Australian Academy of Science

A Submission to the Uranium Mining, Processing and Nuclear Energy Review (UMPNER) Taskforce Secretariat based in the Department of the Prime Minister and Cabinet

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A submission from the Australian Academy of Science to the Uranium Mining, Processing and Nuclear Energy Review (UMPNER) Taskforce Secretariat based in the Department of the Prime Minister and Cabinet.

The Academy recognises the breadth of the terms of reference for the Taskforce assigned with evaluating the role of nuclear energy in Australia's future energy mix (which ranges from economics, environmental issues, health and safety through to proliferation issues). The Australian Academy of Science has therefore approached the discussion by focussing on the strengths that it can offer and by making use of areas where it can provide particular insight.

A response is therefore provided by addressing the following six questions:

1. What new science and technologies will likely impact the relative place of nuclear energy in Australia's future energy mix?
2. What new science and technologies will likely impact the efficiency and economics of reprocessing?
3. What new science and technologies will likely impact the safe storage of waste material (eg, depth of storage, groundwater)? How should retrieval, monitoring, and security issues be best managed?
4. What new science and technologies will likely impact decommissioning of nuclear reactors?
5. What R&D of relevance is being undertaken in Australia at present?
6. What skills are currently available, and will be needed in the future, for a viable nuclear energy economy?

The Academy appreciates that the terms of reference do not include investigation of the social aspects or implications of public participation. It might be of interest that the four learned Academies submitted in 2005 a proposal to the Australian Research Council (ARC) under the Linkage Learned Academies Special Projects to examine Australian attitudes to nuclear energy (attachment – Understanding Attitudes to Nuclear Power in Australia). At this stage, funding is still pending final decision.

In researching this paper, it has become apparent that Australia must build its expertise in all areas associated with nuclear science, in part to permit expert scrutiny and evaluation of emerging technologies and the claims associated with them. Some of the new science and technologies referenced in this submission may not stand up to scrutiny or else will be quickly overtaken by new developments.

The Academy advocates strong support for basic research in nuclear science in Australia, to ensure that Australian scientists are alert to new opportunities and are well poised to develop and adopt emerging technologies. In view of the long term time scale for development of a nuclear energy industry it is appropriate to invest in development of skills and expertise in this area.

The Academy elaborates on the following points:

1. What new science and technologies will likely impact the relative place of nuclear energy in Australia's future energy mix?

- Developments in 'fuel-cycle' and 'non-fuel-cycle' states. For example, developments that, without changing the design, ensure that it is possible for reactors to use different kinds of fuel and operate in different fuel cycles whilst meeting safety and security requirements (for example, those that could be modified to take Thorium as a replacement for uranium as nuclear fuel).

- Advances in technologies for nuclear monitoring that can adequately differentiate the undesirable (weapons-useable) from the good (medical, industrial) (For example, nano-composite scintillators, quantum dots as detector materials, a microcalorimeter array for ultra-high-resolution spectrometry, and ongoing improvements to CdZnTe and high-pressure Xenon detectors).[1]

- Technologies that minimise the production of spent fuel to the maximum extent practicable. For example, the SIGMA technology, a patented new concept for uranium enrichment based on the well-known gaseous diffusion method, has been developed by the Comision Nacional de Energia Atomica in Argentina to be an alternative to compete in the uranium enrichment market. The SIGMA engineering approach stands on the integration of several gaseous diffusion stages in one module, with all the stages sharing one single multiflux compressor, one vessel, and a gas turbine. This

[1] Park, BK et al. (2006). Advances in nuclear monitoring technologies. Forum on Physics and Society of The American Physical Society, 35(3) Available at http://aps.org/units/fps/newsletters/2006/july/article6.cfm

makes use of a double-diffuser cascade configuration to increase the separative gain. The SIGMA technology has also been conceived to incorporate proliferation-resistant features.[2]

- The laser enrichment process will likely be the third generation of uranium enrichment facilities and it is anticipated that they will be more energy efficient than the second generation (gas centrifuge).[3]

- New coupling of technologies such as amorphous solar cells coupled to a CsI (Tl) scintillator are able to generate electric power. Gamma cells, utilising the gamma radiation of nuclear spent fuel, can be expected to be useful for electric power generation in the near future.[4]

- Possible further developments in the use of uranium-eating bacteria for rehabilitation and waste management (eg, *Shewanella oneidensis*; *Saccaromyces cerevisieae*).[5]

- New combinations of renewable energy and advanced renewables, including wind, solar, hydro, landfill gas and biofuels, that further reduce current costs.

