Inquiry into the current circumstances, and the future need and potential for dispatchable energy generation and storage capability in Australia
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Introduction

Energy security is national security

A careful reading of the latest Energy Security Board Post 2025 Market Design Options paper paints an alarming picture of the long-term declining energy security of Australia's electricity sector and much wishful thinking. Many of the complex rule based reforms proposed for consultation have failed in other jurisdictions attempting to support a pathway to high levels of renewable energy, most recently with disastrous results.

Energy sector engineers have understood the emerging issues for decades but simplistic political ideology devoid of any engineering reality continues to dominate in many countries and most notably Australia. In simplistic terms renewable energy with indeterminate dispatch capabilities has an average 30% security rating at best compared with 100% for well engineered electricity sectors based on dispatchable generation using coal, oil, gas, or nuclear energy. Nuclear energy is the only option that can meet international emission level expectations for electricity sectors at acceptable cost and 100% security and also provide realistic opportunities for decarbonising other industrial sectors.

“Experience never errs, only your judgement not based on your experiments errs”.
Leonardo da Vinci

Submission Summary

The requirement to replace at least 20 GWe of retiring dispatchable coal fired electricity generation plant in Australia over the next few decades presents an unprecedented opportunity to financially stabilise the sector and move to zero carbon dioxide emissions while providing significant flow on manufacturing growth to the economy as a whole. A nuclear power electricity generation investment program is shown to be the least cost alternative of all current viable power station replacement options by the OECD - NEA and Australian engineering studies.

Subject to final feasibility study, all technical and economic assessment to date indicates that the introduction of a progressive nuclear power investment program will provide Australia with a reliable electricity supply at minimum cost and significantly decarbonise the sector in line with international expectations and agreements. The electricity system options costing and emission information provided in this submission has been widely circulated for engineering review and has never been challenged.

Renewable energy options cannot meet the same emission reduction levels even at more than double the cost to consumers if reliability is to be maintained and will lead to decimation of Australia's industrial competitiveness. More renewables inevitably pushes more inefficient gas back up generation into the electricity sector negating any possibility of reaching zero emission outcomes. The key detrimental cost issues relate to the financial implications of low utilisation of all capital investment in renewable energy generation including the firming capacity required, and extended transmission assets.

Nuclear power is the only viable option to reliably move the electricity sector to zero emissions at current cost levels. This has been demonstrated around the world both in practice and by ongoing engineering analysis. Unfortunately Australia has chosen to ignore the option of nuclear power after two decades of both federal and state inquiries clearly demonstrating the benefits. The end result of leadership weakness, ideological corruption, financial ineptitude, engineering ignorance, and market manipulation, is an increasingly fragile electricity grid now requiring significant day by day operational intervention with no one held responsible. This situation is not unusual and Australia can be expected to follow more severe International examples towards electricity grid failure if the wishful thinking devoid of engineering reality and political obsession with renewable energy continues.

This submission updates information established by the South Australian Royal Commission into the Nuclear Fuel Cycle. The submission provides more specific recommendations relating to the viability of the introduction of nuclear power into the Australian national electricity market based on subsequent direct investigations into the South Korean nuclear industry by experienced Australian design and construction engineers. South Korea currently has the only economically viable nuclear industry supply chain suited to Australian requirements and committed to progressive local supply development for nuclear power plant customers. Proven domestic and export performance supported by an internationally competitive supply chain for any nuclear plant supplier is the critical requirement for implementation of a viable nuclear power program for Australia.

A key pre-requisite for a nuclear power program is the establishment of a government authority to proactively lead, analyse, and if investment is recommended by final feasibility study, implement such a program. The investment would be self funding through electricity sales at current long term wholesale market rates under standard commercial terms and require no taxpayer subsidy. The Australian private sector is clearly in no position to initiate any significant generation investment and has made that known on many occasions albeit in many obscure and obtuse ways. The current liberalised energy only generation market design actually precludes any significant long term private investment in the Australian electricity sector of any plant without subsidy or output purchase guarantee.

Given the extent of problems across the electricity sector and the serious impact from unstable power prices on Australian industry viability now emerging, the government must consider extending this recommendation to more direct control of the whole electricity sector for the economic benefit of the Australian community. This is a national security duty of care matter requiring sound leadership now clearly flagged by the Energy Security Board. The current market system and forced renewable energy implementation experiment is a dismal failure not serving Australia well and needs complete revision.

Section 1 - Factors Leading to the Consideration of Nuclear Power for Australia

1.1 The Electricity Sector Technical and Commercial Requirements

Reliable and competitively priced electricity is the foundation of modern society and the Australian economy. Power systems must balance the total electricity generation with the total customer demand for electricity, otherwise the power system will collapse within seconds, resulting in blackouts with catastrophic consequences. Customers electricity needs vary continuously over time and are mostly inflexible because of the essential services electricity provides in the community. It is critical that the combined generating system can adjust the amount of electricity produced to match total customer needs, which can vary by a factor of three over short timeframes. Breakdowns of generating units can occur unexpectedly and to avoid instantaneous interruption of customers electricity supplies, the sudden reduction in electricity generation must be immediately taken up by other generators. Simply resorting to a demand reduction philosophy through the use of selective area grid blackouts is not an option for any modern society.

Power systems depend on there being sufficient generators to continuously adjust their electricity generation to follow the varying electricity needs over time; the flexibility to direct output up and down. There is also an essential need for generators to operate at less than full capacity so they can immediately replace any drop in power generation due to unexpected generator breakdowns. In the case of renewable electricity generation support must be provided to manage sudden reductions in wind or solar energy resources. The difference between full rated generator output and prudent operation at less capacity is known as spinning reserve and is an essential component in all well managed power systems.

Intermittent renewable energy sources such as wind power and solar photovoltaics cannot perform these additional roles that are essential for reliable, secure and low-cost electricity supply. This limits the level of their initial integration into any power system to around 10% if stability is to be maintained. Beyond this level substantial backup or firming capacity is required to ensure dispatchable operation usually negating any cost or emissions reduction benefits. Continuous base-load power generation is crucial for system reliability and stability. At the extreme 100% renewable generation in Australia with current hydroelectric storage levels would require up to 90% dispatchable backup generation to cope with essentially unpredictable intermittent supply. In other countries without hydroelectric resources this backup requirement rises to 110% of wind and solar installation levels. Managing this engineering requirement as Australia continues to encourage renewable energy within the current market structure forms a large speculative part of the current Energy Security Board consultation paper.

Renewable energy derived from hydroelectric power stations overcomes these limitations but the options for additional resources from this source of electricity generation at competitive cost have been exhausted in Australia. These essential system reliability support functions have traditionally been delivered by conventional generators which store energy in various stages of the generating process so they can respond instantaneously, or within seconds, minutes or hours.

Wind turbine generators and solar photovoltaics simply convert the available wind or sunshine into electricity totally dependent on the prevailing weather conditions and are technically incapable of storing, controlling, and releasing energy in any way. It is technically possible to interrupt customer electricity supplies or to release energy stored in batteries to partially alleviate some of these issues. These options have limited utility and very high cost compared with conventional operations. For example the South Australian grid would have required 700 batteries the size of the current Hornsdale unit (each $160m) to cope with one hot week in January this year if the connection to coal fired electricity from Victoria was not available. A wishful thinking absurdity.

As engineering knowledge currently stands, electricity cannot be cost effectively stored at grid scale except as potential energy in large hydroelectric pumped storage projects. Even in this case the high capital cost of the total system including transmission augmentation, energy losses from pumping and generation, and low asset utilisation impacting financial return, generally makes this option unviable for new installations compared with the provision of additional spinning reserve from conventional plant. The Snowy 2 project is a case in point with loses expected to be around $200m/yr or greater for the whole $10B system concept in the current market. It should be noted that the Snowy 2 project will only reach its full economic potential when aligned with 2000 MWe or more of nuclear power allowing utilisation factors to rise from the current 2% estimate to around 30%.

System reliability cannot be simply linked to any economic formulae or simple market driven process. Operational reliability is a complex matter of engineering judgement balancing system technical requirements, generation sources, reserve plant availability, potential load, cost, and risk. Recent examples of failure of the current liberalised market system has seen the closure of potential reserve base load capacity in South Australia with subsequent disastrous system reliability results and huge cost to the community. The closure of generation capacity in Victoria has inevitably lead to the same falling system reliability, very difficult to manage at the plant level, and significantly higher cost to consumers.

The South Australia system failures together with South Australia, Victoria, and Queensland cost issues have clearly illustrated that the current market based administrative procedures in place for the Australian electricity supply sector have not served the community well and in fact are failing. Ambiguous leadership and responsibilities, a focus on short term energy only costs, economic gaming, and evidence of risk management issues, compounded by a seeming mindless obsession with subsidised renewables all indicate that significant change is overdue.

There is nothing new in this situation. There are a number of well-documented similar deteriorating electricity supply situations emerging around the world. Not exactly the same scenarios but providing good lessons on the situations that Australia must avoid. The United Kingdom electricity sector provides an extensive market failure example, with Germany, Spain and many US states also exhibiting extensive mismanagement problems. Subsidised renewable electricity policies are forcing out established sources of generation, system inertia, and frequency control leading to fragile networks and operational vulnerability at great additional cost to those communities and with only the most marginal environmental benefits if any. The recent US winter has demonstrated the extent of these issues in that country.

It is clear with the benefit of hindsight that a number of the benefits promoted by international banks and politicians to accrue from electricity sector privatisation and market reform in Australia were of a very short-term nature, poorly thought out, with any benefits long since past. In particular the new electricity marketing structure failed to provide the appropriate incentives for long-term reinvestment through a total focus on short-term energy supply. No support payment was provided for system stability and reliability.

Fragmented privatisation, selective subsidies, and economic gaming have caused electricity prices for Australian consumers and industry to rise well above inflation, when benchmark rises in other countries show around half inflation increases. Given the volatility of the market place and low generation margins it is also currently not possible for Australian industry to negotiate long-term electricity supply agreements at sustainable cost. This makes conventional debt investments in value adding energy intensive sectors such as mineral or metal processing impossible unless they are independent of the grid. Energy intensive business investment in Australia has all but collapsed and local businesses are moving resources and investment offshore.

In addition the introduction of subsidised renewable energy generation investment and operation into a liberalised market system without appropriate engineering design and regulation has destroyed any possibility of a traditional competitive market. A simplistic political obsession with solar and wind renewable energy with no regard for overall system engineering design or cost has added huge cost and unreliability with no significant emission reduction benefit, when less expensive and more secure options to meet environmental targets are available.

