SUBMISSION TO THE NUCLEAR FUEL CYCLE ROYAL COMMISSION

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SUMMARY

As an introduction, I have presented an Overview of the nuclear industry.

The remainder of this summary deals with individual aspects of this submission.

1. IS THERE AN ADEQUATE MARKET FOR THIS INDUSTRY?

I submit that there is more than sufficient long-term market demand to support a nuclear industry in South Australia, as shown in the section entitled The Market

2. IS A NUCLEAR INDUSTRY SAFE?

The current industry standards for the processing of materials, for the manufacture of reactors, and for transhipment, ensure a higher level of safety than has been achieved in any other extractive or power generating industry. This is discussed in the section entitled Safety

3. CAN WE SAFELY DISPOSE OF NUCLEAR WASTE?

If we primarily use the Argonne Laboratory's proven I.F.R. reactor design, as subsequently developed, then we will CONSUME nuclear waste, and need to store a trivial amount of residual material, without adversely affecting the environment. This is detailed in the section entitled Waste

4. IS A NUCLEAR INDUSTRY ECONOMICALLY VIABLE?

When assessed on whole-of-life total cost, a nuclear reactor is significantly less expensive than any other base-load power generator of similar capacity. This is discussed on the section entitled Costs

5. WHAT IS THE POTENTIAL ROLE OF SOUTH AUSTRALIA?

South Australia is uniquely located and equipped to develop a nuclear energy industry, as is suggested in the section entitled Role

6. IS THERE SYNERGY WITH OTHER MARKETS?

The technology and facilities which will be developed in support of a nuclear industry will be of importance in entering other emerging markets, as discussed on the section entitled Synergy

OVERVIEW

Nuclear fission was first demonstrated in the laboratory in Germany in the 1930's. During WWII, serious attempts were made in Germany and in the U.S.A. to develop nuclear fission reactors for electrical power generation and for weapons production.

The American Manhattan Project, which drew upon the efforts of a large team of U.S. and expatriate scientists, was successfully concluded in 1945, when nuclear weapons were exploded over Hiroshima (uranium) and Nagasaki (plutonium) in Japan.

The first commercial nuclear power station came on line in 1957 at Calder Hall, Northumberland, U.K.

Comprehensive information of nuclear power generation topics is available on the internet from the Australian Uranium Association, Melbourne, Victoria, Australia (now incorporated in the Minerals Council of Australia) through the following link:- http://www.aua.org.au

The World Nuclear Association provides very full, up-to-date, worldwide information of current and proposed nuclear power reactors on its web site, http://www.world-nuclear.org

For several years, Professor Barry W. Brook, who held the Sir Hubert Wilkins Chair of Climate Change at Adelaide University and is now Head of the Faculty of Climate Science at the University of Tasmania, has collaborated with other respected international academics in peer-reviewed research into the relative benefits of the available low-carbon technologies for base-load power generation. It is clear that upon consideration of return upon investment, operating costs, safety, pollution and waste disposal, public health, long-term availability of fuel, and environmental protection, nuclear fission energy generation using 21st. century reactors is indisputably the most suitable technology for base-load power generation. For more information, please refer to Professor Brook's web-site, http://www.bravenewclimate.com

In Australia, we have around 30% of the global resources of uranium and thorium. We are desperately in need of a major effort to build a national and export nuclear energy industry, or we will be left alone among the developed countries, without the means of securing our future energy needs. I have proposed one possible solution on the page entitled Role.

Economics of Nuclear Power Generation

Very careful, substantiated economic studies show that, if ALL costs of waste storage or carbon capture, and of capitalisation, are considered, nuclear power is significantly less expensive than power produced by burning coal or other fossil fuels.

Unsubstantiated statements by lobby groups that "it's too expensive" are untrue.

Wind power may have a comparable cost per kWh, but is not continously available and has limited capacity per machine. However, wind power turbines may be interconnected as a grid with a number of machines spread over a wide area, and may be the best solution for the electrical power and water desalination requirements of rural areas in Australia.

Except as a by-product of the construction phase, a nuclear fission reactor does not produce significant amounts of greenhouse gases.

Combined Cycle Power Generation

The overall efficiency of power generation is considerably improved if waste heat is employed for the desalination of water or for other industrial processes.

The energy-efficient Passarell C.V.E.S. seawater/brine distillation process (http://www.passarell-desalination-australia.com) utilises waste heat from the power station, has a small footprint, and produces saleable salt as a by-product. The Passarell system has no adverse environmental impact, has a 25-year service life, has no delicate semi-permeable filters, requires little maintenance, and has operating costs which are one-half of the costs for a comparable reverse-osmosis plant.

Safety

The safety record of the nuclear power industry is far better than that of the coal and other fossil fuel industries.

There has been only one failure of a nuclear power station (Chernobyl), which caused loss of life. This was the result of obsolete design, an unforeseen design fault, and of unauthorised disregard of correct operating procedures during testing and commissioning.