- Improvements in energy efficiency for running appliances which could be reinvested.[6]

- Advances in technology for less carbon-intensive fuels such as coal gasification with geosequestration; LPG.

- Technologies that reduce non-CO_2 greenhouse gases such as methane and nitrous oxide.

2. What new science and technologies will likely impact the efficiency and economics of reprocessing?

- The first thing to note when considering nuclear power is that it is a mature technology that has already been commercialised for more than half a century.

- Optimal use and controlling of risks associated with use of MOX (mixed oxide) fuel cycles. The existing commercial reprocessing capacity is well below that needed to support the widespread use of the MOX fuel cycle. While newer reprocessing technologies like UREX+ or pyroprocessing would have some advantages over the current PUREX process from a proliferation standpoint, the resulting plutonium would still be usable in nuclear weapons, making them a serious concern.[7] Side by side with the developments in the spent natural uranium fuel reprocessing, irradiated thorium reprocessing may also develop THOREX technology into a robust process. The additional challenges in this domain are being addressed to evolve appropriate technological solutions.

3. What new science and technologies will likely impact the safe storage of waste material (eg, depth of storage, groundwater)? How should retrieval, monitoring, and security issues be best managed?

- Some have questioned why the nuclear waste issue hasn't been resolved years ago, given that Europe and the USA have had nuclear industries for decades.

- 'Synroc', originally developed at the Research School of Earth Sciences, ANU, is a portmanteau from 'synthetic rock' and a ceramic which incorporates the radioactive waste into its crystal structure. Synroc has been suggested as a possible means of safely storing and disposing of radioactive waste. There are some issues relating to the problem of compacting Synroc. CEA Saclay, the labs of the French Atomic Energy Commission, work with Synroc, the Australian patents having expired.

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[2] Rivarola, ME., et al. (2006). Proliferation-resistant sigma uranium enrichment plants. Nuclear Technology 154 (3); p. 361-373.

[3] The Watt Daily energy news and discussion. From: http://thewatt.com/modules.php?name=News&file=article&mode=nested&sid=1168; Last accessed: 18/08/06.

[4] Horiuchi, N., Iijima, N., Hayashi, S., Yoda, I, 2005 – Solar Energy Materials and Solar Cells, 87 (1-4 Special Issue SI): 287-297

[5] Marshall MJ, Beliaev, AS, Dohnalkova, AC, Kennedy DW, Shi, L., et al. (2006). C-Type Cytochrome-dependent formation of U(IV) nanoparticles by *Shewanella oneidensis* Public Library of Science – Biology 4(8): e268; Button & Gabriel (1994), Wastewater Microbiology, p. 302.

[6] For example, Saddler et al. Clean energy scenarios for Australia. Energy Policy – in press.

[7] Smith, B. (2006). Insurmountable risks: the dangers of using nuclear power to combat global climate change. Available at http://www.ieer.org/reports/insurmountablerisks/; Last accessed:17/08/06

- The science involved in the safe storage of waste material from the nuclear energy industry involves three aspects:

  (a) Expertise in computational simulation of the fully coupled
    - rock deformation,
    - hydrological,
    - thermal transport,
    - chemical-reaction, system.

