can operate for over 50 years, continuing to deliver reliable low-cost low-carbon electricity over the long-term. In the USA, most plants have secured licence extensions to operate for 60 years and the regulator is considering subsequent licence renewals which would see plants potentially operate for 80 years[xxii]. The IEA recently highlighted that the long term operation of existing nuclear plants was the cheapest form of low-carbon electricity available in countries fortunate enough to have established fleets[xxiii].

Nuclear power plants are reliable and capable of operating 24/7. The median capacity factor of the global nuclear fleet is about 81%, however over a third of the world's power reactors operate with capacity factors in excess of 90%[xxiv]. Modern nuclear plants can also load follow if the right incentives are provided. They can help meet the need for greater flexibility created by increasing the share of variable renewables[xxv].

To accommodate the increasing amounts of variable renewable generation system operators are faced with the need to make significant additional investments in, for example, national transmission and distribution infrastructure, cross-border interconnectors, new solutions to ensure frequency and voltage stability, short-term power storage and back-up generating capacity. These measures add to the total system cost – and are ultimately paid for by consumers. Solar and wind energy give rise to system costs which are much higher than nuclear[xxvi] and which owners typically are not required to pay for. These costs increase non-linearly as the amount of wind and solar increases. Transmission links to dispersed wind and grid-scale solar generation – such as is often the case in Australia – have low capacity utilization and hence cost a lot per unit of power transmitted. The AEMO announced recently that marginal loss factors threatened the viability of some new renewables projects[xxvii] and has called for urgent investment in transmission lines[xxviii].

The bottom line is that a diverse mix of dispatchable and cheap non-dispatchable technologies is needed to control consumer costs and ensure reliability. Nuclear energy and renewables are complementary partners in the future low-carbon grid.

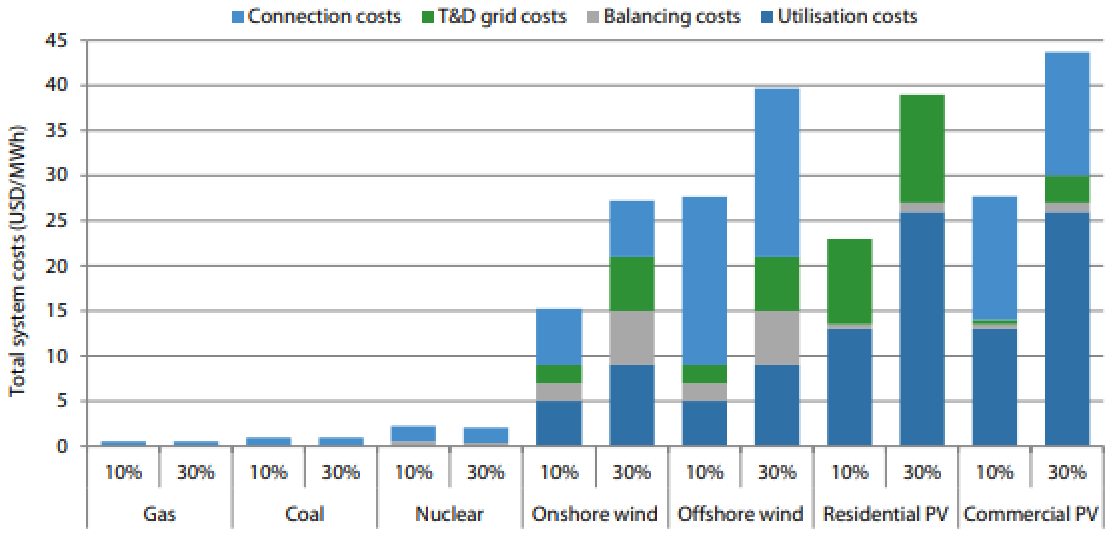

Figure 5: Grid-level system costs of selected generation technologies for shares of 10% and 30% of VRE generation. Source: OECD- NEA[xxix].