Of particular concern is that specific emission levels have been driven up by inefficiently operated base load generators and by the need to provide quick start backup open cycle gas turbines to cover the intermittent nature of renewable energy supply, the opposite outcome thought to be achieved by the general public and a technically challenged media. Australia's annual emissions from electricity generation for the year to June 2014 were 179.4m tons CO_2 (National Greenhouse Inventory). Five years later and after billions of dollars spent on wind and solar installations and subsidies to the detriment of all electricity consumers, Australia's annual emissions from electricity generation for the year to June 2019 were 179.9 tons CO_2. A totally unnecessary drag on the economy.

An ever increasing framework of rules and regulation is required in an attempt to manage and direct the secure supply and low cost outcomes previously achieved by skilled engineers and plant operators. In reality the generation sector is all but completely inflexible because of the high level of fixed investment, plant that is generally difficult to modify, and the long lead times required for any new generation deployment. This partly explains why punitive economic or environmental vehicles such as emission penalties or carbon taxes and the like can have little effect beyond raising costs or shutting older high emission generators but cannot facilitate new investment at any significant level.

The current economic mantra 'leave it to the market' together with inappropriate market design has resulted in a situation that ensures no new power generation system investment can be made without subsidy. Subsidies direct and indirect were at a level of $7B last year. There is a slow awakening that subsidies for small scale solar and wind generation with backup system costs as high as four times that of more effective low emission technologies are patently ridiculous and unsustainable in the long term. All technology focused subsidies should be removed.

Australia faces the prospect of retirement through age of up to 20 GWe of base-load coal fired power stations through to 2040 or earlier. Two major base load power stations have already been shut down with no prospect of equivalent replacement, leading to a doubling of wholesale prices contributing to the issues noted above. A third station scheduled for shutdown in 2022 has led to the private operator proposing only token intermittent renewable and gas plant investment to exploit high market peaking prices. The electricity energy market operator AEMO and ESB have proposed further regulation but this is seen as adding further complexity to a market system already over regulated, understood by few and heading for crisis. The extent and potential severity of the crisis now facing the Australian electricity sector is not well understood by consumers, most media commentators, and the majority of politicians. Even the Energy Security Board has been excruciatingly slow to understand and articulate the problems but no rational solutions have been offered. The reasons for this are rather obvious.

Residential consumer pricing escalation with rising disconnection rates, and energy intensive business shutdown are easily understood. Base-load replacement finance issues in the current market and necessary reform possibilities are not well understood given the current technically challenged political sector and strong renewable energy industry lobbying. The added complexity of solar and wind generation introduced into the existing market structure without an understanding of the full system requirements needed to support the intermittent nature of renewable supply is seen to be very confusing. After all solar panels are cheaper than nuclear power stations. In addition the technical realities in operation that partly lead to intermittent renewable generation creating more carbon dioxide emissions than if they were not there is a particular issue where there is no understanding of the plant and equipment currently installed in the Australian grid and its operating characteristics.

Liberalised free market concepts, ever more complex regulation, and ineffective levels of control have reached a stage where effective long term management of the national electricity sector is not possible even by the Federal government. No single competent authority can be held responsible either for directly managing the national electricity system commercially and technically long term for the benefit of the community or for causing the current problems. Falling utility and occasional system failure has been brought on by inappropriate economic concepts and technical compromise, but principally by leadership abrogation for the sector. The ongoing detrimental promotion of renewable energy is an excellent example of a form of collective madness defined as the Abilene paradox. A duty of care obligation requiring sound leadership by the federal government is emerging.

An excellent reference covering all of the problems noted above in detail beyond this submission is - Shorting the Grid. The Hidden Fragility of our Electricity Grid by Meredith Angwin.

There is a growing understanding that the replacement of base-load generation will inevitably become a government responsibility, state or federal even if the beneficiaries of the current status quo and free market proponents are vociferously opposed but suggest no alternative. The Snowy 2 project illustrates the first step along this path albeit an extremely poorly chosen example. The proposed Hunter valley gas fired power station is the second step. This proposal demonstrates the rush to gas firming generation required as more renewable energy is pushed into the electricity grid and the technical impossibility of reaching zero emissions only using renewable energy. This need for government intervention is a clear demonstration of failure of the current market structure.

Under these circumstances and given the need to balance a complex set of objectives all aspects of Australia's electricity generation and supply need to be bought together under the leadership and management of one independent authority. One independent authority is the only option able to carry through rational commercial and technical management of the sector as a whole in the face of single interest group misinformation, community confusion, and the strategic inaction problem now evident. This is a once in a generation opportunity to regain control of the vitally important electricity supply sector now and into the future given the need for the sector to support decarbonisation across other heavy industrial activities.

It is recommended that an independent Electricity Commission or similar government corporation be established to progressively take over the responsibility for all new grid level electricity investment and operational management. An independence mandate similar to the Reserve Bank of Australia is recommended.

1.2 Electricity Generation Investment Options

In arriving at the nuclear power investment proposal recommended in this submission a wide range of potential power generation engineering concepts have been technically evaluated and costed to provide predicted emission levels and final electricity unit costing as would be seen by consumers.

Past work by a number of institutions and individuals has commonly relied on the Levelised Cost of Energy (LCoE) approach to compare the economics of individual plant concepts such as open cycle gas turbines, coal-fired plants, combined cycle gas turbines, solar panels, wind turbines, etc. This approach can be of academic interest but is of no use for any technical and cost based comprehensive analysis for the Australian electricity grid as a whole. Levelised Cost of Energy figures quoted always show the best possible case not the financial reality of generating plant under utilisation in most electricity grids.

The LCoE approach ignores day by day utilisation of generating plant and consequent full system costs that are incurred in matching generation with consumer demand while maintaining system reliability. In most current debate advocates of particular generation options have left out or deliberately not considered the system costs of inclusion in the existing grid by quoting simple LCoE concepts and missing actual utilisation realities entirely. In a few cases this is understandable as the development of whole of system costs analysis first requires a high level of professional engineering knowledge not generally available in the wider community. This has left policymakers and the general public with considerable confusion, unsatisfactory debate, and an underlying concern that only part of the problem is being explained.

All options considered for this submission have been analysed using a reference system load for winter and summer derived from national energy market actual loads and existing plant physical performance characteristics for all of the year 2017. A large interactive information model recently developed by Dr Robert Barr AM ensures every aspect of actual plant performance characteristics and costs of implementation and operation is included in the context of full inclusion in a reliable grid. Reliability is assessed as no load left unfulfilled and load reduction through demand management is not considered as an acceptable outcome. Option concepts and parameters analysed are all designed to be technically viable and plant underutilisation is clearly illustrated. Over six hundred generation plant configurations have been analysed and optimised to test the modelling design and reach the most technically viable least cost case for each configuration. System Levelised Cost of Energy as might be seen by electricity consumers if profits and subsidies are excluded are listed along with Emission Profile Levels. The Australian Electricity Market Operator (AEMO) 2018 Integrated System Plan for 2040 is included for comparative purposes.

Capital and operating costs used to provide whole of system cost analysis for this study have been derived from data provided by the Australian Electricity Market Operator (AEMO) or when not available calculated from current overseas costs re-estimated to take into account Australian construction and operating parameter factors. Capital cost for the first 1000MWe PWR nuclear power plant built in Australia is estimated to be A$7B. This value has been derived from similar plant constructed in South Korea for US$3000/kw. A major factor underpinning the increased cost for Australia is the high cost of construction labour and concrete supply in this country compared with South Korea. A 17% capital contingency factor has been included.

Final costs include capital repayment combined with yearly operating costs for various interest factors, covering generation, high-voltage transmission, and retail costs giving a complete value but excluding profits and subsidies. More detailed supporting information is available in a submission to the New South Wales Inquiry into the Uranium Mining and Nuclear Facilities (Prohibitions) Repeal Bill 2019 by the author of this submission. Access to the modelling system utilised is also available on request.

The modelling concepts utilised and the output costing summarised below have never been challenged after widespread circulation and peer review.

1.3 Summary of Option Cost and Emission Results

This summary details the System Levelised Costs of Energy for 3% interest rates reflecting funding by government. No taxpayer subsidies are included in any of the option studies. For each case detailed generation mix and estimated costs to consumers together with results for a range of interest rates are available as noted above. Emission profile levels (EPL) are provided for each case.

Case 1) - The existing national electricity market of black and brown coal, open and closed cycle gas with current renewables delivered by existing hydro, solar and wind.
SLCoE $60/MWhr Retail $200/MWhr EPL 0.83t/MWhr

Case 2) - The replacement of all coal with combined cycle gas for base-load and maintaining the remainder of the NEM energy generation as is.
SLCoE $90/MWhr Retail $230/MWhr EPL 0.373t/MWhr

Case 3) - The use of 50% nuclear energy plus an expanded renewables and pumped storage capacity with backup from fossil fuelled generators operated at lower capacity factors.
SLCoE $66/MWhr Retail $210/MWhr EPL 0.35t/MWhr

Case 4) - The use of 20% renewables consisting of expanded wind and solar plus existing generation plant and augmented by pumped storage.
SLCoE $74/MWhr Retail $216/MWhr EPL 0.7t/MWhr

Case 5) -The use of 90% renewables with large scale pumped storage and a small level of open cycle gas generation.

SLCoE $272/MWhr Retail $414/MWhr EPL 0.08t/MWhr

Case 6) - Coal replaced by 42% nuclear energy and 40% combined cycle gas plus pumped storage, hydro, open cycle gas and solar PV.
SLCoE $80/MWhr Retail $220/MWhr EPL 0.21t/MWhr

Case 7) - 82% nuclear generation with daily peaks served by pumped storage, solar PV, open cycle gas and hydro.
SLCoE $71/MWhr Retail $213/MWhr EPL 0.05t/MWhr

Case 8) AEMO 2018 Integrated System Plan.
SLCoE $262/MWhr Retail $405/MWhr EPL 0.33t/MWhr

1.4 Option Analysis

Apart from the high level renewable energy cases, system costs and retail costs do not vary much and are close to the accuracy levels expected for this comparative analysis. The high renewable energy system costs illustrate the impact of additional firming capacity for reliable supply, the underutilisation of those installations, and all additional new transmission investment required (also under-utilised). No option utilising grid level batteries for storage to support renewable supply has been found to be cost-effective. Some batteries would be required to manage supply frequency issues caused by renewable energy generation quality characteristics but these support services have not been included in the analysis.