The failed Chernobyl reactor was of an early Russian design in which an increase in operating temperature increased thermal power output. In this obsolete type of reactor, overheating, if not corrected, results in loss of the water which normally cools the reactor and which moderates the reaction. Chernobyl incorporated a safety shut-down graphite moderator assembly, but graphite is an ineffective moderator at high temperature, and it was not activated until all water had evaporated from the core of the reactor. In the absence of the cooling water supply, melt-down resulted and the containment of nuclear materials failed.

Most designs of Generation IV reactors are endothermic - that is, activity reduces as temperature increases, so preventing thermal runaway. Highly reliable, duplicated, mechanical and electrical safety systems are mandatory.

In the case of Fukushima, the reactor was designed to withstand earthquake and tsunami events of magnitude with a probability of 1 in 200 years. The plant was not rendered unsafe by the unpredictably-high magnitude earthquake, but by inundation of the site power generating plant by the unprecedentedly-large tsunami . This caused failure of the cooling water system, which resulted in core

melt-down. Again, the Fukishima reactor was of obsolete design, and had been scheduled for de-commissioning in 2010. (De-commissioning was postponed because of the onset of the global financial crisis.) Three persons drowned in the flooded area. The nuclear accident caused no fatalities.

Generation IV reactor designs do not have a vulnerable cooling system. The reactor shell is designed to prevent the release of reactor materials, in the unlikely event of a core melt-down.

Toxic Wastes

Most early designs of nuclear reactors, known as breeder reactors, operated with short fuel cycles and intentionally produced radioactive isotopes from natural uranium which sheathed the reactor core. The plutonium which was produced was used either to make reactor fuel elements or was incorporated in nuclear weapons. Unfortunately the plutonium and other products of high atomic number have very long half-lives, so that they present a difficult problem of safe storage.

The new and proposed reactor types, "Generation 3A" and "Generation 4", which are listed on the World Nuclear Organisation web-site, are designed to re-cycle and "burn" long-lived toxic waste products, and to produce a small amount of low activity, short-lived wastes, which present a more readily managed disposal or storage problem.

Generation IV reactors may be produced in a wide range of sizes, or can be delivered to site by barge, so that they are suitable for installation in remote locations. The waste heat from a reactor may be used for the production of potable water at low cost, and with improved efficiency of power generation. In operation, they produce no greenhouse gas emissions.

The Integral Fast Reactor, which was developed and tested in a 10-year programme at the Argonne Laboratories in the USA, finishing in 1996, is specifically designed to process and recycle nuclear waste within the reactor site. The end products are stored on-site for a few years, by which time they may be safely disposed of with other, low-level, radioactive wastes.

Australia has suitable secure locations on Commonwealth ground, e.g. at Woomera, for the safe long-term storage of nuclear wastes. Alternatively, it is proposed that re-cycled wastes should be mixed with spent fuel to reduce the activity level to that of naturally occurring uranium, then buried back at the original mine site. High level wastes may be stored within the reactor shield or in secure above-ground sites for up to 25 years, by which time the activity level will have decayed sufficiently to permit permanent storage at the mine site or with other industrial waste.

Current Installations

Approximately 450 nuclear power stations of all types are currently in service.

There is a trade-off between the reactor operating temperature and efficiency. However, high temperature, high efficiency reactors require careful design to avoid

the metallurgical problems which result from corrosion of the cooling system.

The type of reactor also affects the characteristics of the nuclear wastes which are produced, which may have an effect upon the operating economics of the reactor.

France generates more than 85% of its total power needs by nuclear energy, with about 10% of total capacity generated by windpower. France is a supplier of nuclear power installations to several other countries, including China, South Africa, Korea and Japan. Other developed nations, e.g. the U.S.A., Russia, the U.K., Germany, Spain and others, have re-commenced nuclear power programmes in order to replace the dwindling supplies of fossil fuels and to reduce greenhouse gas emissions. India has a large nuclear power development programme. South Korea now has a flourishing industry, building nuclear reactors for export, as do Canada and South Africa.

The CANDU Reactor

The CANDU reactor (Canadian low pressure, heavy water moderated reactor) is in service in Canada. While the initial charge of heavy water is expensive, it is not a consumable component of the reactor, and the CANDU reactor need not rely upon enriched uranium as a fuel.

The CANDU design has two separate automatic safety shutdown systems. In addition, this type of low temperature reactor becomes less active in the event of an increase in operating temperature.

It has been selected for use in China, and South Africa.

The CANDU reactor may be fuelled with un-enriched uranium or thorium. It may be maintained by replacement of spent fuel rods without being completely shut-down. It can "burn" mixed plutonium fuel, producing a less hazardous waste.

If the manufacture and re-processing of reactor fuel elements is carried out in Australia, then security of access to weapons-grade material may be assured.

The Integral Fast Reactor

The Integral Fast Reactor (I.F.R.), and its successor, the Generation IV Sodium-Cooled Fast Reactor, uses a closed-cycle system for the on-site re-processing of nuclear fuels. It may utilise the long-half-life fuel waste from conventional thermo-nuclear reactors. It eventually produces a trivial amount of short-half-life waste which can be stored on-site, until it is safe for disposal at a nuclear waste storage site or, when mixed and diluted with depleted uranium, it may be buried at the uranium mine site. It ensures almost complete "burning" of uranium and thorium fuel sources.

