Slide 1 - Title

Good Morning Chair, Members of the Committee and guests,

My name is Matthew Hole. I am a plasma physicist and engineer at the Research School of Physics Sciences and Engineering at the Australian National University. I am also Chair of the Australian ITER Forum, a group of multi-displinary scientists and engineers from several Australian institutions presenting the case for Australian involvement in the next step fusion experiment, the International Thermonuclear Experimental Reactor. With me today are : Dr Boyd Blackwell, Director of the H-1 National Plasma Research Facilty. and Prof. John O'Connor, Professor of Physics at the University of Newcastle.

I am here today to explain to you the principles of fusion energy, which offers the world a near zero greenhouse gas emission base-load power supply, capable of sustaining civilization for millions, if not billions of years.

Slide 2 - ITER Forum

The Australian ITER Forum comprises over a hundred scientists and engineers who support a single mission-orientated goal : controlled fusion as an energy source.

ITER Forum scientists are drawn from five universities and ANSTO, and span multiple research disciplines: plasma physics, development and analysis of advanced materials, and surface physics, through to atomic physics. Both the research disciplines, and the research institute list are growing.

Slide 3 – What is fusion

Thermonuclear fusion is the combination of two lighter nuclides to form a heavier nuclide. The process is the exact opposite to fission, in which a heavier nuclide splinters into lighter products. The easiest reaction to initiate is the combination of a deuterium and tritium nuclide to form a stable helium nucleus, and an energetic neutron. The energy output of fission and fusion is millions of times greater than that of coal.

Slide 4 – Fusion : A safe route to nuclear power

Fusion is the process that powers the Sun and the stars. In the Sun, gravity is sufficiently strong to overcome the repulsive force between similarly charged ions. On Earth, gravity is too weak, so instead the material has to be heated to 100 Million ^{o}C. To constrain the material at such high temperatures we use strong magnetic fields. The most advanced magnetic confinement geometry is the tokamak, a donut-shaped vessel in which the plasma resides. The plasma is kept confined along lines of magnetic force. In essence, these act as a thermoflask, keeping the plasma hot.

Magnetic confinement fusion is intrinsically safe. There can be no chain reaction, explosions or melt-down. At worst, a loss of magnetic confinement will damage the first wall of the system. Magnetic confinement fusion can not be used as a weapon, or in weapons development.

Fusion is also environmentally and politically friendly. The fusion process itself generates zero greenhouse gas emissions. Greenhouse emissions are totally derived from the construction and processing of materials and fuel used in the reactor. Unlike fission, the products of fusion are not radioactive. Rather, radioactivity is generated indirectly, by neutron activation of the first wall and vessel structure.

Slide 5 - Low Level Waste

Compared to fission technology, fusion offers low-level radioactive waste. Figure 1 shows the radioactivity per unit power generation of fission and fusion power plants following facility decomissioning. Even employing present-day ferritic technology in the vessel structure, a fusion power plant is 3000 times less radioactive than its fission equivalent 100 years after shutdown. Indeed, within one human lifetime the entire fusion power plant could be completely recycled. Using future Vanadium alloy structures, fusion is a staggering 1,000,000 times less radioactive after 30 years than fission.

Slide 6 – Fusion and Raw Materials

Fusion fuels deuterium and tritium are abundant. Deuterium is present in water - indeed, in this jug of water lies the equivalent of 800 litres of oil. Tritium does not occur naturally in nature, and must be bred by neutron activitation of Lithium, a mineral which Australia has 4% of the worlds resources.

Even using the most extravagant world energy-use predictions, there is sufficient D-T to power the Earth for 10's of thousands of years. This is beyond civilization time scales. Using a next generation fusion reaction, a deuterium-deuterium reaction, there is sufficient fuel to power the Earth for millions of years.

Australia is also well endowed with many of the advanced materials used in the construction of a fusion reactor. These include the structural elements vanadium, tantalum, titanium and zirconium, and the superconductor niobium. Rather than sell these in their raw state, these elements can be value added by processing and component manufacturing.