The AEMO 2018 ISP leads to very high cost in this comparison but is also essentially unworkable. The analysis supporting that plan uses averaging concepts to predict renewable energy output and fails to allow for extremes of real time low output and intermittent operation. Design for operating extremes (not average situations) is a fundamental principle of professional engineering and essential for electricity supply involving intermittent renewable energy. The plan also fails a common sense test by assuming remaining base-load coal fired power stations can be switched on and off on daily basis. None would remain operational in this scenario for both financial and engineering reasons. There is some hope that a current revision of the AEMO ISP might resolve these issues but an unswerving simplistic focus on renewable options makes that unlikely.

Financial analysis also shows that load following by nuclear reactors while technically feasible with modern plant is not recommended as under utilisation of the plant during periods of low power operation incurs large cost penalties. For that reason an installation level above 80% could not be recommended for the Australian grid. There are more cost effective generation options to cope with daily load variations and renewable energy intermittency. It is financially important to operate nuclear power plant near full capacity at all times and this is certainly the best engineering option to maintain long term plant integrity.

The cost and emission outcome results of this Australian study are confirmed in general terms by a comprehensive 2019 OECD-NEA study and report -The Costs of Decarbonisation - System Costs with High Shares of Nuclear and Renewables. That report outlines in great detail all of the fundamental issues impacting technical and cost outcomes for electricity grid decarbonisation. The report supporting discussion also details the negative outcomes and complexity arising from poor planning, inappropriate engineering,

and market design failure within the electricity sectors of OECD countries similar to that now evident in Australia. In particular, the study concludes that;
"… diversity of energy sources drives down total costs of energy in a low carbon system, whereas taking options off the table – such as nuclear – creates extra costs to society".
That benchmark study would provide an excellent base for extension to a similar Australian study to verify the work already carried out by experienced Australian professional engineers and summarised above.

1.5 Future Directions

A progressive more thorough investigation and subsequent introduction of nuclear energy is clearly warranted and is recommended as the best option for a future balance of reliability, cost, and significant emission reduction to meet international obligations.
The introduction of nuclear reactors for power generation provides a cost effective, safe, and reliable option for the progressive replacement of the current base load generation fleet. Direct replacement by small modular reactors on existing sites may be possible with significant savings when these become commercially available. Current work indicates lower specific capital cost outcomes and much smaller recommended exclusion zones for the plant allowing direct replacement on existing coal fired power station sites.

The United Arab Emirates with the support of South Korea has developed a large nuclear power program nine years from first analysis to startup, on time and on budget with a four year construction period, with far less industry and institutional resources than Australia already has in place. Australia could most likely improve on these outcomes given appropriate leadership. Progression towards a low emissions nuclear electricity generation outcome would provide international credibility and eventually go beyond all of Australia's current emissions obligations by supporting electrification of other energy intensive sectors such as transport.

Australian engineers and support staff would have no problems meeting world's best practice benchmarks for construction and operation of nuclear power plant given our oil and gas, mining, mineral, metals, and chemical industry history and experience from the construction and operation of the OPAL research reactor. Australian personnel are already supporting the nuclear power program of Egypt. Guidance on world's best practice for engineering and operating culture for the implementation of nuclear power programs is also readily available through a number of international agencies principally the International Atomic Energy Agency (IAEA).

Investigation into a possible Australian nuclear power plant equipment supply chain by the Westinghouse organisation has indicated a good potential for widespread industry and manufacturing involvement within Australia and possible export potential given support to improve some aspects of quality management.

Consideration of the use of nuclear power as a reliable 24/7 zero emissions generation source has been difficult for most of the Australian community to fully accept given legislated bans but understanding is growing and attitudes are now changing. Experience from around the world indicates that even in those societies with existing reliable and safe nuclear power programs the maximum support that can be expected is around 70%. The reasons for this outcome are complex but tend to focus on earlier Cold War fuelled anxieties around weapons proliferation, long term waste disposal, and potential accident outcomes sensationalised by technically challenged media.

Many sections of the Australian community remain fixated on old arguments against the introduction of nuclear power heavily influenced by early communist propaganda aimed at limiting nuclear weapon proliferation in Western states. At the political level there seems to be considerable fake ignorance on the cost of options to decarbonise the electricity sector given many politicians have already received the costing information provided in this submission. Balancing this are large sections of the electricity sector workforce who now understand the cost and technical limitations of renewable energy and the need for base load nuclear power implementation and advocacy. Recent polls have confirmed that the cost of electricity remains the most important factor for the community well beyond all other considerations. Nuclear power remains the only option likely to hold prices at current levels.

An extensive evaluation of modern reactor types currently proven and commercially available has led to the recommendation that selection of a pressurised water reactor (PWR) rated at 1000MWe for the first Australian power station replacements would currently be the most appropriate. This reactor type uses pressurised water to remove heat generated in the reactor core. The heated pressurised water transfers heat to a steam generator and the steam drives a turbine to generate electricity. This nuclear power station type was first developed in 1956 for the Shippingport 65MWe power station by Westinghouse under the direction of a design team led by Admiral H. G. Rickover using technology developed for the US naval reactor program. The PWR design concept evolution has proven to be the most durable and safest to the current time. Over 300 PWR commercial power plants have now been constructed around the world mainly in 600MWe to 1000MWe unit sizes. The engineering design has evolved to the point where modern plants on large grids have reached unit sizes of 1400MWe. After sixty years of construction and operating experience together with ongoing improvement facilitating life extension, the level of engineering can be considered to be well developed and mature.

There has only been one significant PWR incident, a core meltdown at the Three Mile Island USA plant. That incident caused only minor release of fission products from the core as a result of the inherent safety features of the PWR design. The Chernobyl and Fukushima reactors were not PWR designs but all lessons learned as a result of these incidents have been incorporated in plants now under construction. There are many parallels in the aviation and nuclear industries with the progressive engineering innovation of advanced safer design, construction, and operation. The nuclear industry has moved on from earlier incident problems just as the aviation industry has moved on from the Comet aircraft disasters although this fact seems to be lost on most commentators.

There is a small economic penalty selecting a 1000MWe unit as standard for the Australian grid rather than a 1400MWe unit size. Unit size selection has been limited by considerations of grid stability should one unit go off line unexpectedly although this is becoming very rare with modern nuclear plant. Building two 1000MWe units at each site will give a 10% saving through a more efficient use of labour and all site support facilities. At this stage it is not expected that more than four units would be built at any one site in Australia unless grid capacity is also extended. A construction period of up to four years is expected for a standard existing plant design.

It is recommended that the electricity generated should be sold directly into and underpin the existing market structure as a first option electrical supply supporting the transition to a low emissions electricity sector possibly through a revised National Energy Guarantee concept or similar. The introduction of low emission nuclear power removes a large flaw in the original National Energy Guarantee design concept which caused its demise.

Results of an initial investigation of engineering factors and community attitudes to the construction of nuclear power stations in the Latrobe Valley have been generally positive although there were concerns that there needed to be a more open dialog with government on all energy policy issues and not just a simplistic focus on a renewables option. A first investigation shows a large range of potential sites for nuclear power plant installation in Australia particularly when small modular reactors become commercially available.

The proposed investment and revised market structure is not seen to face any over-riding competitive or technical risk as no other option provides the investment certainty, security, reliability, emissions reduction, and competitive cost structure as the progressive integration of nuclear power into the existing Australian electricity grid.

Section 2 Development Requirements for Nuclear Energy Generation

2.1 Strategy Development

Consideration of a nuclear power program for Australia can be focussed on two stages of development. First, verification of the strategy by financial analysis and final engineering feasibility study basically in line with current Federal government outlines for the authorisation of major projects, and second, action supporting the implementation phase. Some overlap is inevitable and necessary.

At an early point in the process the Federal and State governments should act to remove all legislative bans prohibiting a final decision to proceed so that the work may be developed unobstructed and finally judged on it’s merits. It is clear that the existence of the bans has restricted expenditure and mindful focus on thorough analysis of nuclear power plant options to date particularly by government agencies. This has been a severe detriment to the establishment of a coherent energy policy for the nation. There seems to be some evidence emerging from earlier inquiries that the bans have acted to compromise the professional integrity of some key organisations mainly by attempts to overestimate nuclear costs and make renewable energy options more politically palatable by ignoring grid engineering requirements. On the other hand it may just be that many government agencies no longer have sufficient appropriately qualified and experienced professional engineering staff to lead and manage such work.

Stage one.
All work carried out in Australia to date including any results from this and other public inquiries, comparative studies summarised in this submission, and international studies could not immediately warrant the authorisation of a nuclear power plant program. The information is too general, not subject to rigorous engineering review process, and is barely at sufficient level to justify pre-feasibility study status. In many cases nuclear sector information provided to inquiries such as this, reflects lack of authentic personal practical knowledge, and world views formed by a technically challenged sensational media twenty years out of date. This is not an unusual situation but at this stage there seems to be sufficient positive information to justify further more rigorous investigation.

It is recommended that the Federal government initiate a full feasibility study process basically in line with current outlines for the authorisation of major projects. That study should follow a staged iterative process from generality to engineering detail, eventually covering site specific investigation and full engineering costing supported by budget quotations for key nuclear plant items. The outcome of this work will allow a rational investment decision based on factual evidence and should go some way to corralling extremes of view in the community. A wide range of guidelines for and lessons from major project feasibility studies is available on request.

Stage two.
The development of a new nuclear power program for Australia will require time and funding. The substance of the program involves the management of issues associated with nuclear material, ionising radiation, and related technological and social challenges. These intrinsic characteristics emphasise the need for careful planning, and investment in appropriate support infrastructure that provides high level legal, regulatory, engineering, human, and industrial outcomes. For successful preparation and promotion the integration of diverse knowledge is paramount. In addition the development process should incorporate feedback on assessment of all plans and decisions utilising diverse viewpoints and investigations that reflect world nuclear power implementation experience. Through these planning and development efforts Australia can create competent strategies and processes for human resources, economic benefit, and localisation strategies for a nuclear power plant program. A well developed final feasibility study should provide the initial guidelines and clear scope definition for the program.