It is estimated that there is now sufficient suitable nuclear waste, mainly weapons-grade plutonium, to supply the world's energy requirements, using the I.F.R., for 1,000 years. This is a supreme example of the possible use of appropriate technology, to turn the problem of waste disposal into the benefit of safe, cheap

power,

Marine Reactors

Small floating nuclear reactors of established, safe design may be manufactured or deployed quickly and efficiently in the developed countries. The possibility of mass construction techniques and the development of a trained labour force, with long-term employment, makes this course of action potentially attractive.

They may be deployed flexibly to provide non-polluting power stations, co-generating potable water supply, at any coastal location. If located in a dry-dock, they are suitable for long-term deployment. They require a minimum of infrastructure support. The supplier may retain full control of the reactor fuel elements, preventing any possibility of the proliferation of nuclear weapons.

This is probably the quickest way of providing efficient power generation capacity to the developing countries, without producing greenhouse gas emissions. The same facilities could be used to provide regular major maintenance, returning the complete reactor by sea to the place of manufacture. A new or re-furbished reactor could replace the reactor which is to be returned for maintenance.

Whyalla in South Australia would be an ideal location for the mass production of floating reactors. It has an existing steelworks, a shipyard with dry dock and deep water harbour facilities, an established sub-contractor area, adequate housing and civic resources, and access to electrical power. It is conveniently located for access to uranium mining facilities, or to Woomera, where fuel enrichment and processing facilities could be established.

Australia has about 30% of the world's reserves of uranium. Uranium is the most commonly used fuel for nuclear reactors and so will be in increasing demand for the task of reducing global warming.

For political, moral, ecological and financial reasons, we will be unable to resist international pressure to expand the mining and export of uranium.

Fuel Processing

The processed uranium ore, uranium oxide or "yellow-cake" consists mainly of the oxide of U_{238}, with about 0.72% of the oxide of U_{235}. It is moderately radioactive.

To sustain a chain reaction in most designs of commercial reactor, the proportion of U_{235} must be enriched, typically to between 3% and 5%. For weapons applications, the enrichment must be increased, to in excess of 90%. Enrichment is usually accomplished by centrifuging or, less commonly, by the diffusion of gaseous uranium hexafluoride through a semi-permeable membrane. Since the difference in molecular weight of compounds of the two isotopes U_{238} & U_{235} is very small, the difference in the rates of diffusion or separation is also small. In order to achieve the necessary level of U_{235} hexafluoride which is required, the enriched gas stream is returned to the input of the separator and is recycled many times. Note that uranium which has been enriched for use in nuclear power stations is unsuitable for

use in nuclear weapons, and is unable to cause an explosion.

The enriched uranium is converted back to uranium oxide and manufactured into fuel assemblies, as required for the design of reactor which is to be fuelled.

(Note that the Manhattan Project enriched uranium, using a mass spectrometer (now totally abandoned), and the process of diffusion of gaseous uranium hexafluoride.)

As noted above, Australian scientists have recently developed a more efficient, less expensive, laser enrichment process for uranium. (The Silex Process).

It is recommended that Australia's uranium output should be enriched and manufactured into fuel assemblies at or near to the mine sites, e.g. at Woomera, to ensure security of the material, to enable the return of waste material to the ore body, and to add value to the exported fuel.

MOX Reactors

The plutonium which is recovered from a reactor, or from de-commissioned nuclear weapons, may be re-used by adding depleted uranium from an enrichment plant or from re-cycled fuel elements, to produce MOX (Mixed Oxide) fuel. Apart from producing fresh reactor fuel to generate energy, the use of MOX fuel increases the "burn-up" of uranium and has the added benefit of converting plutonium into less hazardous nuclear wastes, which facilitates the safe storage of wastes. Also, the extraction of weapons-grade material from spent MOX fuel assemblies is more difficult.

MOX fuel is used in 30 European reactors and an additional 20 reactors are awaiting licenses. Japan planned to use MOX fuel in a third of its reactors by 2010. In addition, both Russia and the United States may possibly use MOX fuel in five reactors and six reactors, respectively. The fuel is currently produced in commercial quantities at plants located in France and the United Kingdom. The UK plant is scheduled for closure. New plants are scheduled to commence production in Japan in 2015 and in U.S.A. in 2019.

In 2014, the World Nuclear Association published a full article upon the preparation, applications and benefits of MOX Fuel.

Thorium v. Uranium as a Fuel

Australia has about 30% of the world's reserves of uranium, and perhaps three times as much thorium. Only 0.72% of naturally-occurring uranium is the fissile isotope, U_{235}, which is suitable for use in nuclear fission reactors. It is separated from natural uranium by a most expensive enrichment process. Recent Australian research has developed a much less expensive laser enrichment process for uranium.