E. Economic feasibility

The basic economic premise of nuclear energy is that nuclear plants have high construction costs, but are comparatively cheap to operate. Currently-operating nuclear plants produce low-cost power and support stable electricity prices. For example, the operation, maintenance and fuel costs at US nuclear plants are about one third lower than for fossil steam sources (24.4 USD/MWh compared to 35.4 USD/MWh) according to official figures[xxx].

In many parts of the world new nuclear plants are directly cost competitive on a levelised cost of electricity (LCOE) basis with other energy sources – for example China, India, Korea, Russia, Japan and UAE. In other parts of the world new nuclear costs appear to be higher and notably some recent nuclear new build projects have come in considerably over budget in USA and Europe. However, there are no fundamental reasons why future project costs cannot be brought down in these countries and other countries can certainly learn from and avoid their mistakes.

The LCOE for nuclear power plant projects varies significantly and is affected by many factors. LCOE is heavily influenced by capital cost – including construction costs and financing costs. (This also means that nuclear plant economics are particularly vulnerable to construction over-runs and anything that increases construction duration).

Nuclear construction costs are influenced by local factors such as resource availability, labour costs, whether it is a first-of-a-kind project or part of a fleet programme, and whether it contains any design change from the reference plant. While some recent projects have experienced major difficulties others have proceeded much more smoothly and come in close to their original projections. Nuclear plants can be built faster and at lower cost by following international best practice and by building multiple units of the same design. For example, EDF estimates that construction costs can be reduced by 20% for the proposed reactors at Sizewell C in the UK by incorporating learnings – and using the same supply chain and key personnel – from Hinkley Point C [xxxi].

China also demonstrates the clear benefits of committing to the series build of nuclear reactors and developing a strong skills base and supply chain. The LCOE of nuclear energy has fallen to be one of the cheapest generating options in the country. The cost of electricity in China from onshore wind, solar PV and offshore wind is respectively 16%, 50% and 140% higher than that from nuclear, even without including the additional costs of adapting the grid and providing backup generation to compensate for intermittent supply[xxxii].

Table 1: The costs of nuclear energy and other energy sources in different regions for 2017. For all technologies, a standard weighted average cost of capital was assumed (7% in developing economies and 8% in advanced economies, in real terms). Source: IEA's World Energy Outlook 2018[xxxiii] (Based on Table B.6)

Region	technology	Capital costs (USD/kW)	Capacity Factor (%)	Fuel and O&M (USD/MWh)	LCOE (USD/MWh)
USA	Nuclear	5000	90	30	105
	Coal	2100	60	30	75
	Gas CCGT	1000	50	30	50
	Solar PV	1560	20	10	105
	Wind onshore	1620	42	10	60
	Wind offshore	4720	45	40	180
European Union	Nuclear	6600	75	35	150
	Coal	2000	40	45	120
	Gas CCGT	1000	40	55	90
	Solar PV	1300	12	20	160
	Wind onshore	1820	28	20	100
	Wind offshore	4260	50	35	150
China	Nuclear	2320	75	25	60
	Coal	800	70	35	50
	Gas CCGT	560	50	70	85
	Solar PV	1120	17	10	90
	Wind onshore	1200	25	15	70
	Wind offshore	4120	46	35	145
India	Nuclear	2800	80	30	70
	Coal	1200	60	35	60
	Gas CCGT	700	50	80	95
	Solar PV	1120	19	10	80
	Wind onshore	1080	25	10	60
	Wind offshore	3320	40	40	155