Lessons from other countries accentuate the importance of many of these aspects and provide wide-ranging guidance on implementation. Key milestones formulated by the International Atomic Energy Agency for successful implementation are well developed and have evolved utilising expert practical experience from all countries with nuclear power plant programs over many years. These milestone requirements cover all aspects of national position, nuclear safety, management, funding and financing, legislative framework, safeguards, regulatory framework, radiation protection, electrical system, human resources development, stakeholder involvement, site and supporting facilities, environmental protection, emergency planning, security and physical protection, nuclear fuel cycle, radioactive waste, industrial capability, and plant procurement. The following sections summarise lessons from countries with successful long-term nuclear power programs and are recommended to form the basis for an appropriate development program for Australia.

2.2 A Strong National Commitment to the Nuclear Power Program

The execution of an effective Australian nuclear power program requires close collaboration with many local and international organisations. These diverse involvements need significant leadership and authority with clear roles and responsibilities for each organisation. Australia will have to reach a strong national consensus and a firm Federal government commitment to the program. Ultimately the decision is a political one that needs to be made on the basis of fact, not rhetoric, not conjecture, not hope or as a result of the widespread current tendency to sensationalise the topic by the media and other vested energy sector interests.

The Federal government needs to emphasise the long-term economic advantages to the overall economy and also the implementation of a nuclear energy program as a vehicle for introducing advanced engineering, science, and technology as well is satisfying the rising demand for low carbon emission electricity to replace retiring coal-fired plant. A successful outcome for the national commitment rests heavily on the strength and authority of a well qualified Nuclear Energy Program Implementing Organisation.

2.3 Nuclear Energy Program Implementing Organisation

Nuclear power electricity generation technology is the product of integrated knowledge from comprehensive early research and development over many decades, and a broad worldwide industrial base with extensive practical experience. Planning a nuclear power program and the assessment of viable options to introduce the first nuclear power plant requires various inputs from a range of disciplines and diverse sources in engineering, science, manufacturing, and social understanding. Such planning must not be rushed so the earlier this is started the more effective will be the outcome. The early planning phase has the highest impact on final cost outcomes of any phase in all major project work.

The International Atomic Energy Authority recommends the implementation of a Nuclear Energy Program Implementing Organisation an integral organisation that plays the central leadership and planning role by evaluating and disseminating the program options available based on expert level knowledge and experience. With the strong support of government the organisation can be established by organising competent human resources from diverse fields.

The government usually forms and leads the implementing organisation. The organisation structure should contain not only experienced major project engineering leaders but possibly scientists, economists, lawyers, and psychologists. A diverse expertise field is recommended including nuclear engineering, mechanical engineering, electrical and electronics engineering, civil engineering, physics, chemistry, geology, metrology, economics, politics, and diplomacy, with recruitment based on merit. A personnel track record of extensive and direct experience covering major technically complex projects with key safety requirements is essential. Through the invitation of foreign experts, the organisation can also secure the necessary high level knowledge that may not be currently available in Australia and increase the diversity of involvement and viewpoint. These high level personnel resources and the synergy effects within an initial planning program is seen as vital to ongoing success.

2.4 Government Leadership and Continuous Investment in Nuclear Infrastructure

In most developed countries such as USA and UK private companies are not willing to invest directly in nuclear power plant because of the financial risk particularly if a liberalised electricity market has been adopted as in Australia. In contrast to some large conventional investment programs, nuclear power does not have any funding return before the operation of the first plant which could extend over an initial development period of eight years. Australia would take approximately eight years to first power from launching a national nuclear power plant program with initial turnkey basis construction- four years planning and four years construction. The Federal government therefore should play a lead role in the program from the initial phase with investment funds, manpower selection, and appropriate planning.

With the existence of a firm financial guarantee from the government, local and overseas companies will actively participate in the national nuclear power construction program with reduced risk. The Australian government must also direct a strong commitment to overall regulation, long-term safe design standards for the plant, and occupational health and safety standards for both construction and ongoing operation, all key aspects for community acceptance.

A nuclear power program can be a significant part of a national economic development plan during the whole implementation period. In order to finance a large nuclear power program a strong economic base is required and ongoing economic development is a strong motivation for developing a long term nuclear power program. The implementation of a nuclear power plant program will provide Australia with a secure and stable electricity supply which will accelerate economic development and will generate sufficient revenue to construct further power plants. Similar development programs and funding cycles have been a great success in other countries ultimately developing high-tech infrastructure support industries with very good export potential but this has only been achieved through careful planning not a weak attitude to implementation.

Only government agencies can arrange and manage the required level of investment estimated to total $150B across Australia to eventually replace all retiring coal fired power stations, to ensure maximum benefit for the community and minimise risk. The Reserve Bank has noted that this time of unprecedented low interest rates is the perfect opportunity for government investment in productive new assets such as power stations. The secure cash flow guaranteed from electricity sales also provides an initial range of attractive options for private sector and superannuation investment support, possibly involving no taxpayer funding support and leading to eventual self funding.

It is recommended that the groundwork for an inevitable future nuclear power program is put in place beginning with the removal of all legislated prohibitions and increased support for familiarisation and training programs. There are many opportunities available overseas for intensive training for graduate engineers and scientists on operating nuclear power plants. The Australian general public is arguably the most in need of familiarisation opportunities given the failure of the education sector to appropriately cover nuclear science and its application benefits.

2.5 Strategy for Securing Manpower and Education Development

The nuclear energy program implementing organisation will need to establish and develop human resources recruitment and development programs to provide the manpower needed to launch, execute and operate a national nuclear power program. Australia currently has a number of appropriately qualified personnel in this area but also good track record in preparing education and training programs for future nuclear engineering and science development. To immediately secure high-quality human resources it is recommended that the government will need to guarantee high level positions with appropriate salaries for qualified persons coming from existing nuclear engineering areas or other appropriate fields, and provide good working environments.

There is huge confusion with the understanding of the differences between science and engineering across all levels of Australian society and particularly within the Australian media. A straightforward explanation is that science seeks to understand what is and engineering creates what never previously existed in many cases utilising science support. ANSTO is primarily a science organisation supported by engineering. An initial nuclear power program in Australia would be an engineering project supported by science. New advanced nuclear power concepts currently under development around the world are mostly a step-by-step progression of both science and engineering.

Experienced nuclear and civil engineering staff are currently available to commence an immediate final feasibility study program for a build time of four years after investment and site approvals. There are already a sufficient number of Australian engineers with nuclear engineering project management experience as a result of both periods of employment in this field overseas, at ANSTO, and after previous involvement with the construction and operation of the research reactor OPAL. Many of those engineers have moved on to other heavy engineering or consulting sectors and in some cases overseas but it is anticipated that there would be few problems recruiting key personnel with sufficient practical knowledge for the early phases of a national nuclear power program. Any areas of expertise not immediately available locally can be augmented by foreign staff for all phases of development including the operational phase of the first nuclear power plant. There are many ongoing requests for employment opportunities in Australia from overseas nuclear engineers.

Postgraduate nuclear engineering departments have already been established in Australian universities and these can be further advanced to include undergraduate engineering and training possibly with government providing support to encourage participation. Overseas training for younger personnel in countries with existing nuclear power plant programs can be very effective. For example South Korea has a world class engineering and science graduate university facility adjacent to operating and under construction nuclear power stations. Practical experience directly supported by academic learning is the key to successful outcomes.

Local consulting engineering companies have sufficient expertise and staff to carry out all of the basic engineering work not directly related to the nuclear island. The Australian construction sector workforce has all of the expertise necessary to carry out the implementation of a nuclear power plant program in Australia. There is currently no shortage of appropriately qualified personnel to implement an initial nuclear power plant program in Australia contrary to many inexperienced commentators.

2.6 Encouraging Industry Involvement in Business Plans

The first nuclear power plants will require government funding support because of the investment scale and approximately 60% of products and services will need to be locally supplied. It is recommended that the government commit to a strong long term plan to encourage ongoing and increasing local manufacturing and industry involvement. Overseas experience indicates that early government commitment can have very long term positive outcomes for local industry ultimately facilitating near total local supply of nuclear power plant. Preliminary investigations by potential overseas nuclear power plant suppliers has indicated that Australian industry is well-placed to not only support a such a program but also export nuclear plant and equipment to other countries that do not have advanced manufacturing capabilities.

Some local companies supporting a nuclear power plant manufacturing and services business may face a potential high investment risk compared with other industry sectors. This is mainly because of the quality management, safety, and integrity standards requiring appropriate inspection and documentation for much of the safety related plant and equipment. A long term program commitment would lessen this risk.

2.7 Localisation through Technology Transfer

It is recommended that the first two nuclear power stations are constructed on a turnkey basis. Based on the experience of building the OPAL research reactor at Lucas Heights it is clear that not all Australian domestic industries are immediately capable of meeting all of the requirements of nuclear plant quality management assurance for the construction of the initial nuclear power plants. Forcing non-turnkey construction can result in economic and confidence losses due to construction delays, low performance, and safety problems. In addition ensuring the capability and experience for non-turnkey construction by local suppliers requires extensive periods of evaluation. This is why it is recommended to introduce the initial nuclear power plants on a turnkey basis and to limit initial domestic roles to non safety related areas such as basic civil engineering and construction work with direct supervision by the foreign contractors. This would comprise approximately 60% of the work value required.

Over the first construction period a localisation plan can be developed by progressively starting non-turnkey basis contracts for the next nuclear power plants and to gradually increase the role of Australian industry most likely as subcontractors to foreign main contractors or when appropriate by joint venture.

Experience has shown that an appropriate technology transfer approach can be started by on-the-job training and on-the-job participation under the direction of foreign suppliers. A progressive system of joint design with one of the main foreign supplier balance of plant designers can be developed for architectural and engineering aspects of the program beyond major reactor plant. Local companies can gradually be trained or established for design, engineering, and the production of manufactured components given that long term programs are in place.

Localisation projects for nuclear power plant safety related component supply can also be spread over both research institutes with suitably qualified manufacturing facilities such as ANSTO, and other private enterprises under a well thought out quality assurance program with links to initial foreign suppliers. All foreign companies involved would be required to work with domestic industry within the contract term ensuring an agreed level of localisation. Localisation strategies should be carried out in close collaboration with foreign bidders for the development of a standardised nuclear power plant in Australia. With growing experience of construction and operation Australian organisations can subsequently undertake the main contractors role for later nuclear power plants. Overseas experience indicates that a carefully designed localisation program can lead to full local design and construction by the sixth plant.

Localisation policy can contribute not only to save foreign currency but also to increase nuclear plant capacity factors with a fast supply of spare components from local suppliers. Experience shows that a well planned localisation program leads to a decrease of unplanned outages and an increase of load factor with later plants. Quality management development and responsibility at local suppliers also develops a strong driving force to improve the quality of both nuclear and non-nuclear products leading to improved industrial and export competitiveness. This benefit of nuclear power technology transfer will also propagate into other supporting industrial manufacturing sectors.