  The term ‘coupled’ means that each of the processes involved has first order feedback influences on the other processes. The basic approach in the design of a waste repository is to simulate the proposed waste storage site together with the proposed disposal technologies with the view of engineering a suitable array of natural and human-designed barriers to decrease the probability that leakage into the environment will occur. In general the design of such barriers is not only site specific but is also specific to the storage technology so it is essential to have long term local access to expertise that enables commitment and dedication to the design, implementation and monitoring processes. The engineered barriers, comprising containers, packing around the containers, and backfill, are physical and chemical in nature and rely on generating impermeable barriers that have adsorption properties in the form of special clays or special chemical properties that buffer the chemistry of any ground waters resulting in very low solubility of radio-nucleide species that may be carried in solution. In general this translates into creating reduced conditions: if one were to adopt a Swedish proposal to store high level nuclear waste in oxygen free copper canisters then near neutral pH and reduced conditions are essential. Other technologies such as synthetic ceramics would have their own specific chemical requirements for buffered groundwater chemistry. The far-field natural barriers to leakage comprise the surrounding rock mass that must (i) buffer the chemistry of ground-waters so as to precipitate rather than transport radio-nucleides and (ii) naturally inhibit the migration of radio-nucleides by ensuring that very high fluid flow permeability pathways in the form of joints or other high permeability pathways do not exist. The processes that operate to destroy the integrity of these barriers are thermal expansion and rock mass/barrier degradation through natural or thermally-induced deformation of the environment. It is essential to have very substantial computational resources to be able to explore a very large set of scenarios and perform extensive parameter sweeps of individual designs so that final decisions are made on the basis a complete exploration of parameter space rather than simply limited modelling scenarios.

  (b) Expertise that enables the computational simulations to be transferred to robust geological, geomechanical and geochemical design and construction procedures and for monitoring of the final implementation. The need is for geological site selection that ensures the proper geochemical environment (chemically reduced conditions) in the near and far field together with integrated geomechanical integrity in the near to medium to far field.

  (c) Expertise that enables the storage process to be automated as much as possible, so as to reduce exposure to humans and to proceed with monitoring in the future. Autonomous operating systems have been developed in the mining, particularly the coal mining, industry in Australia over the past decade and can be adapted to site specific installations as will be required here.

- The increased use of computers and digital systems create important safety tradeoffs with improvements possible during normal operation, but with the potential for unexpected problems to arise during accidents. The U.S. National Research Council has noted that there remains an ongoing “controversy within the software engineering community as to whether an accurate failure probability can be assessed for software or even whether software fails randomly”. This controversy has led to an inconsistent treatment of software failure modes in the PRAs for nuclear plants. For example, General Electric’s new Advanced Boiling Water Reactor design did not include any possibility of software failures in its risk assessment. In addition, the guidelines for performing PRAs contained in the Electric Power Research Institute's Utility Requirements Document did not include any discussion of how to incorporate software failures. On the other hand, Westinghouse chose to include a subjective estimate for software unavailability in its analysis of the AP600 pressurized water reactor's protection and monitoring system.[8]

- In identified repository sites, research is required on the extent of ‘fast’ water pathways, which allow water to migrate from the surface down to the level of the repository in as little as 40 to 50 years, rather than the hundreds to thousands of years.

[8] NAS/NRC 1997 - Douglas Chapin et al., Digital Instrumentation and Control Systems in Nuclear Power Plants: Safety and Reliability Issues, National Academy Press, Washington, DC, p.7 & 55.

4. What new science and technologies will likely impact decommissioning of nuclear reactors?

- Improved rehabilitation procedures, especially those relating to capping and landform design of repositories for minimising erosion and impacts on surrounding soils and sediments.[9]

- New research demonstrating the possibility of active movement and dispersal of radioactive materials by biological organisms. This may range from insects, groundwater crustaceans in aquifers through to higher levels in the food chain such as birds.