Almost 100% of thorium is usable as reactor fuel, and no enrichment is necessary, so that it is a much more efficient nuclear fuel. Thorium is "fissile, but not fertile",

that is, unlike enriched uranium or plutonium, it does not produce excess neutrons as a result of nuclear fission. It cannot produce a chain reaction, and reactor activity ceases if the neutron source is removed or shut-down. Russia is currently developing a thorium/plutonium MOX fuel.

The isotopes produced by fission of thorium have shorter half-life than the products of a uranium or a plutonium reactor, so that the nuclear waste is more readily managed.

It is almost impossible to produce weapons grade material in a reactor which uses the thorium fuel cycle.

India, and several other countries, are constructing thorium-fuelled nuclear reactors. The mining and processing of thorium in Australia should be encouraged.

Nuclear Heat Sources

Nuclear waste which is thermally active, but which is not capable of sustaining a chain reaction, may be stored in unmanned low power installations to provide heat and to generate electricity for such applications as the desalination of water, pumping etc.

Such installations may be shielded with concrete and with an earth backfill, to ensure secure and radiologically safe storage of suitable thermally-active wastes.

Nuclear Fusion Reactors

Please refer to the comments on this document's page entitled Synergy

1. THE MARKET

Peter Drucker, the founding father of the marketing profession, is recorded as saying that "Selling satisfies the needs of the Seller, while Marketing satisfies the needs of the Market".

With the steady increase in global demand, there is a durable and expanding market for all sources of energy and for potable water supply. If we are to halt or reverse global climate warming, then we must preferentially promote low-carbon technology. This is particularly true of the developing countries, where economic development, food and water, and public health, are seriously restricted by a lack of energy resources.

In September 2014, Dr. Barry Brook (now Professor of Climate Science at the University of Tasmania) and his former colleague Dr. Corey Bradshaw (Professor of Climate Science at the University of Adelaide), supported by more than 75 internationally-eminent scientists, published an Open Letter to Environmentalists, in which they sought a scientifically-based consideration of all energy sources, in the search for solutions to the global problem of climate warming. Professor Brook maintains an internet web-site http://www.bravenewclimate.com for public comment.

Over the past 5 years, while he had tenure of the Sir Hubert Wilkins' Chair of Climate Science at Adelaide University, Professor Brook sought solutions to the problem of global warming. Within Australia and internationally, he has diligently and methodically researched all energy sources. His work has been published in reputable scientific journals and has been meticulously reviewed by his peers. He has demonstrated the urgent need for an expanded international nuclear energy industry, to satisfy the future needs of Australia and, more importantly, of the developing nations.

As a result of the reduced demand for nuclear weapons, there is a currently a global over-supply of uranium enrichment facilities. Forecasts to 2020 predict that there will be at least a 20% excess enrichment capacity for several years. However, there is justification for the establishment of a Silex laser nuclear separation plant at Woomera, for the reason of greater operational efficiency than existing centrifuge facilities, and to process the spent fuel returned by our international uranium customers, and to re-cycle our own nuclear waste, and to add value to that proportion of our 10,000 tonne annual exports of yellow-cake which is to be used to fuel nuclear energy reactors.

There is a continuing demand for new reactors, for the replacement of end-of-life power stations, for the supply of spare parts, and for maintenance support.

Within Australia, all of the existing thermal power stations will have reached end-of-life within the next 25 years, and will require replacement. In most cases, the existing steam-raising section of the installation may be replaced by one or more dual-unit 360MW modular nuclear reactors. The U.S. Government assisted development programme at Babcock & Wilcox is rapidly reaching the production stage, as discussed on the link: SMR manufacture under license In many cases, the

existing generators and switch-yard may be refurbished and re-used.

The two existing Port Augusta brown-coal fuelled power stations, which are scheduled for replacement because of dwindling fuel supplies from Leigh Creek, and insoluble problems of carbon emissions, have a total generating capacity of 520MW. They could be replaced by two Small Modular Reactors, each of 360MW capacity, producing an increased total capacity of 720MW.

It is suggested that at least one Integral Fast Reactor (I.F.R.) should be built in each mainland State, in order to re-cycle spent fuel assemblies for re-use in other Australian and international nuclear reactors.

As Professor Brook and others have commented, the agricultural economies in developing countries in Africa and Asia have a scarce supply of fuel for household use. They are forced to reply upon very inefficient fuels, such as cow dung, for heating and cooking. These fuels produce large quantities of toxic compounds, often carcinogens, resulting in high morbidity within the population.

We will best be able to serve these markets by supplying barge-mounted nuclear reactors, with co-located seawater distillation plants. These may be located in dry-docks at coastal locations, and returned by sea for maintenance or replacement.

For inland locations, for example in the Latrobe Valley and in many developing nations, nuclear reactors may be assembled on-site, using pre-fabricated components. In the absence of seawater, other means must be provided to remove waste heat, e.g. cooling towers or buried heat exchangers.

South Australia is fortunate, in that it has adequate existing resources, a skilled workforce, the necessary infrastructure, and supplies of raw materials, to succeed in this important growing market.

South Australia will not have sufficient manufacturing capacity to satisfy more than a small part of the global market demand for nuclear reactors, barges and nuclear-powered shipping, but will be able to meet the requirements for steel plate, fuel assemblies, and other reactor components for other Australian shipyards, e.g. in Brisbane, Newcastle, Melbourne and Fremantle.