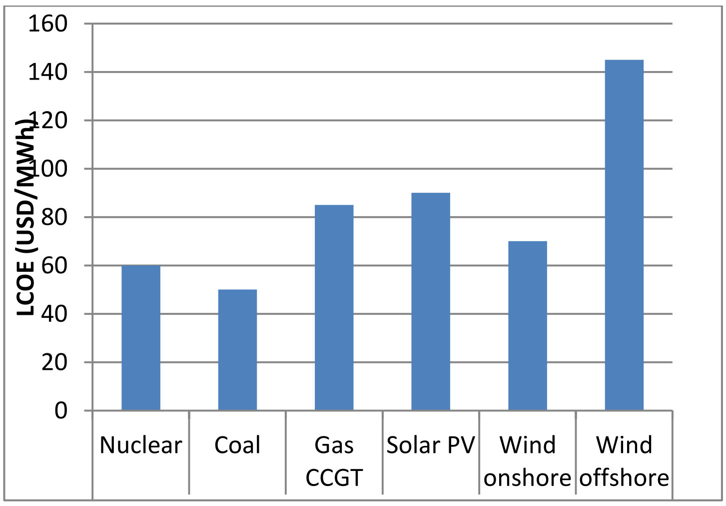

Figure 6. LCOE of different energy technologies in China. Source: IEA WEO 2018.

Financing costs (often reflected as discount rates or a weighted average cost of capital) have an enormous effect on the LCOE of nuclear energy, as shown in Figure 7. The difference between a 3% discount rate and a 7% discount rate almost doubles the LCOE of a nuclear project. At 10%, the LCOE is 50% higher than at 7%. Financing costs are influenced by interest rates, the presence of any guarantees, growth rate of the economy, underlying market structure and any power purchase agreement. These factors lie mostly within the sphere of influence of governments. For example, the UK government is in the process of consulting on a Regulated Asset Base financing model which it predicts could significantly cut the financing costs of subsequent nuclear projects after Hinkley Point C[xxxiv].

Together, the reduction in both construction and financing costs are expected to greatly reduce the levelised costs of Sizewell C compared to Hinkley Point C, an example of the savings possible through series build.

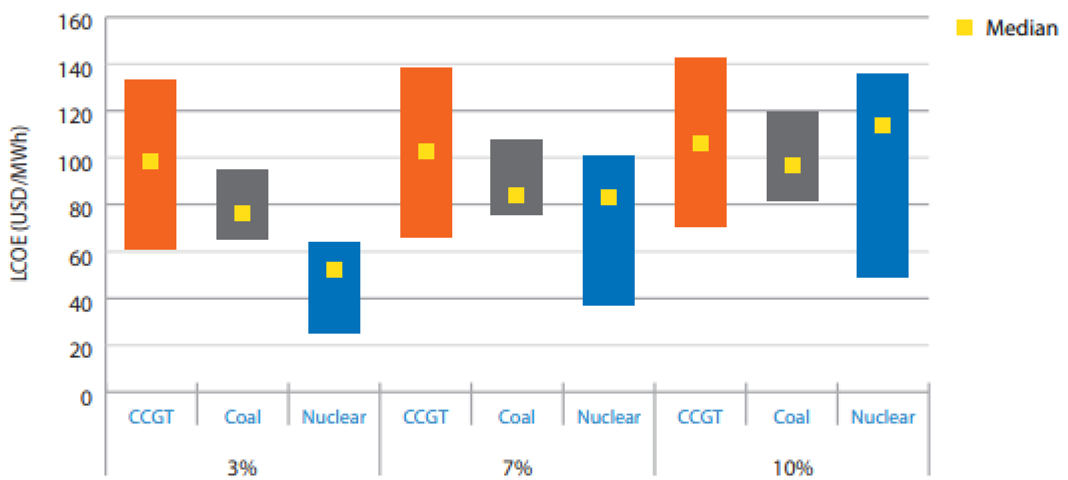

Figure 7: LCOE ranges for dispatchable technologies at different discount rates, highlighting the sensitivity of nuclear projects to financing costs. (The cost data is prior to 2015, and therefore less recent than table 1) Source: OECD[xxxv]

SMR and advanced reactor costs

The joint AEMO CSIRO GenCost report which is apparently considered authoritative in Australia[xxxvi] certainly cannot be considered as credible when it comes to nuclear costs. The latest edition excludes the technologically mature gigawatt-scale light-water and pressurized heavy water reactor designs – for which data are available – in order to focus on small modular reactors, for which prices are currently speculative. There is scant reasoning provided for this exclusion in the report and the supporting material. Australia has 13 major sites for coal electricity generation and those plants will have to replaced sooner or later. Eleven of those sites house more than 1.3 gigawatts of power capacity and could be suitable for gigawatt-scale nuclear facilities.