5. What R&D of relevance is being undertaken in Australia at present?

- Separation of Isotopes by Laser Excitation (Silex) Systems are making some improvements.[10] To quote Michael Goldsworthy, a nuclear scientist and leader of the project, the technology may halve enrichment costs, which he estimated accounts for 30 per cent of the price of nuclear fuel. There are at present only two methods for sifting uranium atoms, or isotopes, to create the right mix. One, called diffusion, involves forcing uranium through filters: being lighter, U-235 passes through more easily and is thus separated from its heavier counterpart. The second method, widely adopted in the 1970s, uses centrifuges to spin the heavier and lighter atoms apart. Both, said Dr Goldsworthy, are "very crude. You have to repeat the process over and over," consuming enormous amounts of electricity. The spinning method requires "thousands and thousands of centrifuges". Laser enrichment has been around for quite a while; the Australians have now made this technology commercial though by selling the rights to General Electric.[11]

- Much of the computational simulation expertise resides in the Predictive Mineral Discovery CRC, particularly within CSIRO and Geoscience Australia. The group has designed and implemented a very sophisticated fully coupled software environment that has been used in a uranium exploration project in Saskatchewan and is planned to be used for another in the Northern Territory. Such uranium exploration exercises employ technologies that are the inverse of what is required to ensure safe disposal of radio-nucleides. The necessary coupling between processes is well developed but would need extension to include: multi-phase flow (in an unsaturated near surface environment); kinetic control over chemical reactions; the simulation of adsorption onto clay particles and strong coupling between chemical reactions; fracture initiation and propagation; and thermal effects.

- The geological, geomechanical and geochemical expertise resides again within CSIRO, both in Western Australia – in the Predictive Mineral Discovery CRC and the CSIRO Mining Geomechanics Group in Queensland – and in Geoscience Australia. These groups have strong links mainly with the European nuclear waste disposal groups both in thermodynamic data base development and modelling and in software development for coupling fracture initiation with chemical processes. The geomechanical expertise also exists in some universities such as The University of Wollongong and The University of NSW and within consulting companies, such as Golders.

- Research on the ability of bacteria to reduce metals to insoluble forms is certainly not new, and in fact Australian researchers have been, and are still, working with a group of sulphate-reducing bacteria for bioremediation of a range of metals in contaminated mine waters. A group working with Professor David Parry did some work with these bacteria and uranium back in 1998, but due to lack of funding did not pursue it at the time. The sulphate-reducing bacteria have a similar Cytochrome c3 reductase enzyme for reducing uranium (VI) to uranium (IV) as that in the *Shewanella* bacteria. This probably gives some indication of the state of play with implementing these bioremediation processes. Some of this work goes back to the early 1990's but has not really developed to what could be described as a routine application phase. There is certainly a heightened interest in the mining industry in bioremediation.[12]

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9 For example, Lottermoser, B.G. and Ashley, P.M., 2006. Physical dispersion of radioactive mine waste at the rehabilitated Radium Hill uranium mine site, South Australia. Australian Journal of Earth Sciences, 53(3): 485-499.

10 SILEX - Separation of Isotopes by Laser Excitation. Available at http://www.silex.com.au/

11 Macey, R. The Sydney Morning Herald. May 27, 2006. “Laser enrichment could cut cost of nuclear power’.

12 Jong, T and Parry, DL. 2006. Microbial sulphate reduction under sequentially acidic conditions in an upflow anaerobic packed bed bioreactor. Water Research. 40, 2561-2571; Jong, T and Parry, DL. 2005. Evaluation of the stability of arsenic immobilized by microbial sulphate reduction using TCLP extractions and long-term leaching techniques. Chemosphere. 60, 254-265.

6. **What skills are currently available, and will be needed in the future, for a viable nuclear energy economy?**

- Much of this question is answered above but the need is to have the capability to design and implement a solution that is both site specific and disposal-technology specific. Within the Predictive Mineral CRC there is a team of software engineers, mathematicians, geologists, geochemists and computer modellers that are capable of addressing international standards. There is considerable expertise in geotechnical design, implementation and monitoring within CSIRO, some universities and consulting companies to design and build a repository. Considerable expertise and experience exists within CSIRO to design and deploy the necessary robotic systems.