2. SAFETY

We should consider the radiation and toxic material hazards in transit, in manufacturing, and in operation of nuclear energy installations.

There are well-known hazards and established safety protocols for the transport of radioactive materials and reactor components, e.g. new and spent fuel elements. We are fortunate in South Australia, because we have the potential to develop secure processing and manufacturing facilities at Woomera and at Whyalla. These centres are close to the uranium mines snd are interconnectd by an existing sealed highway and by a railway. There is no need to transport radioactive materials or components through centres of population. Whyalla has a 75ft. deep port anchorage, suitable for the forwarding and receipt of materials, components and reactors, to and from Australian and international locations.

Some of the raw materials which are processed in the nuclear industry, e.g. beryllia, uranium, thorium, cesium etc., are moderately radioactive. Low-energy alpha particles (helium ions) and beta particles (electrons) are unable to penetrate the skin. As is the case with asbestos dust, they are harmless except when ingested. Some radioactive materials emit neutrons or high-energy gamma rays, which are able to penetrate deeply into the body, may damage body tissues, and so require the use of radiation-absorbing screens.

It is essential that persons who work in the industry are adequately and appropriately protected in each potentially-hazardous situation, and are monitored to detect harmful exposure to radiation.

The level of radioactivity outside a nuclear power station is similar to that of a coal-fired power station. Because it is built on a granite rock body, the inhabitants of Edinburgh, Scotland experience a background radiation level which is 3 times greater than the average for the U.K., and yet, together with Japanese citizens, the incidence of cancer in Edinburgh is less than that in Australia.

There have been only three significant recorded accidents in commercial nuclear reactors. This a much better record than may be claimed by the oil, gas and coal energy industries, which have suffered several major polluting mishaps in off-shore and inland oil and gas wells, in the transhipment of oil, in fracking and in coal-seam gas production. There has been a deplorable loss of life in underground coal mining. Exposure in the production and use of carcinogenic aromatic hydrocarbons such as benzene, of solvents such as carbon tetrachloride and tetrachlorethylene, and of poly-chlorinated bi-phenyls (PCBs) poses high risk.

The Three Mile Island reactor developed a minor leak of radioactive cooling water from a cracked pipe into a containment pond, with no harmful radiation exposure to site personnel or to members of the general public. The Cherbonyl explosion, in an obsolete design, was the result of unauthorised high level testing during commissioning, causing total loss of cooling water, which rendered the graphite moderators transparent to neutrons and therefore ineffective. The Fukishima reactor, also of obsolete design and scheduled for de-commissioning 2 years before the accident, survived the earthquake (as it was designed to do) but suffered a loss

of cooling water when the unprecedently-high tsunami flooded the coolant-pump system's emergency generators in the basement. This resulted in thermal runaway, but unlike Chernobyl, there was a release of radioactive material without loss of life.

Generation IV nuclear reactors are intrinsically-safe by design - an increase in operating temperature results in a reduction in activity, so that thermal runaway is impossible. They do not rely upon pumped coolants. There are multiple redundant safety systems. The reactor shell is typically constructed of 20cm thick steel and is designed to contain the radioactive fuel in the highly unlikely event of a "meltdown".

In the case of thorium-fuelled reactors, activity requires an external source of neutrons and is readily controllable. Thorium is mildly radioactive. Unlike uranium, no enrichment of the fuel is required. In a thorium-fuelled reactor, almost 100% of the fuel is consumed. Thorium is fissile but not fertile - it can never produce excess neutrons, to produce a chain reaction. Neither thorium, nor the products of a thorium-fuelled nuclear reactor, are usable for weapons production without extraordinarily difficult processing.

3. WASTE

In the Manhattan project, the small proportion (0.7%) of U_{235} isotope was separated with great difficulty from natural uranium, to produce the first thermonuclear weapon, which was detonated over Hiroshima. At the same time, the experimental reactor was used to produce the plutonium which was used in the second thermonuclear weapon, which was detonated over Nagasaki.

In the early days of the nuclear energy industry, "breeder" reactors were constructed to produce plutonium from U_{238}, primarily for weapons production, but secondarily as a source of fuel for commercial power reactors. The breeder reactors also produced substantial quantities of other long-half-life isotopes, which required secure, long term storage. With the end of the "Cold War", the U.S. Government ceased reliance upon the nuclear reactor industry, because they had a substantial stockpile of weapons-grade plutonium, and a need to dispose of de-commissioned and outdated nuclear weapons.

Long-term storage facilities were constructed in geologically-stable locations. Australia's C.S.I.R.O. developed a mineral glass-like material, named "Synrock", for the encapsulation of radioactive wastes.

Over a 10 year period, ending in 1996, the U.S. Argonne Laboratories designed, developed and successfully tested their Integral Fast Reactor (I.F.R.). This reactor re-processed spent nuclear fuel elements by remote control, within the reactor shield. The recovered material was combined with other nuclear fuel and used to manufacture new fuel assemblies by remote control. These re-cycled fuel assemblies were then used to re-charge the nuclear reactor. The result of this on-site recycling was that, after storage for 5 years, the final waste was of low activity and could be returned to the original uranium mine site, for dilution with depleted uranium, and burial.