2.8 Continuous Feedback and Review by Internal and International Experts

The process of critical reviews, feedback, and assessments of planning and decisions derived from diverse viewpoints is recommended to reduce the possibility of unexpected problems and delays to a nuclear power program. This process should be conducted for major milestones starting at the feasibility study development stage. Reviews and comments on a Australian nuclear power plant implementation plan should be made by local experts, foreign specialists from the IAEA, and countries with successful nuclear power implementation programs. All review and feedback results should be incorporated into the nuclear power plant development plan. This process of consensus development and multiple confirmations is instrumental in preventing costly mistakes for any technologically advanced and capital intensive project at each key planning and decision making step. The programme should utilise in-depth reviews and feedback from diverse knowledge and experience sources.

Beyond review by a high level experts further review and comment may be required from consulting engineering and construction companies to ensure a wide range of viewpoint on planning and technical decisions. The planning process should include the categories of nuclear reactor plant, balance of generation plant, localisation strategies, fuel and structural materials development, securing uranium fuel resources, radiation applications, radiation safety supervision and protection, fundamental research requirements, human resources and industry development. This approach is particularly important for the initial site selection processes for nuclear power plant ensuring appropriate engineering feasibility and leads to overall greater confidence in the final selection decision. A strict review process with clear recommendations will also obviously contribute to reducing the project risk profile perceived by all stakeholders and particularly the Australian public.

2.9 Active International Cooperation and Understanding of Global Trends

A nuclear power program cannot evolve competitively in isolation because it must be tailored to meet a very large range of international standards and codes. Close international collaboration and study of world technology and safeguards are among the most important activities with the launch of a nuclear power program. Australia is already actively involved through ANSTO and other government agencies with many aspects of international nuclear programs for improving technical capability and obtaining high-quality human resources support. This involvement can easily be extended to cooperation with those countries with existing nuclear power plant programs to develop international confidence in Australia's plans and implementation program. Australian energy planners will need to consider and incorporate the results and trends of international activities into local plans.

The international nuclear power sector is one of the most openly collaboratively industrial sectors in the world. There is generally no barrier to the provision of engineering data or other relevant information from both international agencies, national governments, and nuclear power plant operating organisations from around the world. Advice covering all major aspects of a nuclear power plant program including the current state of technological development, economic efficiency of plants, the know-how of local nuclear power plant programs, the construction and operation experiences of nuclear power plants, the process of site selection, fuel cycle policy, strategy for securing nuclear fuel, and financing options for nuclear power plants, is all readily available. The IAEA is an excellent initial source of information for all aspects of nuclear power program development and ongoing operation.

2.10 Concentrating All Appropriate Resources and Efforts on the Nuclear Power Generation Activities

In the initial period most states starting a nuclear power program have shortages of the most needed resources from manpower and finance to industrial capacity. Australia does have a good track record mobilising appropriate resources for large heavy engineering construction programs. However the initial development period for a nuclear power program will require a wide range of experienced staff to guide all aspects of planning, site selection and implementation.

As noted above it is recommended that the first two plants be constructed on a turnkey basis which considerably lessens the detailed engineering workload required in the initial period. The lessons from overseas show that a concentrated effort putting in place an experienced initial guidance group as quickly as possible is an important factor for a successful program outcome. The initial group can be supplemented by staff from overseas if local personnel are not initially available.

Australia is already a party to all international nuclear safeguards conventions. This ensures that the focus can remain strictly on a nuclear power plant program for the generation of electricity and not be diverted on questions of weapons production from the local or international community. The reactor types recommended for installation in Australia are the least suitable for any long term weapons development program.

2.11 Benefit of a Standard Nuclear Plant Design

Australia has had the considerable but dubious benefit of time to analyse overseas options and experiences in the development, construction, and operation of nuclear power plant for the generation of electricity as a result of the extensive delay for the introduction of such a program.

Many countries had initial concerns over the supply of enriched uranium fuel and opted to diversify nuclear plant designs to enable the use of natural uranium fuels. This situation has gradually become of less concern with the appearance of several enrichment uranium suppliers over time. Enriched uranium is currently a buyer's market due to the strong competition among several international providers. The concept of nuclear fuel banks and standard fuel designs has also eased many fuel supply concerns. Past nuclear plant design diversification has led to lack of plant commonality and failure to benefit from standardised design construction and operational efficiencies.

The nuclear engineering technology benefits or problems with differing plant concepts have become very clear and the major point of consideration has now come down to the size of individual units and how they might fit a particular electricity grid. When the electrical engineering performance of the Australian grid is analysed an initial nuclear plant size of 1000 MWe is considered to be the best fit in locations with grid connections supporting existing large power plants. Large installations can be later supplemented by smaller plants in the 100 to 600 MWe unit size where load and grid capacity could not realistically manage supply from the larger units.

Nuclear power plant designs now available range from those plants with a long history of development and operation to the point where they may be considered mature and well proven designs to those still on the back of an envelope. Sections of the nuclear reactor industry will always be fixated on the innovative future design concept which embodies ultimate safety and the possibility of very low cost of electricity production. The first nuclear power plant project manager, US Admiral Rickover famously noted the contradictions arising with this conflict between the academic and the practical applications of nuclear power and the public confusion it does generate.

It is not appropriate for Australia to pursue first of a kind reactor types in an initial nuclear power program however attractive they may appear on paper. In previous decades there may have been good strategic and economic reasons to pursue a range of engineering designs in particular countries. The long international history now available allows Australia to focus much more clearly on a single practical and proven outcome best suited to the real engineering, strategic, and economic requirements for local power generation. It is recommended that Australia settles on a long proven design that has evolved and developed over the course of much construction and operational experience as noted above and to standardise construction until a better option is demonstrated and proven in operation.

A key aspect of this recommendation is an understanding of the documentation and supply chain maturity underpinning this long experience as evidenced by the South Korean nuclear industry. Supply chain maturity has become the major overriding factor for consideration of any nuclear power plant program. It has been highlighted as a serious problem in the USA and a number of countries with re-emerging local construction were manufacturing equipment and personnel expertise must be re-established. International experience has shown that reactors with a long continuous development heritage can be constructed on time and on budget and subsequently operated at very high availability, all crucial aspects for any initial program development for Australia. Tight project management control over personnel capabilities, equipment supply, construction period, and early operation on a standard plant design, substantially overrides most other considerations including theorised engineering finesse or operational niceties because of the overriding financial implications of the high initial capital expenditure. Control of the implementation critical path has become super critical with all high capital investments.

2.12 Selection of Radioactive Waste Disposal Sites

A number of countries have taken as long as twenty years to gain public acceptance for their low and intermediate level waste storage sites. This process is already underway in Australia for low and intermediate level waste storage albeit originally made difficult to manage through selective site focus and local challenge. When an addition storage facility for used fuel is required there are alternate sites available which have full community support, lower capital cost, and conform more closely with international guidelines.

Energy planners need to recognise and consider radioactive waste storage and disposal facilities from the beginning of the nuclear power program by launching positive and extensive public awareness and acceptance activities. What has emerged for most international nuclear power programmes is the need to consider long term used fuel storage facilities from the time of beginning any nuclear power program. Considering the very long institutional control period required for the storage of used nuclear fuels the process of public discussion and legislative framework should be started as early as the preparation phase for the first nuclear power plant.

The work carried out for the Nuclear Fuel Cycle Royal Commission based in South Australia has provided sufficiently detailed pre-feasibility studies to commence final feasibility work for the implementation of used fuel storage in Australia. It is recommended that used fuel storage be available ten years from first plant commissioning and that storage allow for eventual fuel recovery. There are many lessons to be taken from countries such as Finland where facilities for used fuel storage have public acceptance and are now under construction. Equally the lessons available from countries such as the

USA which has had extreme difficulty gaining public acceptance for used fuel storage are particularly important in assessing how this may be achieved in Australia.

The economic viability and revenue streams defined for imported used fuel storage as part of the work carried out by the South Australian Royal Commission could in the extreme provide sufficient revenue to fund the development of a nuclear power program for all of Australia. This massive economic opportunity cannot be overlooked and there are no engineering issues that could not be managed by Australian industry. The engineering design and construction factors involved are all well covered by current world class underground mining experience in Australia and could be implemented in a number of alternate areas. The implementation of a used fuel storage facility for both an Australian nuclear power plant program and those countries with less secure geological or other location issues remains an outstanding economic proposition to be taken up at some stage.

2.13 Preparation of the Nuclear Power Plant Safety Regulation System

Australia is fortunate to have a world-class nuclear sector regulator, the Australian Radiation and Nuclear Safety Agency (ARPANSA) although some work is required to extend the current regulatory oversight of that organisation into a nuclear power plant sector. The preparation of a regulatory framework for nuclear power can be a time consuming and thorough process potentially resulting in a heavy workload for the organisation.

Under the guidance of the International Atomic Energy Agency most technical codes and rules are readily available or can be supplied and adapted from countries with existing nuclear power plant programs including the country of the first installation power plant reactor origin. However considerable care is required to resolve potential conflicts and confusions at various levels of the regulatory development process which can arise from different cultural attitudes and language interpretation differences between countries.
It is recommended that the regulatory development process must take high priority with sufficient funding and manpower and high recognition of the necessary timescale to ensure that the subsequent nuclear power plant program licensing activities do not result in delays to the investment and construction program. Funding for this activity will be needed as soon as an investment program is established.

The nuclear regulator must remain completely independent and separate from the nuclear power program manager. The regulator must be provided with sufficient ongoing funding for all activities from development to inspection, to ensure that current problems now seen across a number of other regulated industries in Australia never arise otherwise community acceptance will be completely compromised.

2.14 Clear Definition of Responsibility and Contractual Rights in the Nuclear Power Plant Construction Program

It is recommended that at least the first two possibly four nuclear power plants should be obtained on an all-encompassing turnkey basis. This would require only minor technical input from the Australian client group and then only in areas where local knowledge and supply is required for site evaluation, civil engineering and non-safety related balance of plant supply.