Slide 7 – Fusion Power plant designs

Conceptual designs for a fusion power plant have many similar characteristics to other base-load generation schemes. The heat of reaction is converted to steam, which subsequently drives an electric generator.

Slide 8 – Moore's law

Figure 2 shows the spectacular progress towards fusion power over the last 40 years. The fusion performance measure is a normalized product of pressure and confinement time The ITER objective is a relatively close to current results, compared to the progress already made. In fact, progress in fusion has outstripped Moore's Law, the famous rapid growth rate of the semiconductor industry. ITER only needs the equivalent of the improvement from a Pentium to a Pentium 4.

Slide 9 - ITER

The next step in fusion energy is the International Thermonuclear Experimental Reactor (ITER). In latin, ITER means the way. ITER is a 500 MW fusion experiment, designed to explore the burning plasma regime, where the energetic products of reaction self-heats the plasma. Put in perspective, one of Australia's largest coal-fired power station, Erarring, has four 660MW generators. ITER is hence comparable in size to a medium size coal-power plant.

The plasma will sit in a cylindrical tank 60m high. Inside, the entire vessel will be cryogenically cooled to permit operation of the superconducting magnetic field coils. At the plasma core, the central ion temperature will approach 100 million degrees centrigrade, nearly 7 times hotter than the core of the Sun. At 837 m3 , the plasma volume approaches the volume of an Olympic swimming pool. Finally, nearly 70 MW of externally injected heating will be used, which equates to about a million light globes.

Slide 10 – ITER Objectives and Consortium

The ITER project has three principle objectives. Programmatically, ITER will demonstrate fusion energy for peacefull purposes. Indeed, ITER is a pre-protype power plant, and the last large scale fusion energy experiment en-route to power production. Physics objectives include an exploration of the “burning plasma” regime, where the products of reaction self-heat the plasma. Whilst we understand the principles of magnetic confinement, and are confident that ITER will meet its objectives, there are unresolved physics issues which will affect the design and performance of a power plant. This research also has impact to other laboratory and natural plasmas. Finally, ITER will demonstrate the integration of technologies, and address the crucial materials issue. The first wall in ITER has to withstand massive heat flux and neutron damage. Over the lifetime of a power plant, every single atom in the first wall will be displaced over 100 times by a high-energy impact event. This is a research field in which Australia has ripe expertise upon which to build.

ITER is a growing consortium of nations and alliances, comprising the European Union, the US, Russia, China, South Korea and Japan. On Tuesday this week, India became the seventh full ITER partner. Brazil has expressed interest as a minor partner, and negotiations have commenced. The ITER partners are anxious to formalize the ITER legal entity, and commence construction in Cadarache, in the South of France. Once the ITER legal entity is formalized, and contracts awarded, additional minor partners will only be able to enter the ITER project under the terms of the ITER legal entity, with diminished benefit. This window of opportunity is quickly closing.

Barring the International Space Station, ITER is also the world’s largest science project. The construction/10 year operation costs are AUS$10bn/$6bn. Over 80% of the construction costs will be ploughed straight into industry. Whilst the costs of fusion research seem high, in other developed nations such as the US, they in fact represent only ~0.1% of the energy consumption bill.

Finally, to give a sense of international perspective and importance, ITER is ranked as the highest funding priority from the worlds largest physical sciences research body, the US Dep. Of Energy.

Slide 11 Fusion Development Time Scales

The ITER experiment will start to produce results in 10 years, enabling the construction of a demonstration reactor “DEMO” in 2025. In turn, this will allow the first commercial power plant in 2050. By 2060, we envisage 10 plants operating, and by the beginning of the 22nd century about 1000 – 20% of global electricity.

Whilst these time scales seem long to us, they are short in energy Research and Development. Assuming carbon sequestration can be made to work, it will likely be ~100 years before hundreds of coal fired power stations in China are replaced. Development and significant deployment of the production and distribution structure for the hydrogen economy will take decades. On this issue, we note that the hydrogen economy will double C02 emissions, unless a greenhouse friendly baseload power supply is used.