- Skills relating to planning infrastructure – power uprates typically involve the use of more highly enriched uranium fuel that enables the reactor to produce more thermal energy. In order to accomplish this, the existing infrastructure must be able to accommodate the stress conditions that exist at the higher power level.[13]

- Skills relating to improved life-cycle analyses to better account for external costs as defined as those incurred in relation to health and the environment borne by society at large. I.e. beyond the Vattenfall 2002 life-cycle study.

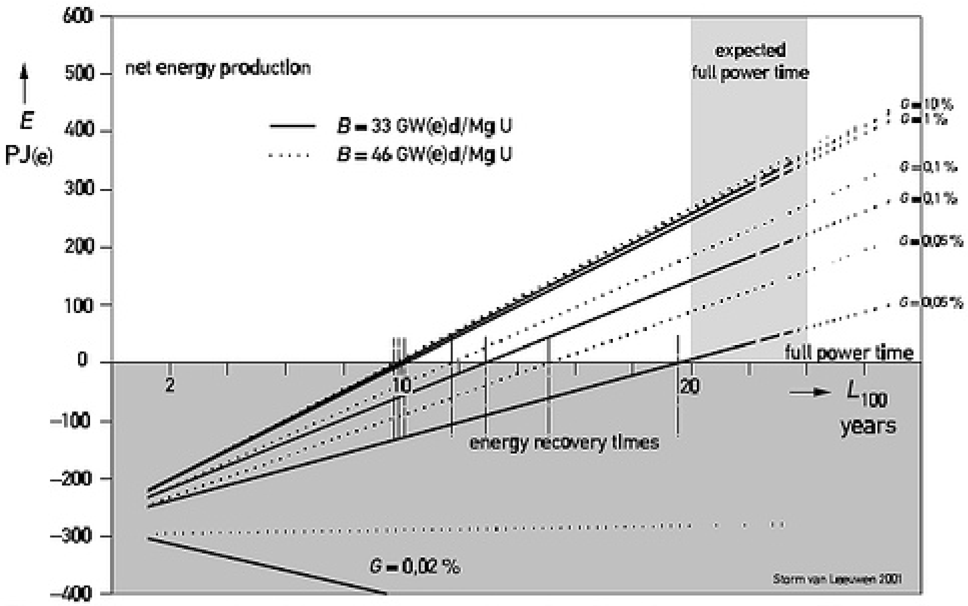

Figure 7 A representation of the energy costs and benefits of a nuclear power plant. Where the lines are in the shaded area the costs exceed the benefits. Only when they rise into the white area above the baseline, does the energy production exceed the energy costs.

Figure from: Storm van Leeuwen, JW and Smith, P. Background information pertaining to: Is nuclear power sustainable: would its use reduce CO2 emissions? Available at http://netserv.ipc.uni-linz.ac.at/~dieter/DsWeb/Private/Energy/StormSmith.pdf

- Skills relating to prospecting for high-grade ores.

Conclusion

The Academy considers it important that the discussion should be transparent and cover all aspects of the nuclear energy cycle. The Academy advocates strong support for basic research in nuclear science in Australia, to ensure that Australian scientists are alert to new opportunities and are well poised to develop and adopt emerging technologies. In view of the long term time scale for development of a nuclear energy industry it is appropriate to invest in development of skills and expertise in this area.

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13 Penm, J. (2006). Energy Outlook to 2011. Australian Commodities, 13 (1), March Quarter. http://www.abareconomics.com/australiancommodities/pdfs/energy_outlook.pdf

AUSTRALIAN RESEARCH COUNCIL
LINKAGE LEARNED ACADEMIES SPECIAL PROJECTS
APPLICATION FORM FOR FUNDING COMMENCING IN 2006

LA

Project ID: [ARC to allocate]

Information on this form is collected in order to make recommendations to the Minister on the allocation of financial assistance under the Australian Research Council Act 2001 and for post award reporting. The information collected may be passed to assessors for the purposes of obtaining a peer review assessment of the application. It may also be passed to the National Health and Medical Research Council, the National Occupational Health and Safety Commission, the Department of Foreign Affairs and Trade, the Department of Industry, Tourism and Resources, the Department of the Environment and Heritage, the Department of Education, Science and Training, the Department of Agriculture, Fisheries and Forestry and the Department of Veterans' Affairs for the purpose of checking eligibility. In other instances, information on this form can be disclosed without your consent where authorised or required by law.