The contract for the first nuclear power plant, must define very clearly the division of responsibilities between the supplier and the client. Any ambiguity can lead to wasteful disputes and possible delays in supply and construction resulting in major loss of time and money. It is worth starting very early in the program to ensure that contract documents for turnkey nuclear power plant supply are carefully developed and considered to ensure coverage for any potential eventuality. There is now sufficient experience from around the world to foreshadow issues that can arise and procedural methods available to ensure turnkey contract procedures run as smoothly as possible. It is recommended that pro-former contract documentation be developed during the final feasibility study phase to ensure all potential issues are identified well in advance.

Selection of an existing plant design from a supplier with a long track record building and operating similar plants is major step in mitigating project contract risk for the first installations. Australian technical and legal experience gained across a wide range of recent major heavy engineering development projects can be utilised to appropriately review and negotiate turnkey contract proposals.

2.15 Insurance Requirements

Ever since the first commercial nuclear power reactor construction there has been a concern about the possible effects of a nuclear accident, coupled with the question of who would be liable for any resulting third-party consequences. This concern was based on the supposition that even with the reactor designs licensable in the West a cooling failure causing a core to melt could result in major consequences similar to those of the Chernobyl disaster in 1986 and Fukushima in 2011. It was supposed that the damage caused would be extensive creating the need for compulsory third-party insurance schemes for nuclear operation and international conventions to deal with transborder damage.

On the other hand it was realised nuclear-power makes valuable contributions to meeting the worlds energy demands. In order for it to continue doing so individual operator liability had to be curtailed and beyond a certain level risk had to be socialised. It is now understood that the state needs to accept responsibility as insurer of last resort, as with everything else in industrial societies, though attempts have been made to represent this as a specifically nuclear subsidy.

Western designed nuclear installations are sought after business by international insurers because of the high level of engineering development and advanced risk mitigation standards. This has been the case for over fifty years. Apart from the Three Mile Island case the claim claim history has been very good. Given this performance record the Australian government may choose after due consideration to self insure all nuclear power plant installations.

2.16 Civil Nuclear Industry And Proliferation Considerations

The term proliferation refers to the rise in the number of states in possession of nuclear weapons. It is sometimes extended to describe the misappropriation of weapons or fissile material by subnational groups. The term non-proliferation refers to the political or technical means implemented to combat proliferation. One line of understanding is that over time all major sovereign states will obtain nuclear weapons for deterrent reasons alone.

The first application of nuclear fission was the development of nuclear weapons and not nuclear power. Fission cannot be uninvented and there will always be some risk that a state or a large super national group will decide to make nuclear weapons, to devote to that purpose the required financial and technical efforts and to bear the political consequences. On the other hand, no country opting for proliferation has yet done so by misappropriating materials or facilities covered by commitments to peaceful use such as nuclear power under IAEA safeguards.

The real question is “does the development of nuclear energy for civil applications increase or decrease the risks of nuclear weapons proliferation?” Although possessing a civil nuclear facility within its borders may give a state quicker access to the necessary fissile materials, the civil nuclear industry also means conformance with international agreements and treaties, commitments not to misappropriate materials, and international inspections with highly sensitive and effective measuring devices. Such commitments make it much more difficult to carry out clandestine operations as can be witnessed from the North Korean and Iranian experiences.

Nuclear weapons proliferation is essentially a matter of political will, not technology. It is difficult to determine exactly how proliferating a technology can be. Different factors must be taken into account, like the ease of access to pure concentrated fissile material, detectability, throughput etc.

Most nuclear power technologies are not sensitive in terms of nuclear weapons development. Light water reactors such as the PWR produce plutonium of poor military quality and are easy to monitor or control since they must be shut down to unload the fuel. Online refuelling reactors such as Magnox, AGR, CANDU, and RBMK, types have the intrinsic physics capability to produce weapon grade plutonium and can therefore be more carefully controlled and safeguarded. The most sensitive technologies are the centrifuge enrichment process and spent fuel reprocessing if associated with low burn up fuel.

Australia has a long history managing proliferation considerations as a result of the export of uranium over many decades, earlier research into potential enrichment technologies, and operation of the ANSTO facilities. The introduction of nuclear power is not expected to introduce any additional nuclear materials management issues beyond those already undertaken as part of current domestic and international programs. The engineering scale of operations will certainly increase given the quantity of material to be managed. The early implementation of a used fuel storage facility would lower management control issues.

2.17 Leadership and the Project Management Team

The successful Manhattan project and the following US Navy nuclear submarine program wrote the rule book for leadership and project management requirements for subsequent commercial nuclear power programs. In fact these nuclear-based engineering programs became the leadership and project management benchmark for all major capital intensive technology programs from offshore oil exploitation to the space program.

Recent US and European nuclear power programs have run into cost and project management issues as a result of breaking a cardinal rule well understood by engineers, starting construction works when the final detail design was only 50% complete. An extensive study of these controversial programs by the Massachusetts Institute of technology highlights how these issues have impacted recent nuclear power plant programs in the West.

A nuclear power program management scope for Australia would cover all of the factors noted in this submission from safety culture development program, feasibility study, engineering design, construction, commissioning, operations, maintenance, through to decommissioning and return of the site to original status. In other words the total life cycle. The foundations for a successful (or difficult program) are set by the initial leadership and project management team. For most large complex projects the key scope and detail issues are established, optimised, and settled in principle, in the later stages of the final feasibility study phase. It becomes progressively more difficult and expensive to change direction as the program proceeds.

It is recommended that the program leader and project management team is appointed as early as possible in the final feasibility study stage and go on to implement the program at least through to initial operations. It is essential that the initial team include the future operations manager and key technical managers. A fundamental leadership attribute for the program manager is an understanding of the needs of all stakeholders and participants including foreign equipment suppliers. An understanding of the safety needs for employees and the community, and the capabilities of designers, suppliers, constructors, and operators is essential to ensure smooth integration of all facets of the project.

A nuclear engineering background would be useful but more important is a full and total understanding of how staff in the above areas manage their work and the boundaries or interactions with all of the overall team managing the discipline interfaces. Balancing the application of local and foreign engineering standards to ensure cost and time is not compromised in the project is just one example when large value mechanical and electrical equipment is sourced from foreign suppliers.

Section 3 Other Relevant Matter

3.1 Nuclear Power Plant Siting

Siting is the term used to describe the process used to select where a nuclear installation is built and whether the proposed location is suitable. Siting is one of the important decisions in the early stage of a nuclear energy program. The selection and evaluation of a site suitable for a nuclear installation are crucial processes. They can significantly influence the costs, public acceptance and safety of the installation. Poor planning and lack of knowledge can lead to faulty decision-making and can cause major delays to the project. Siting is a multifaceted process, involving many types of site characteristics. Those characteristics can affect the safety of a nuclear installation over the whole period during which it is planned, constructed and operated.

Site characteristics that can affect safety include earthquakes, geotechnical phenomena, volcanism, flooding, meteorological events, human-induced events, dispersion of radioactivity and feasibility of emergency plans. These are also called safety-related characteristics. There are also non-safety-related factors: local community acceptance, grid connection access, topography and foundation characteristics, security considerations, technology, economics, availability of cooling water, and transport infrastructure to cater for heavy component access.

In Australia the siting of nuclear power plants is likely to be one of the most contentious issues. Overseas evidence suggests that even in countries that rely on nuclear power for a large proportion of their electricity needs, there can be a considerable amount of community opposition to the nuclear industry and siting issues are often a source of significant conflict. In Australia, approximately half of the population currently opposes nuclear energy and two thirds say they would oppose a nuclear power plant in their local area. In order for there to be a thorough informed debate about nuclear energy, it is recommended that the sites that are best suited for nuclear power plants are identified at the earliest possible stage.

Using four primary criteria, nineteen locations across Australia have been identified as the most likely sites for nuclear power plants. Six secondary criteria were then used to identify potential issues at these sites. Further investigation would need to be carried out before it could be concluded that any of these areas are definitely suitable for nuclear power plant defined in this submission. There are a number of other areas that would be suitable for current designs of small modular reactor nuclear power plant.

3.2 Nuclear Power Plant Safety and Radiation Protection

The International Atomic Energy Agency Convention on Nuclear Safety is an agreement that sets out the guiding principles under which the international community accepts responsibility for the safety of all nuclear related installations under their various jurisdictions. The objectives of the Convention are;
- To achieve and maintain a high level of nuclear safety worldwide through the enhancement of national measures and international cooperation including where appropriate, safety related technical cooperation;
- To establish and maintain effective defences in nuclear installations against potential radiological hazards in order to protect individuals, society, and the environment from harmful effects of ionising radiation from such installations;
- To prevent accidents with radiological consequences and to mitigate such consequences should they occur.

The Convention was adopted in June 1994 by a Diplomatic Conference convened by the International Atomic Energy Agency (IAEA) an agency of the United Nations. The scope of the Convention defines a wide range of applications that apply to the safety of nuclear installations. There are provisions to cover, the implementation of an appropriate legal, regulatory, and reporting framework, the review upgrading or closing of existing nuclear installations, the focus on nuclear safety as a priority, ensuring adequate financial and human resources to support appropriate safety levels, keeping radiation exposure as low as reasonably achievable, and providing and testing emergency plans.

Safety requirements for location, design, construction, and operation are also covered in the Convention. There is provision for joint review and information sharing by the contracting parties to the Convention and for the ongoing management review of the Convention processes and documentation. Australia is a signatory to the Convention Supporting the implementation of all aspects of the Convention is a wealth of documentation and training resources incorporating the research and experience of members of the International Atomic Energy Agency.

The extent of knowledge is huge and most of the information can be traced back to origins in the large research programs carried out for military purposes in the mid to late 20th-century. The extent of information available ensures that all elements of nuclear safety and radiation protection engineering for new or existing installations can be adequately covered. Ionising radiation and its health impacts are well understood and there are established international safety standards that can be utilised for all operational practice.

The generation of electrical energy is now the major use of the nuclear fuel cycle. All industrial activities involve some risk to human health and safety. No means of generating electricity is risk-free and nuclear-power exhibits the best safety record. The choice of any technology or mixture of technologies will inevitably be a matter of balancing different costs, benefits, and risks.

The radioactivity of uranium has potential health impacts when it is used to produce electricity. Ionising radiation is produced when the nucleus of an atom disintegrates, releasing energy in the form of an energetic particle waves of electromagnetic radiation. Radiation exposure can arise from sources outside the body (external exposure) or from radioactive material inside the body (internal exposure). Radioactive material can enter the body by inhalation or ingestion in water or food. Some parts of the body are more sensitive to the effects of radiation than others, and some types of radiation are inherently more dangerous than others, even if they deposit the same level of energy. To take these characteristics into account, tissue weighting factors and radiation weighting factors have been developed. These can be combined with a measurement of absorbed dose of radiation to give an effective dose. The unit of dose is the sievert (Sv). The millisievert (mSv), 1000th of a sievert, is the more usual unit for the sorts of exposures found in day to-day life.