The report then assigns a surprisingly high estimated cost to SMRs of $16,000 AUD/kW, as well as assuming almost no learning rate. Confidence about the costs of as yet unbuilt reactor designs is naturally lower than in the (excluded) gigawatt-scale reactor segment. However, confidence is increasing as several prospective vendors undertake the necessary studies to advance through licensing processes and secure private investment. We can therefore say categorically that the figure of $16,000 AUD/kW is not in concordance with current international expectations.

For example, a recent detailed independent cost evaluation carried out on the NuScale SMR design, arrived at a figure of 3,465 USD/kW (~5,200 AUD/kW) for a twelve module 720 MW plant[xxxvii]. Several recent government-industry initiatives analysed the drivers of SMR costs and have projected the LCOE cost ranges shown in Figure 8 and Figure 9, reflecting much lower capital cost estimates than the GenCost report.

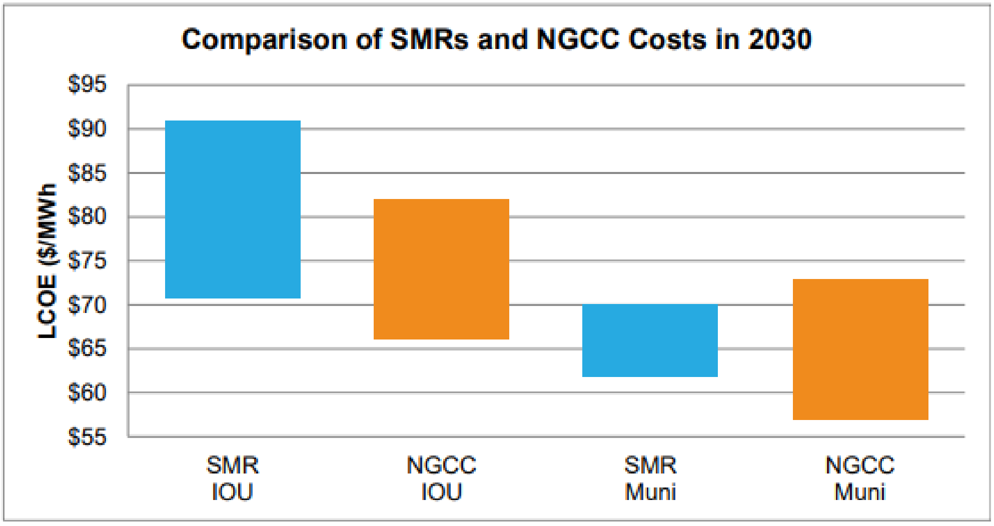

Figure 8. Projected LCOE costs (USD) for SMRs and combined –cycle natural gas plants in the USA in 2030. IOU refers to investor owned utility. Muni refers to municipal owned utility. The difference in price is largely attributable to financing costs. Estimated SMR capital cost: 4,600 – 5,150 USD per kW. Source: SMR Start[xxxviii]