Total number of sheets contained in this application	

PART A - ADMINISTRATIVE SUMMARY

A1 ORGANISATION TO ADMINISTER GRANT

Name: **The National Academies Forum**

A2 PROJECT TITLE (50 word limit)

Understanding Attitudes to Nuclear Power in Australia

A3 PARTICIPANT SUMMARY (Up to 20 people can be entered. The first Chief Investigator (CI) must be the Project Leader. Other participants have the role of CI or Steering Committee Member (SCM), if appropriate.)

Family name	Organisation	Role
Byron, Dr J. C.	Australian Academy of the Humanities	First CI
Richardson, Prof. S.	Academy of Social Sciences in Australia	SMC
Laver, P. J.	Academy of Technological Sciences and Engineering	CI
Serjeantson, Prof. S. W.	Australian Academy of Science	SMC

A4 SUMMARY DESCRIPTIONS

A4.1 Summary of Project (250 word limit)

There have been many recent calls for a re-opening of the debate regarding nuclear power in Australia. Rather than claim a lead role in this re-opening, however, this project centres more on understanding why the debate faltered and stalled in the first place. It seeks to analyse the attitudes of numerous sectors of the Australian community towards several key aspects of nuclear power. Five key aspects have been thought to cause the most controversy in the past: the issue of security (both weapons proliferation and waste safeguarding), the environmental benefits and hazards of nuclear generation, problems of management and governance, the financial costs and benefits (including the ethics of nuclear business), and – possibly above all – the storage and disposal of by-product.

The project will concentrate on both historical and contemporary formations of attitudes. Among the groups to be analysed for their influence in shaping the debate are: federal, state, and local governments; pro- and anti-nuclear lobby groups; professional scientists including physicists, ecologists, engineers; the media and popular culture; the medical establishment; uranium, hydrocarbon, and renewable energy-source industries; ethicists; aboriginal communities, economists; and international users. It is proposed that a better understanding of how the debate has been and continues to be shaped will lead to a more effective and productive debate in the future.

All four learned academies will be equally involved in this project, contributing a range of disciplinary expertise across the whole spectrum of knowledge.

A4.2 Summary of National/Community Benefit (For Public Purposes) (250 word limit)

The debate on nuclear power at the present time is often viewed as either hysterical or moribund. This project will provide vital ground-clearing work at the national level so that a more mature and profound debate may proceed. Such a service will benefit the many communities that have recently called for a re-opening of discussion about nuclear power. They include the Federal Government, some conservationists, many energy-source industries, and all those concerned about the world's future response to climate change.

This project will clarify the political, scientific, environmental, and social contexts in which decisions on nuclear energy will be made. It will not, though, seek to participate directly in the decision-making process: rather, it will provide the essential basis that informs good policy.

Since the project will involve all four learned academies in Australia, its successful implementation will teach an invaluable lesson in the benefits of multi-disciplinary work. It will bring together the research and analysis of historians, political analysts, physicists, environmentalists, legal analysts, economists, cultural critics, and anthropologists – to mention only the most obvious experts for this issue.

Web publication of all papers involved in the project will make the outcomes of its activities accessible throughout Australia and the world. A book publication many also result from the project.

PART D – PROJECT DESCRIPTION

D1 Purpose and Background

There have been many recent calls for a re-opening of the debate regarding nuclear power in Australia: from the Federal Government, from some conservationists, from various energy-source industries, and from ordinary Australian citizens with a deep concern about the world's future response to climate change. Many of these bodies have noted and often despaired at the impasse at which the debate seems to have arrived. Having gone through two loud bursts in the 1950searly 1960s and then in the 1970s-1980s, the debate on nuclear power has lost much of its cohesion and its vital public profile. Some critics of the debate describe both sides now as 'hysterical' while others – possibly according to their opinion of the value of hysteria – declare the debate moribund.