People are continuously exposed to natural background radiation and this may vary substantially from place to place. The worldwide average is 2.4 mSv/year with maximums above 12 mSv/year depending on local geology and altitude. There is no evidence that this variation leads to any differences in terms of human health. Evidence is emerging that the small background radiation exposure we experience may have an overall beneficial effect. The dose rate estimated for individual members of the public from nuclear power generation is very low, on average 0.005 mSv/year for people resident within 50 km of a pressurised water reactor power station. To place radiation exposure to the public in perspective, a person taking a return flight from Melbourne to London would receive the same dose (approximately 0.25 mSv) as someone living fifty years in the vicinity of such a power reactor. Ionising radiation exposure can only be detected and measured by instruments as the body has no natural detection mechanism for other than extreme situations.

The International Commission for Radiation Protection (ICRP) issues guidelines on safety standards after ongoing review of the emerging scientific information from around the world. The standards are used as the basis of design criteria for all aspects of nuclear power plant radiation exposure for both workers and the general public. The following levels of exposure to ionising radiation are the generally recommended limits above background levels:
-1 mSv/year above natural background radiation for the general public
-100 mSv over five years for occupational exposure

On a comparative basis the safety record of the nuclear industry is orders of magnitude better than coal or oil or natural gas generation of electrical energy. The reasons for this outcome can be traced back to both the level of investment in safety related plant engineering and well understood international safety standards and regulation. Comprehensive incident reporting and dissemination of resulting information under the guidance of the IAEA has resulted in a worldwide culture of safety driven continuous improvement for both existing nuclear power station operations and new designs. General community concern remains related to the potential risk of a single serious accident similar to those at Chernobyl, Three Mile Island, and Fukushima nuclear power stations heightened by sensationalist media replay and exaggeration. Early cold war propaganda to limit nuclear weapon acquisition also used safety sensationalism to dissuade many communities from any involvement in nuclear related activities and this aspect has been difficult to counter in Australia at the political level.

The Three Mile Island accident in March 1979, when an operational failure caused severe damage to the reactor core, injured no one and led indirectly to the release of only minor amounts of radioactive elements. After extensive expert review, no measurable impact on health was found. It demonstrated the robustness of the PWR design and the value of containment structures required in all Western power plants.

The Chernobyl accident in April 1986 released radioactive gas and dust high into the atmosphere and directly caused the deaths of twenty eight response workers and emergency staff. A further nineteen have died since with many these deaths associated with lifestyle choices. The design of the reactor was inherently unstable and there was no containment structure a key feature of most Western designs. The accident occurred at shutdown power levels as staff were testing safety performance parameters - outside the prescribed operating limits for the reactor and in violation of existing regulations for the safe operation of the reactor. Over the time since the accident there have been thyroid cancers in children (mostly in Belarus and Ukraine) with about 160 deaths predicted. The World Health Organisation considers that there may eventually be 4000 further cases of cancer in the workers involved in the clean up of the site who received larger doses than those living nearby.

The Fukushima accident on 11 March 2011 was initiated primarily by the tsunami following the Tōhoku earthquake. Immediately after the earthquake, the plant reactors that had been operating, automatically shut down. The tsunami disabled the emergency generators that would have provided power to control and operate the pumps necessary to cool the reactors. Insufficient cooling led to three nuclear meltdowns, hydrogen-air explosions, and the release of radioactive material from 12 March to 15 March 2011.

There was a twofold reaction to the accidents. Public opinion forced a slowdown or hold on the power reactor construction programs by many governments around the world and regulators undertook a wide range of design and operational reviews based on the outcome of the accident investigations. Public concerns based on real or imagined information remains strong. Over the period since the accidents the international technical and regulatory community has moved forward to the point where engineering design, equipment development, and operational practice has made very considerable advances to enhance general safety for both existing and new designs of nuclear based electricity generating capacity.

After the accident at Chernobyl an international nuclear safety regime was fully developed. This regime is based on binding international conventions, internationally accepted safety standards, and an extensive system of peer reviews. IAEA safety standards are periodically revised and updated to reflect the state of the art for nuclear safety, and to include new areas, such as the nuclear fuel cycle; modern techniques such as human/machine interaction, and assessment of the probability of occurrence of certain postulated accidents. These standards are now accepted worldwide and although not obligatory, have been adopted by several countries on a voluntary basis, and a used as the basis of national regulations in numerous other member states.

The fundamental safety requirement for all nuclear power stations is to ensure that no radioactive material or ionising radiation from the area of the heat producing nuclear reaction is transmitted to any location at a level adversely impacting human safety or the environment. This isolation requirement is achieved in a number of linked ways.
-- Control of the nuclear reaction, most commonly by neutron absorbing control rods inserted partially or wholly (for shutdown) into the reactor core. The control rods are moved automatically through the station instrument and computer control systems. The control system monitors all operating parameters to maintain defined operating power levels or to shut the reactor down in the case of any emergency condition.
-- Removal of heat generated in the fuel from the nuclear reaction, typically achieved by a cooling water circuit for a nuclear power station.
-- An engineering design which ensures that all radioactive products or components are isolated or contained in locations away from possible harmful contact.

In a modern nuclear power station design the isolation barriers start with fuel metallurgy designed to hold or contain radioactive products both internally and within a surrounding metal barrier. A fuel element is now typically a string of ceramic uranium oxide pellets that are held in a sealed metal tube. The second isolation barrier is a fully enclosed reactor heat transfer system most commonly water in a steel pressure vessel, pumps, heat exchanges, and associated pipe work. The third isolation barrier is an enclosing building designed to be leak tight in the event of any release of pressure from the reactor cooling system. The reactor containment building may itself consist of a number of layered barriers and is generally now designed to withstand external breach by an aircraft crash. The ongoing integrity and effectiveness of the engineered safety isolations noted above is maintained over the life cycle of a modern nuclear power station principally by carefully managed design, construction, operation, and maintenance processes taking into account all of the experience and lessons from the past.

A key part of the design is the incorporation of systems capable of monitoring and assessing all plant operating conditions or any deviation from operating limits, and initiating immediate action to correct any deviation ultimately by shutting the reactor down. The ongoing development and reliability of modern computer-based systems now allows a much wider range of monitoring, assessment, and control systems to be incorporated supporting plant operators with overall control information than was available for past designs. Even given the sophistication and reliability of current instrumentation systems it is normal to allow at least three levels of isolated redundancy within the design and installation of control systems for modern reactors.

Above all of the engineered safety features that might be incorporated in design, construction, and operation of modern nuclear power stations, or any similar facility requiring high reliability of operation, the experience of the past shows that the safety culture of the controlling organisation is of paramount importance. The overall safety culture of the organisation reflects on every aspect of nuclear plant design construction and operation through the balance of factors and sometimes conflicting interests that need to be managed. Factors such as time, finance, customer issues, staffing levels, operating principles, and maintenance philosophy can all have an influence on how safety matters are viewed and resolved within the controlling organisation.

An uncompromising focus on safety leadership and safety responsibility at the most senior executive levels and on down through all levels of line management has proven to be the most important directing influence in the development of best practice safety culture for any organisation. Safety monitoring or advisory or training roles within the organisation are important but ultimately these roles should only support executive management responsibilities and not act as a substitute or alternate. Experience has shown that large safety divisions in high reliability organisations can be counterproductive with many management and staff abrogating responsibility for safety to the safety division or at best allowing confusion of responsibility. The ultimate and most desirable outcome is that all personnel accept personal and collective responsibility for safety leadership within their sphere of influence and to the best of their ability.

There are now many excellent (and poor) safety culture examples documented across the nuclear power sector, across countries, and across all other industries to provide both benchmark examples and guidance for the highly effective and safe operation of nuclear power plant. Extensive investigations of a number of serious accidents particularly in the international oil and gas industry have highlighted the need for effective management of organisation safety culture covering all levels of operation. The key areas of attention for the development and ongoing maintenance of an excellent safety culture include owner and management commitment, workforce empowerment, workforce hiring and training methods, pre-project planning and risk mitigation, and prompt accident and near miss investigation by well trained local staff with timely implementation of improvement recommendations.

The nuclear power industry currently has a good safety understanding and a good track record as a result of both the general experience of the past and the considerable lessons learnt from the Three Mile Island, Chernobyl and Fukushima experiences. The IAEA has a range of programs supporting information exchange and specific training for safety culture understanding to ensure that all nuclear power plants can be designed, constructed, and operated with an ongoing excellent safety record.

3.3 Reactor Selection

Recent OECD and local studies confirm that action to introduce nuclear power is the only economically viable option to meet minimum cost of supply, maximum reliability of supply, and key environmental imperatives for the Australian electricity sector. The majority of important aspects concerning the possible introduction of nuclear power and associated facilities were well covered in a general sense by the South Australian Royal Commission into the Nuclear Fuel Cycle. A subsequent more intensive investigation of the South Korean nuclear power industry and supply chain in 2018 by Dr Robert Barr, Mr Robert Parker, and the author confirm that it is currently the only economically viable option worldwide for supply and all aspects of support for the introduction of modern nuclear power plant for Australia. Detailed reports on the investigation are provided on the Australian Nuclear Association website. Detailed in country investigations have also been previously carried out in France and the USA.

The standard reactor plant recommended for installation in Australia is the South Korean Advanced Power Reactor 1000MWe (APR1000) an evolutionary pressurised water reactor (PWR) which has been developed from the proven design of the Optimum Power Reactor 1000MWe (OPR1000). The design is based on the experience that has been accumulated through the development, construction, and operation of the OPR1000, the first standard pressurised water reactor (PWR) plant in the Republic of Korea. The APR1000 also utilises the state-of-the-art proven technology and incorporates a number of advanced design features from the APR1400 design and construction program to meet the needs for enhanced economic goals and to improved plant safety.

A total of ten OPR1000 units are in operation with excellent performance. The APR1000 benefits from the proven nuclear power plant design technology gained through repeated construction and long term operating experience of the OPR1000. The main design philosophy of the APR1000 incorporates several important development features, such as the enhancement of safety, the utilisation of proven technologies, the creation of a common design adaptable to each country where it is built, and a stable construction cost comparable to that of currently operating PWRs. Achieving a higher level of plant safety is an important goal among the various development policies. The following safety goals in terms of measurable criteria are established to upgrade the plant safety level by one order of magnitude compared to those of currently operating plants in the Republic of Korea.