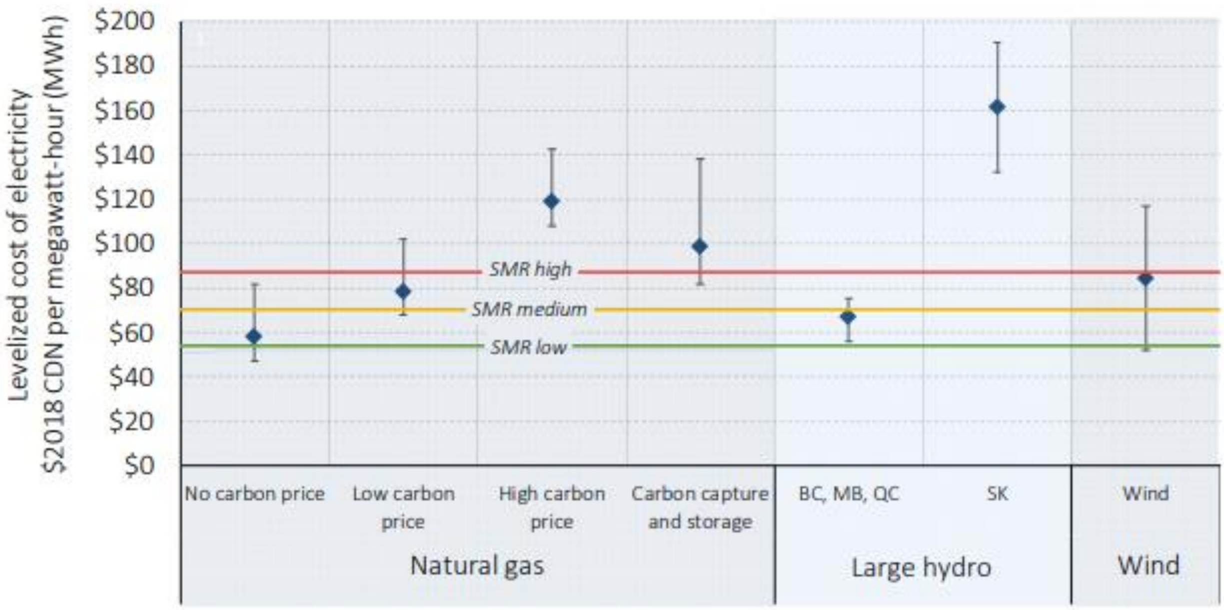

Figure 9. Projected LCOE costs (CDN) for SMRs compared to other options in Canada. This is considered the best case – with a 6% discount rate and the use of more innovative technology. Low, medium and high reflects the different capital cost estimates. BC: British Columbia, MB: Manitoba, QC: Quebec, SK: Sasketchawan. Source: Canadian Small Modular Reactor Roadmap[xxxix]

The assertion of essentially no learning rate for SMRs is also weak. The stated logic of aggregating SMR production with gigawatt-scale reactor production to assign only very slow rates of doubling runs counter to the entire SMR economic principle, and would seem to invalidate the reason for focusing on SMRs in the first place. SMRs seek to exploit economies of series production as opposed to economies of scale for large reactor designs. Expert analyses suggest that while the learning rate for SMRs may be less than for some comparable industries, it should still be significant[xl].

We are, frankly, confused that the World Nuclear Association is quoted as the source of the SMR cost data in the GenCost report. We do not believe that the figure of 16,000 AUD/kW has ever been presented in our reports or in our online Information Library. We have no record of consultation, or request for consultation, on this matter.

In order to gain an accurate picture of the likely costs of nuclear energy in Australia, the government would need to enter into discussion with vendors and conduct its own detailed modelling. Whether these vendors would be willing to provide significant resources to this task while their product remains illegal within the country is of course questionable. The legal prohibitions are evidently preventing clear-sighted, quality analysis of these technologies in Australia. In the absence of adequate analysis, Australia will be unable to make informed decisions relating to nuclear energy.

F.Community engagement

We would point the Committee to the Get to Know Nuclear campaign conducted after the South Australia Nuclear Fuel Cycle Royal Commission as an example of good practise in community engagement, although there are notable flaws in the citizen jury system which should be avoided in the future[xli].

While attitudes and underlying cultural drivers vary by location, a common finding is that people typically do not consider nuclear energy highly on the list of issues that they are concerned about. Like energy in general, nuclear is a 'back- of-the-mind' issue which people only think about when it is mentioned in the media or otherwise brought to their attention. The results of surveys on nuclear are heavily influenced by recent events, how questions are framed and even individual word choices. The questions 'given the risks of radiation, do you support phasing out nuclear energy?' and 'given the importance of preventing climate change, do you support expanding nuclear energy?' will result in inconsistent responses.