This project is emphatically *not* about claiming a lead role in re-opening the debate or about claiming an adjudicatory position. Instead, it seeks to undertake critical ground-clearing work about the debate thus far so that a more mature and productive discussion may proceed in the future. It seeks to gain a deeper understanding of how various attitudes from various sectors have formed; how they have connected or alienated other attitudes from other sectors, and how future trends may shape future patterns of national response to the issue of nuclear power.

The project will consider both historical and contemporary formations of attitudes. Among the groups to be analysed for their influence in shaping the debate on nuclear power in Australia are: federal, state, and local governments; pro- and anti-nuclear lobby groups; professional scientists including physicists, geologists, ecologists, and engineers; the media and popular culture; the medical establishment; uranium, hydrocarbon, and renewable energy-source industries; ethicists and philosophers; aboriginal communities, economists and business councils; and international users.

The National Academies Forum has been prompted to conduct such a project now because various sector leaders have recently voiced their frustration with the state of discourse at the present time. Many note that critical levels of CO2 emissions, the problem of powering water desalination, increasing fears over terrorist capabilities; new worries over international nuclear armament programs, and the ethics of selling a product without taking responsibility for its waste all mean that a radical improvement in the level, clarity and prioritisation of the discussion regarding nuclear power is necessary. Several fora and publications have of late tried to engage with the issue of nuclear power in the changed social, political, and technological matrices of the 21st century. NAF seeks to give its assistance, not necessarily by producing more opinions, but by providing a close analysis of how opinions have worked in the past and how they might carry weight in the future.

The whole-of-knowledge capability of a National Academies Forum is particularly well-suited to this project. The debate on nuclear power needs the expertise of humanists, social scientists, engineers, technologists and nuclear and environmental scientists together if it is to reach a profound and usable understanding of how it formed, what it faltered over, and how it might become more vigorous and productive for all pundits in the future.

D2 Outcomes

By the end of Year One, the project will have:
convened an Expert Reference Group of about 12 members to advise on content as well as a Project Director to ensure implementation

- gathered together key analysts of key sector attitudes to five main issues regarding nuclear power – that of security, the environment, governance, economics, and waste
- fostered a network of scholars and non-academic bodies who have an interest in understanding the debate about nuclear power
- published all papers from the three symposia on a designated, interactive website
- published a report of final progress that will review the state of discussion about nuclear power at the national level and make a series of recommendations for potential policy shapers
- demonstrated the utility and vitality of multi-disciplinary approach to issue of pressing national concern
- arrived at a deeper understanding of how the debate on nuclear power in Australia has been shaped in the past and how it might proceed more productively in the future.

D3 Methodology and Governance

Methodology
The project will revolve around three symposia held in Canberra, Adelaide, and Melbourne respectively. After each symposium, papers and a report will be published on a designated website. Upon completion, the project will produce a summary of outcomes and make a series of recommendations. The three symposia will each address a theme or set of themes, loosely related to the organizations in or concerns of the host city. Each will be led by slightly different combinations of the four participating academies, according to location and concern, but importantly all will involve a large range of disciplinary expertise represented by all the academies. They will each be held in one day, allowing for individual papers in the first part of the day and ending with a panel-led open discussion of issues raised.

CANBERRA SYMPOSIUM ON UNDERSTANDING ATTITUDES TO NUCLEAR POWER:
SECURITY AND THE ENVIRONMENT
This symposium will be led chiefly by the Academy of Science and the Academy of the Humanities. It will exploit the proximity to Federal Government by concentrating on attitudes to issues of federal importance, chiefly those of security (armaments, defence and counter-terrorism) and the environment (CO_2 emissions, the status of the land, etc).