The major design requirements for safety and performance goals set for APR1000 are as follows;
Type and capacity : PWR, 1050 MWe
Plant lifetime: 60 years
Seismic design: SSE 0.3g
Safety goals: Core damage frequency < 1.0E-5/RY
Large release frequency < 1.0E-6/RY
Occupational radiation exposure < 1 man -Sv / RY
Plant availability: more than 90%
Unplanned trips: less than 0.8 per year
Refuelling interval: 18 ~ 24 months
Operability: Fully Digitalised
MMIS Construction period: 40 months

The cost estimate for two adjacent build APR1000 (2000MWe) built in Australia is as follows:

	A$M
Nuclear steam islands	1200
Generation and electrics	1200
Mechanical plant	1600
Instrument and control	900
Construction materials	1600
Site labour	3100
Engineering and licensing	900
Project management	900
Commissioning and fuel	500
Contingency	2100
Total capital two units	$14000m

Equivalent to A$7000/MWe

A nuclear power alliance with South Korea would promote a wide range of flow on benefits for the Australian heavy engineering sector given South Korean promotion of the need for well supported technology transfer. It is recommended that the Inquiry committee contact the Korean Nuclear Association an agency of the South Korean government and visit a number of operating and under construction nuclear power plants and associated facilities to gain a full understanding of how a well managed nuclear power program supplying low cost electricity leads to a vibrant economy. My colleagues and I would be pleased to support that investigation. A significant level of knowledge of nuclear, electrical, and civil engineering is required to ensure full understanding and accurate translation of technical and cost information from the South Korean context to application for Australia. A long experience introducing complex modern technology new to Australia from foreign suppliers is also useful.

3.4 Fuel Management

The fuel that is used in most PWR nuclear power reactors today is based on ceramic uranium oxide. The design of the fuel and its fissile content varies between different reactor types. The fuel in light water reactors, such as pressurised water reactors and boiling water reactors, and in modern gas cooled reactors, uses uranium enriched to increase its fissile uranium-235 content up to 5 per cent. A 1000MWe PWR core typically contains between 120 and 200 fuel assemblies. Each fuel assembly contains around 500 kg of uranium oxide and can generate about 200 million kilowatt hours of electricity over its lifetime in the core. A reactor of this size discharges about 40 spent fuel assemblies per year containing about a total of 20 tonnes of uranium oxide.

The nuclear fuel is considered spent when it no longer can sustain the fission reaction. In a PWR, this takes about three to seven years, depending on the fuel and its location in the reactor core. When it is removed from the core, spent fuel looks similar to a fresh fuel assembly, but remains hot from decay heat and is highly radioactive. Spent fuel is transferred to a storage pool since water provides both good cooling and shielding material. After a period of cooling, it can be transferred to a dry storage facility.

The safe, secure and sustainable management of spent fuel from nuclear power reactors is key to the sustainable utilisation of nuclear energy. This covers many technological aspects related to the transportation and storage of spent fuel, and high level waste disposal generated from spent fuel reprocessing if this is utilised. In some countries, the uranium and plutonium remaining in spent fuel are recycled as mixed oxide (MOX) fuel in thermal reactors, saving natural uranium resources. Future advanced fuel cycles based on next generation reactors aim at making nuclear energy production almost independent of uranium natural resources and will dramatically reduce the generated wastes. This is one reason why a used fuel storage facility should allow for the eventual recovery and re-use after processing of remaining fissile material.

3.5 Risk Analysis and Risk Mitigation

Humans are poor risk managers, focusing too much on consequences and too little on probabilities, something insurance and lottery salesmen relish. The original military application of nuclear fission ensures that exaggerated consequence factors promulgated by detractors causes the greatest general community concern with the peaceful uses of nuclear science and engineering.

Within a nuclear power plant program, risk can arise from many sources, feasibility studies and site selection, licensing, design and construction, operational processes, training processes, social responsibility including communication with the public, outside influences including natural disasters and economic factors, and financial processes. Many different sources of information can be used to identify potential risk, such as industry specific or generic risk exposure checklists, flowcharts of critical processes, examination of contracts, physical inspection, analysis of financial statements, and employee, contractor, or regulator interviews. A wide-reaching integrated information system needs to be used to provide continual updates covering the acquisition of assets, operations and changing relationships with outside entities and stakeholders.

A major objective of early risk identification is to avoid the unintentional or unconscious retention of risk that occurs when a source of performance variability remains obscure or undiscovered, and therefore, not part of the formal risk assessment management system. After identifying sources of risk, there is a need to characterise the risk. Deterministic and probabilistic safety analyses have been used extensively in nuclear power plants around the world for assessment of nuclear safety risk. These techniques can be expanded, to measure and assess the risk of non-nuclear events, such as protecting plant investment, maintaining plant availability, and analysis of licensing issues.

Risks identified and characterised are next evaluated with respect to the best combination of techniques for mitigation. Three generic categories of risk management techniques include reduction of risk, retention of risk, and transfer of risk. In practice one or more of these techniques is likely to be used in managing risks associated with a particular issue. It is also important to examine whether the use of a particular solution takes account of interaction amongst other different areas of risk. For example, in the implementation of a design change to improve nuclear safety there needs to be examination if the change would have unacceptable industrial safety consequences. The chosen mitigation techniques or strategies need to be implemented after appropriate authorisation.

After implementation the results are monitored providing feedback so that risk analysis is always updated as the operating environment changes. This is an iterative process, as the sources of risk may change over time, or are re-evaluated as the external influences on the three sectors of the risk management strategy change.

Nearly all of the available tools for identification, measurement, and management of risk have built into them the monitoring and feedback mechanisms that constitute a comprehensive risk management program. In many cases the feedback mechanisms are automatically built into the tools utilised, while in other cases, a more formal feedback analysis is necessary.

Key risk factors evident at the commencement of a nuclear power plant program through to first operations are community acceptance risk, licensing risk, engineering risk, technical performance risk, cost risk, schedule risk, and financing risk. In the case of this submission all of these up front risks are minimised by the recommendation to select a nuclear plant with a long track record supporting the design, construction, and operation, and a proven supply chain expertise.

Included in the safety-related analysis of potential risk are the categories of nuclear, radiological, industrial, and environmental safety. In identifying and characterising these risks, there is a need to consider not only the type of risks involved, but also both internal and external consequences. Tools for assessment of nuclear safety-related risks are, arguably, the best-developed risk assessment tools in any industry. Those for radiological, industrial, and environmental safety are well researched and are already part of the standard safety assessments and management of nuclear power plant. Standards and tools are supplemented by various national and international guidelines for industrial and environmental safety.

Well run nuclear plants have made impressive improvements in operational processes that have resulted in reduced outage times, decreased number of plant trips, reduced levels of staffing, and better-managed discretionary projects. Effectively balancing the competing objectives of maximising safety and reliability while minimising costs is an important area of operational risk management. Identification of operating risk factors is now well documented for nuclear power plants.

Commercial and financial variables that need to be analysed for volatility include prices of resources, prices of electricity produced and sold, credit risk of major customers, counter party risk in legal contracts, costs of financing of new ventures, probability of losses due to more than one unit being down at one time in a multi-unit operating organisation, potential losses due to contractual agreements, and currency fluctuations when multi-national transactions are present in the project.

Financial market risks arise from changes in the prices of assets and liabilities and can include absolute risk measured by potential loss in dollar or currency based value and related to volatility of total returns, relative risk relative to benchmark indices, and basis risk which occurs when the relationships between products used to hedge each other break down or are nonlinear, called gamma risk in finance.

Credit risk can lead to losses when a borrower's credit rating is downgraded, leading to decline in market values. Credit risk also arises when counter parties are unwilling or unable to fulfil their contractual obligations. The level of credit risk here is estimated by determining the cost of replacing cash flows if the other party defaults. Credit risk also includes the risk that a country may impose foreign-exchange controls that make it difficult for a counter party to meet obligations. Financial operations risk relates to potential losses resulting from model misspecification, inadequate systems, management failure, faulty controls, fraud, or human error in the management of financial resources.

The risk management processes now applied to major construction and operations are mature procedures which have allowed clear definition and mitigation actions for many major projects in Australia including the development, construction, and operation of the OPAL research reactor at Lucas Heights. Development of a risk management identification and mitigation framework should form part of the final feasibility study exercise as this will certainly be required prior to final project approval.

End Note

Renewable energy and the current market structure ideologies dominated by a technically challenged thicket of economists and lawyers have both been demonstrated to be hopelessly impractical and continue to erode Australia's previous competitive industries. Australian electricity consumers have suffered unprecedented price fluctuations from a failed asset privatisation policy, poor electricity market design, and a flood of subsidised renewables. Consumers are being exploited by incomprehensible pricing contracts and fragmented management responsibilities across the sector. Industry and retail electricity users are facing unprecedented electricity sector reliability deterioration as renewable energy is pushed into the system by ideologically driven subsidies.

Ageing base-load assets are sweated with minimum maintenance resulting in increased failure rates within a market structure that precludes any chance of replacement. Private investors have confirmed that they will play no direct part in future new base load generation investments of any type without subsidy, given the current market arrangements. An unthinking rush to renewable energy implementation with final outcome prices estimated by engineers to at least double, possibly triple and reliability set to plummet provides a looming foretaste of economic disaster for Australia if these policies continue.

A step change of philosophy for management of Australia's electricity sector is required.

A nuclear power investment program provides the least cost, lowest emissions option of many proposals investigated with the objective of ensuring long term secure, reliable and low emission electricity supply for the future benefit of all Australians. Given the level of replacement investment now required for electricity sector operational security, direct government control and a carefully structured move to maximum local industry involvement is timely.

A recommendation to progressively abandon the current Australian electricity market concept, stop subsidising expensive renewable energy, and adopt nuclear power is probably beyond the capability of this Inquiry as it has been for earlier Inquiries on the subject. An option to more fully investigate the future options for the Australian electricity sector by expert conference, or suitably qualified professional engineering consulting organisations, or both, would be a step in the right direction.

I would be happy to expand on any aspect of this submission that the Inquiry my find may find useful

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BE, MIMechE, MIPENZ, FIEAust, CPEng, NER.

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This submission reflects the personal experience and views of the author for the purposes of this Inquiry only and not the views of the organisations noted above.
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