If this process, and the Silex laser enrichment process, is adopted by an Australian nuclear industry, we will be able to re-process the nuclear reactor waste which is to be returned by our overseas uranium customers. We will be able to re-cycle some of the more active waste which is produced by the A.N.S.T.O. facility in NSW. We will need to develop a waste storage faciity, only for the residual short half-life waste, possibly on Commonwealth property at Woomera. There will be, effectively, no adverse impact upon the environment.

Professor Brook has estimated that the existing stockpile of plutonium and other nuclear waste, if used in I.F.R. plants, will meet the world's energy needs for 1,000 years. A very effective method of turning swords into plough-shares!

4. COSTS

In 1958, the Electricity Trust of South Australia sent a Senior Project Engineer, Mr. Phil Williams, to the U.K. on a 2-year mission to study the operation of the Calder Hall Nuclear Power Station, and to report upon the feasibilty of constructing such a facility in South Australia.

He found that design improvements at Calder Hall had improved operational efficiency, so that it was competitive with existing black-coal fuelled thermal power stations. However, these improvements, e.g. in heat exchanger design, were equally effective when incorporated in new conventional power stations. There was only a marginal benefit at that time in abandoning the German-designed lignite-fuelled power stations, which were to be built at Port Augusta to use the Leigh Creek brown coal reserves.

(In 2010, it was reported that, in Korea, the cost of electrical power from a nuclear power station was US$31 per MWhr, compared with US$43.3 per MWhr from a coal-burning power station. The additional costs applicable to the nuclear power station, for additional safety measures which were mandated following the Fukushima accident, have not been disclosed, but would probably be no more than one or two dollars per MWhr. The cost for the coal fired plant, if including a carbon price, was US$67.1 per MWhr.)

Now, however, the newer designs of nuclear power stations operate at much higher temperatures than conventional fossil-fuelled power stations, and so are significantly more efficient. When the waste heat is utilised to distill saline cooling water, we can also produce very inexpensive potable water. If, of course, we include the feasibility and expense of storing wastes, e.g. carbon dioxide vs nuclear wastes, then there is a clear benefit in replacing fossil-fuelled power stations by thermo-nuclear power stations. While no one has yet demonstrated a viable system for carbon capture and storage, and so claimed the Richard Branson prize, the Generation IV nuclear reactors ultimately produce a trivial amount of low-activity radioactive waste which can be mixed with depleted uranium and buried at the mine site, or stored with waste from the A.N.S.T.O. NSW facility, possibly on Commonwealth ground at Woomera.

While I have no resources to carry out a comprehensive comparative study of the whole-of-life costs of the many competing energy generation technologies, this has already been accomplished by reliable independent scientists, such as Professor Barry Brook of the University of Tasmania, and Professor Corey Bradshaw of the University of Adelaide. Their work has been extensively peer-reviewed, is unbiased, and is authentic.

5. ROLE

Australia has around 30% of the global resources of uranium and thorium. We have in A.N.S.T.O. a professional nuclear energy research, pharmaceutical and regulatory body, with a staff of more than 1,000.

Alone among the developed nations, we have steadfastly refused to develop a nuclear energy industry. We must proceed urgently to bring the country into the 21st. century, or risk disastrous damage to our economy. This page proposes a possible course of positive action.

Mineral Resources

Continue to develop the mining and processing of metals, not only the familiar iron, aluminium, zinc, copper, lead, etc., but also the scarce products of mineral sands and rare earths, such as lithium, zirconium, beryllium, which are key ingredients in modern technology.

It is vitally important to generate sufficient non-polluting base-load power to support local metallurgical industries, for the production of alloy steels, aluminium and zinc, using electric furnaces and electrolytic smelting. Possibly, we may be able to reduce iron ore to iron, using catalytically-produced hydrogen from nuclear power plants, rather than using coal in a blast furnace.

Uranium Enrichment

Establish an Australian-patented Silex uranium enrichment plant in the Commonwealth Government secure area at Woomera. The necessary community and engineering support facilities already exist. Woomera has well-established road, rail and air transport links to the uranium mining sites and to the northern industrial cities of South Australia. Hazardous materials may be transported between Woomera and the Whyalla seaport without passing through any centre of population.

Whyalla Re-Development

In its heyday, Whyalla had the civic facilities to support a population of 75,000 residents. The BHP steelworks supplied plate and sections to the shipyard. There was a large industrial area, accommodating many sub-contractors for ship-sections and other engineering components. The shipyard incorporated a dry dock with capacity to build bulk ore carriers up to 75,000 tonnes. There is a deepwater port for ships up to 75ft. draught. The workforce had the skills and equipment necessary to produce high performance, low-hydrogen welded pressure vessels and ships' hulls.

These facilities could be re-activated to produce modular nuclear power stations, IFR reactor components, marine reactors, barges for the export or delivery of nuclear reactors with co-located Passarell CVES waste-energy water distillation plants, nuclear powered freighters, conventional- and nuclear-powered defence surface vessels and submarines.