Topics to be analysed could include the attitudes of:
- governmental counter-terrorism agencies, including the Attorney General's Department and the Department of Defence
- national civil liberties organizations
- renewable energy source advocates
- green pro-nuclear advocates
- hydrocarbon industry
- professional scientists including physicists and ecologists
- aboriginal communities
- the media and popular culture
- key electorates and political parties

ADELAIDE SYMPOSIUM ON UNDERSTANDING ATTITUDES TO NUCLEAR POWER:
GOVERNANCE AND ECONOMICS
This symposium will be led chiefly by the Academy of Social Sciences. It will recognise the centrality of involving the South Australian Government in any significant debate about attitudes to nuclear power, given that most Australian uranium mining occurs at Olympic Dam in South Australia. It will also address the nexus of uranium mining companies – many of which have large stakes in South Australia – and government. It will concentrate chiefly on attitudes to federal relations with state and local governments regarding nuclear management and on attitudes to the costs, benefits, and ethics of nuclear business.

Topics to be analysed could include the attitudes of:
- mining corporations
- hydrocarbon industry
- ethicists
- economists
- political analysts
- local governments
- state governments
- business councils
- international clients
- aboriginal communities
- the media and popular culture
- key electorates and political parties

MELBOURNE SYMPOSIUM ON UNDERSTANDING ATTITUDES TO NUCLEAR POWER:
WASTE
This symposium will be led chiefly by the Academy of Technological Sciences and Engineering, which is based in Melbourne. It will concentrate on possibly the most controversial aspect of nuclear power, that of waste. It will address attitudes to the engineering, technology, safeguarding, and financial and moral responsibility of the storage and disposal of nuclear waste.

Topics to be analysed could include the attitudes of:
- engineers and nuclear waste technologists
- physicists
- medical establishment
- international clients
- hydrocarbon industry
- philosophers
- economists
- aboriginal communities
- the media and popular culture
- key electorates and political parties

Governance
Under the advice and guidance of a Expert Reference Group – of about twelve members – a Project Director will ensure that activities and outcomes are implemented in a timely and optimal manner. Among the Expert Reference Group will be four Chief Investigators – each one a Fellow of each of the four participating academies.

The Expert Reference Group will meet once early in the year to confirm the proposal, appoint the Project Director, advise on the content and structure of all symposia, arrange for construction of website, and decide on details of the first symposium.

The four CIs/SCMs will meet briefly after the first symposium to ensure that the project is on track and that its proposed methodology is optimal. The four CIs/SCMs will meet again at the end of all the three symposia to oversee the project's completion.

The Australian Academy of the Humanities will act as the administrative 'hub' for the project. The Project Director will work out of the offices of the AAH. The Project Director will carry out or direct all preparation for the symposia, including airfare booking, accommodation booking, room hire, and catering arrangements for the events, as well as the collating and publication of papers and reports after each event.

Each Academy will contribute considerable in-kind support to the project, as noted in the Costings Section of this application.

D4 Objectives

The project will further all three specified objectives of the Learned Academies Special Projects Scheme. On a problem that patently calls for a whole-of-knowledge approach, the project will capitalise overtly on the unique capabilities of the National Academies Forum. It will call upon and analyse the work of physicists, ecologists, geologists and medics; mechanical and mining engineers and nuclear technologists; political scientists, economists, ethicists, and anthropologists; and cultural critics, historians, and philosophers. (And these are only the most obvious candidates: the project could also fruitfully hear from and study the views of oncologists, metallurgists, demographers and artists).

The outcomes of this project will greatly aid all bodies interested in taking the debate over nuclear power in Australia to new levels. Such bodies include researchers, lobbyists, and public service providers.

The project may be expected to benefit future research and scholarship into several aspects of nuclear power in Australia. A greater understanding of why pro-nuclear physicists, for example, have failed to convince anti-nuclear conservationists in the past may point to new ways for science to accommodate a wider public. A greater understanding of why anti-nuclear community groups have failed to deter pro-nuclear professionals – another example – may point to new ways for those in the human sciences to understand social division.

The problem of discussing nuclear power in Australia is of clear contemporary national importance. Due to pressing global concerns, numerous sector leaders in this country have recognised the necessity of re-vitalising the debate.