Where the public feels informed about nuclear, support levels tend to be greater. The results of surveys in the European Union demonstrate this[xlii]. On average EU citizens do not feel well-informed (74%) about nuclear issues and radioactive waste in particular. However in countries where the level of real knowledge is greater, such as Sweden (Knowledge: 47%, Acceptance: 62%), Finland (51%, 61%), the Netherlands (44%, 55%) and the Czech Republic (41%, 64%), public opinion is more favourable to nuclear energy. Building this knowledge and a clearer national consensus should be considered a key part of any community engagement.

G. Workforce capability

Nuclear energy provides opportunities for qualified workers across a large number of fields. Often jobs are long term and skills are internationally transferrable. Industry is developing international training and education programs designed to bring new people into the industry and to address potential worker shortages in countries which are developing nuclear energy. For example, Russia's National Research Nuclear University consists of 11 research institutes and 15 colleges and boasts international links with organisations throughout America, Europe and Asia[xliii].

Nuclear projects act as growth engines for the regions hosting them. In the European Union the nuclear sector supports over 1 million jobs and generates over €500 billion in economic impact[xliv]. Canada's nuclear industry offers stable and well-paid jobs to more than 60,000 people in areas such as exploring and mining uranium, generating power and advancing nuclear medicine[xlv]. In general these jobs also pay significantly higher than similar jobs in competing sectors and therefore contribute more to induced employment throughout the rest of the economy.

Table 2: Examples of jobs in the nuclear industry. Source: Nuclear Energy Institute

SKILLED TRADES	**ENGINEERING & PROFESSIONS**	**TECHNICIANS & RADIOLOGISTS**
Carpenters	Accountants	Chemists
Electricians	Chemical engineers	Mechanics
Operators of heavy equipment	Civil engineers	Radiation protection specialists
Masons	Health physicists	Reactor operators
Pipefitters	Lawyers	Scientists
Sheet metal workers	Mechanical engineers	
Welders	Nuclear engineers	
	Entrepreneurs	
	Financial managers	

H. Security implications

Uranium is abundant and is supplied by many countries. Most experts agree that there will be no shortage of fuel, even with a large expansion of nuclear energy globally. There are over 130 years of known uranium resources based upon current usage rates – a number that has grown over time[xlvi]. This is over twice that of oil (50 years) and gas (52.6 years)[xlvii]. Uranium occurs in minable concentrations all over the world, and exists naturally in land-based mineral deposits and seawater. Australia is of course a major international supplier.

For most countries nuclear energy unambiguously strengthens energy security and can reduce dependence on fuel imports. Given that Australia is energy independent already this argument does not apply. Thanks to its very large uranium reserves Australia would be secure in this fuel resource, but it would still need to procure fuel enrichment and fabrication services. It is possible to develop these facilities but for a nuclear newcomer country it makes more sense – economically and politically – to rely on the well-established international market. There has never been a serious disruption in these services. Nuclear energy is resistant to fuel price shocks and disruptions in supply. Doubling the cost of nuclear fuel increases the cost of nuclear electricity by less than 10%[xlviii] and several years' worth of nuclear fuel can easily be stored at a nuclear plant.

Nuclear energy does not increase the risk of nuclear weapons proliferation. Countries with nuclear energy programmes historically have not been more likely to pursue or acquire nuclear weapons than those without[xlix]. Besides which, Australia's non-proliferation status is impeccable. Nuclear plants can even help eliminate warheads by using the nuclear material to create reactor fuel. Under the now-completed Megatons to Megawatts programme that ran from 1999 to 2013, material from Russian and US stockpiles equivalent to 20,000 bombs was converted to reactor fuel and used for power generation[l].