Nuclear Reactors

It is proposed that an IFR (Integral Fast Reactor) with co-located Passarell CVES seawater distillation plant should be located at Point Lowly, South Australia, at the site originally planned as part of the BHP Olympic Dam Expansion Project. This would generate the power needed for the Eyre Peninsula and for BHP, including the Whyalla steelworks and shipyard.

It would produce adequate supplies of distilled water, with dry salt as a by-product, without damaging the marine environment through the discharge of warm water or brine. Any surplus potable water could be returned to the River Murray through the Morgan-Whyalla pipeline. The energy efficiency and maintenance costs of the co-located distillation desalination plant would be significantly better than for the originally-proposed reverse osmosis desalination plant.

The IFR would process high-level radioactive reactor wastes and re-cycled nuclear weapons, on-site using remotely controlled robotic handling equipment. It would produce fuel assemblies for other reactors. The residual low activity, short-half-life wastes may be stored on-site for up to 5 years, by which time they will have decayed sufficiently to be stored at a nuclear waste site, or mixed with depleted uranium and buried at the original mine site.

Other IFR/water distillation plants could be manfactured at Whyalla, for deployment at coastal cities, where there would be adequate supplies of seawater for cooling and for the inexpensive production of potable water.

Modular 360MW reactors of a standardised design are now in production, and could be deployed at such locations as Geelong and Gove, for cost-effective low-emission aluminium production. Greater energy output capacity may be provided by inter-connecting two or more modular reactors, as might be required for the replacement of the end-of-life fossil-fuel generating plants at the Playford Power Station at Port Augusta in South Australia.

We could barge-mount modular reactors and co-located CVES water distillation plants, for global deployment to dry-docks in coastal locations. The barges could be withdrawn for reactor fuel re-charging and maintenance when necessary, and replaced with new or re-furbished barges. In this way, it would be unnecessary to transport reactors or components through populated areas. Since it is virually impossible to extract weapons-grade material from a thorium-fuelled reactor, it is suggested that thorium-fuelled reactors should be exported if there is a security risk.

Several designs of marine propulsion reactor are in service, and have established performance and safety records. The establishment of shipbuilding and nuclear reactor manufacture at Whyalla could open a whole new market for Australian exports. As the supply and acceptability of fossil fuels diminishes, we may anticipate increasing use of nuclear reactors in military and commercial shipping of all types.

Remote Handling Equipment

CNC "robotic" mechanical handling equipment is required for the re-processing of radioactive materials, in the nuclear power industry. At present, it appears that feed-stocks of precision mechanical components, such as lead screws, are sourced from Germany. Finished lead screw parts and other components for CNC machines are usually machined in Asian countries, principally China. These manufacturing activities could be carried out in Australia by the automotive components industry, which is currently facing a gloomy future, particularly in South Australia.

Reactor Fuel Containers

We also require a metal refining and machining facility for reactor components, such as nuclear fuel containers.

6. SYNERGY

The development of a nuclear energy industry in South Australia will generate opportunities for other industries, not only in direct support of the nuclear industry but also to satisfy other, new, growing markets.

For example, components for the CNC machines, which are required for the remote processing of radioactive fuel assemblies in an IFR nuclear energy plant, are also required for the tracking mechanisms in a commercial solar power station.

U.S.A. is currently seeking component suppliers to participate in the Small Nuclear Reactor Programme (S.M.R. Programme) so, just as Australian industry has successfully competed in the U.S.A. aircraft industry, there are export opportunities, for our component manufacturers, in the nuclear energy industry. Export market information is available on the internet web page entitled The US New Build Market For Component Suppliers

The generators which are required for large wind turbine power plants would be applicable to small regional community nuclear energy plants. There will be a substantial demand for electrically-powered vehicles. We should be able to establish a viable industry for the production of electric generators and motors. And, of course, we will need steam turbines for our power plants.

The manufacturers of lead acid batteries are concerned by the reducing level of demand in the local automotive industry. If weight/capacity ratio is unimportant, then deep-cycle, long-life sealed lead acid batteries have a clear 4:1 cost advantage over lithium batteries, and so are the storage battery of choice in solar power installations. Additionally, unlike lithium, the materials in a lead acid battery are readily recycled at the end-of life. Since, in Australia, household domestic power consumption accounts for about 30% of total generated capacity, we could achieve a 15% reduction in carbon dioxide emissions if only 50% of households converted to battery-backed solar power. (Note: a cost/benefit analysis shows a financial benefit to householders who take this action. Please refer to my article "Off the Grid")

Why should we not also manufacture solar photovoltaic cells in Australia? Given a low-cost source of power, and a growing local market, we should be able to compete in the automated business of growing semi-conductor grade silicon crystals and manufacturing PV solar cells. The "sole Australian manufacturer of solar panels" in Adelaide is, of course, assembling imported PV cells into locally-manufactured frames. The facility is highly automated, and therefore competitive.