Slide 12 Australian Expertise

Australia has an impressive history of fusion research. Indeed, an Australian, Sir Mark Oliphant, discovered the fusion process in 1934, via the same reactions which will be exploited in a fusion power plant. In 1946, a graduate of the University of Sydney, Peter Thoneman pioneered early fusion research in the UK. In 1958, Sir Mark Oliphant commenced plasma physics research at the ANU. Since 1964, fusion research in Australia has grown across multiple institutions, and made important contributions to the world fusion program. One of these, the Spherical Tokamak, now one of the worlds leading confinement configurations, was pioneered by Flinders University and ANSTO.

To preserve and grow the fusion program, fusion science needs to be a national research priority. That it is not a research priority is inconsistent with the research orientation of nearly every other advanced nation on Earth.

Slide 13 : Benefits and Opportunities

The benefits to Australia through growing an ITER-engaged fusion research program are multifold. Fusion energy promises an abundant energy supply. Combined with a translation to electric transportation, it offers Australia and the world energy independence from oil, and an end to the geopolitical instability brought by concentrations of oil.

While the overall goal is far sighted, with horizons of 20 to 40 years, economic payoffs will commence immediately. Nearly 80% of the construction costs of ITER will be delivered straight to industry through industrial contracts. Most importantly we have essential resources which will be in demand for the construction of fusion machines. We can increase our benefit from these if we actively work to value add to these rather than sell them in their raw state. Australia has world significant resources in Li, V, Ta, Ti, Zr and Ni – all of which will play a part in this energy future.

Research findings will bring scientific and industrial benefits immediately which will impact not only on fusion research but on other forms of energy production and on raising essential skill levels in this future field of technology. Australian graduates are highly sought by the worlds large fusion laboratories. A domestic fusion research program is hence essential to preserve and grow existing competence.

Fusion energy is a near zero greenhouse gas emitter, which provides base load energy generation. As such, it is a responsible investment course to counter the real threat of global warming.

Finally, ITER, by definition, is an international research project, and so builds and fosters international research links. Through ITER, we would be able to build Australia’s scientific credibility, and consolidate Australia’s position within the IAEA as the most advanced nation in atomic energy in our region.

Slide 14 : Part of a low C02 solution.

Figure 3 shows Australia’s past and projected electricity generation capacity, as appearing in the Federal Government’s energy White Paper. Over a 40 year time span, the relative components of each energy sector remain more or less unchanged. Renewable energy contributes to about 8% of total supply. Fusion energy offers a future base-load power generation. It has an energy density sufficiently high to power modern civilization and industry, as well as providing power grid stability. Magnetic confinement fusion has the following three additional benefits : zero nuclear proliferation, very low level radioactive waste, and a universal abundance of fuel.

Slide 15 : Bottling the Sun

In closing, we support the development of alternative energies but as part of that strategy we need a solid "base load" generation which is low green house emitting. In the long term the prime candidate for this role is fusion. A **responsible** low C02 emission energy future requires investment in a blend of nuclear + renewable power technologies

Fusion provides not only an endless source of energy for our civilisation, but an endless range of opportunities for Australian science and industry if we embrace its opportunities early enough to remain competitive.

The ITER project offers a path forward to access these opportunities. The window of opportunity to maximize Australia's competitive advantage is however closing as I speak. For this reason alone, involvement in the ITER project needs to be urgently addressed by the Commonwealth.

In summary, the Australian ITER Forum has a vision for the future, which promotes sustainable and responsible economic growth and fosters creation of a fusion-energy industry through research.

We have two recommendations for the committee to consider:

1 – Australia negotiates a subscription to ITER as a matter of urgency.

2 – A national or international centre be established to consolidate Australia's research efforts in fusion related research

Ladies and gentleman, thank you for your attention.