I. National consensus

Without consistent nationwide polling we cannot confidently assess Australian attitudes towards nuclear energy. There is some evidence that opposition to nuclear energy in the country is not as strong as commonly thought. In 2013 and 2016 the South Australian Chamber of Minerals and Energy conducted polling of the South Australian public to ascertain attitudes towards uranium mining and nuclear power. In both polls the proportion of South Australians supportive of uranium mining and nuclear power was over 50% and 45% respectively and opposition to both propositions under 30%[li]. Since this Committee has launched, one informal media poll yielded approval ratings for nuclear of 65%[lii].

We can state that there is good support for nuclear energy in many countries where nuclear plants operate and that support for nuclear tends to grow when people feel better informed about it[liii]. Building this knowledge and a clearer consensus should be considered a key part of any community engagement.

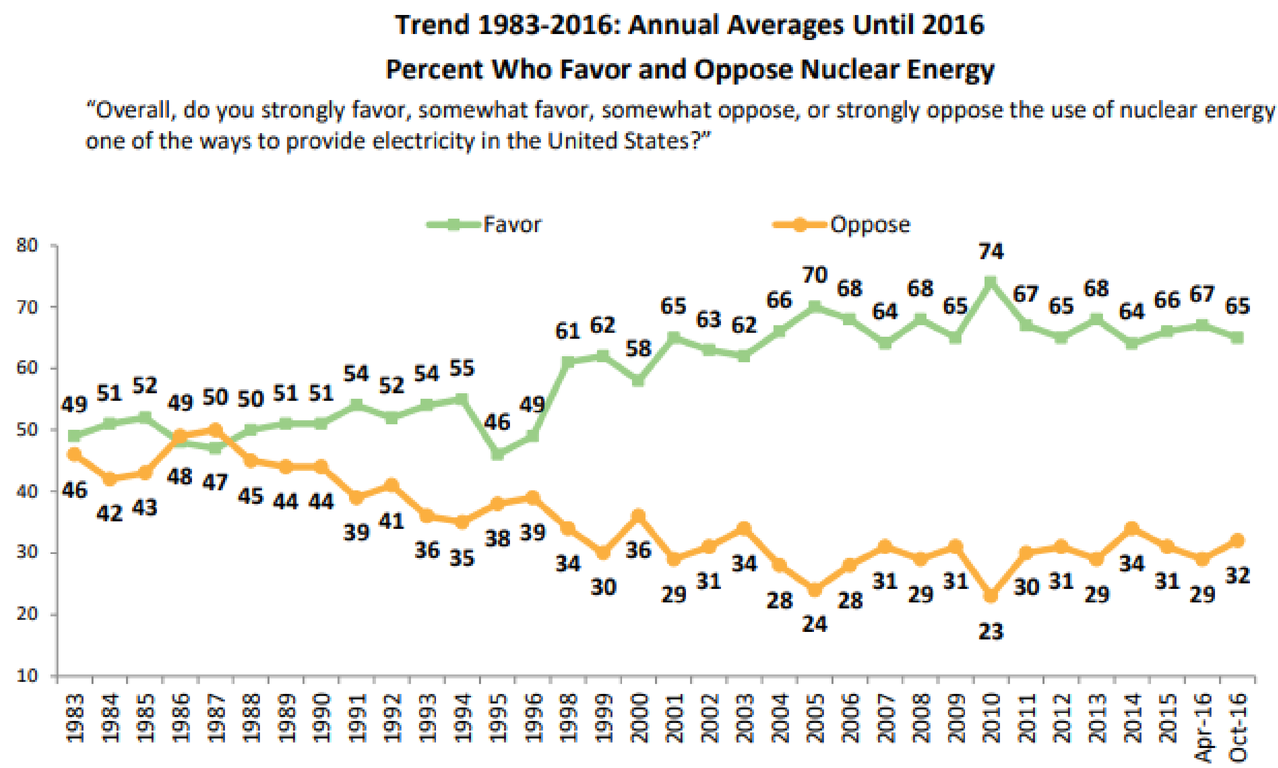

Figure 10: US attitudes towards nuclear energy have improved over time. Source NEI[liv]

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