Given low-carbon low-cost industrial power, electrolytic aluminium production could be resumed at locations which are close to the market, such as Geelong, or at bauxite mining locations, such as Gove and the other Australian mines. If it should be decided to build defence vessels with aluminium superstructures at Whyalla, then it could also become a suitable location for an aluminium refinery. Aluminium will become an essential structural material, alongside steel, manufactured timber products, and carbon fibre.

If, of course, we re-open the Whyalla steel plate mill and fabrication workshops for the construction of reactor containment vessels, we would also be able to use the shipyard to build submarines and other vessels. The available space at Osborne is already committed to the maintenance and refitting of the fleet, so why not follow the usual practice of ship construction at a shipyard, and fitting-out at another location?

(Note: I have previously published on my web-site, http://www.nvicon.org, a much more complete listing of potential New Markets, relevant to the whole of Australia, rather than particularly to South Australia.)

It is possible that, at some future time, Australia could take part in the manufacture of nuclear fusion reactors. However, the current international research projects, e.g. the I.T.E.R. Project (in which Australia is not a participant), are not expected to result in a commercially-viable fusion reactor design before 2050. The I.T.E.R. machine will necessarily be of large size and of high power capacity, so that we could probably justify only one nuclear fusion power station for the whole of Australia, with a large interconnect system, much of which already exists. I have provided more details on my web-page "Nuclear Fusion", link: http://www.nvicon.org/id39.htm

Recently, the Skunk Works research division of Lockheed Martin in the U.S.A. has announced the invention of a small-size plasma containment cell which, if successful, could allow the design of a smaller nuclear fusion reactor. Such a machine could be built with a wide range of models of different size and energy capacity. Skunk Works predict that they will achieve proof-of-concept later in 2015, and produce a prototype commercial reactor within 10 years. Although Skunk Works has a record of success, the international science community is evenly divided between those who believe that the announcement was made to attract investment partners, and those who expect to see a practical breakthrough by the end of this year, 2015.

APPENDIX I - C.V. of Clive M. Pearson

My name is Clive Maurice Pearson.

I have no pecuniary interests in, nor membership of, any social, environmentalist, industrial, commercial or political organisation.

After graduating in 1954 with a degree in Special Physics (i.e. Nuclear Physics), I was employed for 7 years as a Defence Electronic Engineer/Senior Defence Engineer by G.E.C. Ltd. in the U.K. and Australia. I was principally involved in the design and production development of airborne radar and counter-measures equipment.

I was next employed by the Hawker Siddeley Group for a total of 7 years, as Chief Engineer for Defence and Industrial Projects in South Australia, then as Victorian Branch Manager and Commonwealth Market Development Manager, then for a brief period as Sales Manager for S.A. and WA. While working as Chief Engineer in South Australia, I devised and developed a very effective system of cost estimation, and of cost and progress control, for cost-plus Defence R&D projects. This enabled Company participation, on cost and on schedule, in the Ikara Project and the Army Manpack Radio Project.

Upon leaving employment with the Hawker Siddeley Group, I applied for and was granted qualification as a Chartered Engneer.

For the next 7 years, I was employed in the Forest Products Industry, as S.A. Branch Manager for Gibbs Bright & Co. Pty. Ltd., an Australian multi-state manufacturing and distribution Company, headquartered in Melbourne. While in this position, I acted as an Electronics Consultant to their Panelboard factory at Mt. Gambier and to their systems research division in Sydney. Reporting to the Board, I carried out market studies for proposed new ventures.

For the next 2 years, I worked as a Microcomputer Consultant to Hunting Systems and to the Radio Group of W.R.E.

Next, for 7 years, I was the Manager, then Proprietor, of Tracker Communications Pty. Ltd., an Adelaide-based HF/VHF radio communications equipment design and

manfacturing company.

For the remainder of my career, I was self-employed with a small support staff in my own proprietary companies. I designed and manufactured communications equipment for Indonesia, automatic weather stations for Singapore, and computers for the R.A.A.F. Air Defence System. I was a Consultant to the R.A.A. for tender assessment of a communications equipment replacement programme. I was a Contract Engineering Consultant to Telstra for 3 years on the Jindalee O.T.H.R. Project. I established a retail computer business, provided internet services, and opened the first two web cafes in South Australia, outside Adelaide.

In volunteer service, I joined the South Australian Civil Defence organisation in 1962, and attended several Scientific Officer, Light Rescue, and Control & Staff Training Courses at the Commonwealth Training Centre at Mt. Macedon. From 1965 to 1967, I served as Controller of Civil Defence for the City of Salisbury. I was also for several years, until it was replaced by the S.A.F.B., a member, then Chairman, of the Elizabeth North Brigade of the E.F.S. I have participated in the foundation and administration of several interest groups, in amateur radio, microcomputer technology, and business networking & development. I qualified as a T.A.F.E. Lecturer and conducted classes in computer operation and business management.

Since retirement in 2004, I have engaged in a wide range of social, scientific and market research work, pro bono publico. I maintain several internet web-sites, most relevantly http://www.nvicon.org, which deals with the broader problem of Climate Change, as it affects the whole of Australia.