27 PRODUCT STEWARDSHIP AND THE NUCLEAR FUEL CYCLE

A number of issues raised in submissions on the Draft EIS were about nuclear non-proliferation, arms control and disarmament, international politics, treaties and conventions. These issues are, principally, the responsibility of government. However, the responses below outline BHP Billiton's general appreciation of such issues based on publicly available information.

27.1 STRATEGIC AND POLICY

27.1.1 ACCOUNTING FOR URANIUM

Issue:

Clarification was sought on how the Government selects countries to which Australia will sell uranium to ensure it is not used in nuclear weapons. It was also questioned how Australia accounts for, and reports on, Australian Obligated Nuclear Material (AONM) in the international nuclear fuel cycle (NFC).

Submissions: 2, 7, 10, 12, 26, 44, 88, 278, 299, 302 and 390

Response:

Australia only sells uranium for peaceful purposes to states that:

- are parties to the Treaty on the Non-proliferation of Nuclear Weapons (NPT)
- have implemented a safeguards agreement with the International Atomic Energy Agency (IAEA)
- for non-nuclear weapon states (NNWS), those which have a safeguards additional protocol (AP) in force, and have a good non-proliferation record, and
- have acceded to relevant international treaties.

Further, to be eligible to receive, store, process, and use Australian uranium a country must have signed a bilateral safeguards agreement with Australia. Australian safeguards requirements are based on IAEA safeguards, which provide the basic assurance that nuclear material is not being diverted from peaceful to non-peaceful purposes and that there are no undeclared nuclear programs and materials in NNWS receiving or involving Australian uranium. Under the *Nuclear Non-Proliferation (Safeguards) Act 1987* the Australian Safeguards and Non-Proliferation Office (ASNO) is charged with accounting for AONM in the international nuclear fuel cycle and to report this matter to the Australian Parliament in its annual report.

This issue was discussed in the Draft EIS in Appendix E3 (Sections 3, 5.2, 5.3 and 7.3).

Uranium export policy

The Australian Government has operated a consistent and coherent uranium export policy for over 30 years.

After Australia ratified the NPT in 1973, an inquiry with the powers of a royal commission was conducted into whether Australia should mine its uranium and, if so, under what conditions. As a result of what became known as the Fox Inquiry, the Australian Government determined in 1977 it would supply uranium only to NNWS that were a party to the NPT. While this policy did not require that nuclear weapon states (NWS) had to be parties to the NPT, it did specify that exports to NWS would require an assurance of peaceful use and that any Australian uranium export would be covered by IAEA safeguards.

Domestic legislation

As part of its ratification process for international treaties and conventions, Australia enacts legislation to implement its international commitments under those treaties and conventions into domestic Australian law. In the case of uranium and nuclear exports, applicable federal legislation are the *Nuclear Non-Proliferation (Safeguards) Act 1987* (Safeguards Act) – this includes the *Convention on the Physical Protection of Nuclear Material* (CPPNM) – and *Customs (Prohibited Exports) Regulations 1958*, which are made under the *Customs Act 1901*.

Bilateral safeguards agreements

Australia has 22 bilateral safeguards agreements in force covering 39 countries plus Taiwan. An agreement with Euratom covers all 27 member states of the European Union. These treaty-level agreements are concluded between Australia and countries receiving nuclear items, and serve as a mechanism for applying conditions in addition to IAEA safeguards.[i]

The key point is that Australia's safeguards requirements are based on IAEA safeguards, which provide the basic assurance that nuclear material is not being diverted from peaceful to non-peaceful purposes and, where an AP is in force, that there are no undeclared nuclear programs and materials. Generally IAEA safeguards are not concerned with attributing an origin to nuclear material, that is, the 'flag' (i.e. country of origin) and conditions attached by suppliers, although there are limited exceptions, such as under certain non-NPT safeguards agreements. It is the bilateral safeguards agreements that manage supplier flags (such as AONM) attached to nuclear material.

When negotiating these bilateral agreements the Australian government considers issues such as a state's proliferation record and its accession to relevant international treaties. Recent Australian governments have chosen not to link directly bilateral nuclear negotiations with other matters (acknowledged as matters of concern) such as human rights or democracy issues[ii].

Further, in the case of NNWS, countries must meet the NPT full-scope safeguards standard: that is, IAEA safeguards must apply to all existing and future nuclear activities. Since 2005, for uranium supply to NNWS, Australia has made implementation of the AP a prerequisite for nuclear supply.

In the case of NWS (for example, China) before Australian uranium is supplied there must be a treaty-level assurance that nuclear material will be used only for peaceful purposes and will not be diverted to military or explosive purposes, and that IAEA safeguards will apply to that material. Facilities storing, processing or using AONM must be subject to each NWS safeguards agreement with the IAEA. Therefore, operators of these facilities are required to keep, among other things, nuclear material accountancy records to IAEA standards like any other NNWS subject to safeguards.

Other principal conditions in Australia's bilateral safeguards agreements for the use of AONM include:

- none of the following actions can take place without Australia's prior consent:
    - transfers of the AONM to third parties
    - enrichment to 20% or more in the isotope uranium-235
    - reprocessing
- provision for fallback safeguards or contingency arrangements in case NPT or IAEA safeguards cease to apply in the country concerned
- an assurance that internationally agreed standards of physical security will be applied to AONM in the country concerned
- detailed 'administrative arrangements'[iii] between ASNO and its counterpart organisation, setting out the procedures to apply in accounting for AONM
- regular consultation regarding the operation of the agreement
- provision for the removal of AONM in the event of a breach of the agreement.

A supplementary control included in agreements with China, Russia, and Japan is that AONM can only be used, processed or stored at predetermined facilities agreed between the parties. The list of such facilities is known as the Delineated Nuclear Fuel Cycle or Eligible Facilities List. For nuclear weapon states, such as China, all facilities that use, process or store AONM must also be subject to the safeguards agreement which that state has with the IAEA (i.e. these are civil nuclear facilities) and can be removed from the Eligible Facilities List only by mutual agreement between the parties. Australia does not allow AONM to be used, processed or stored at dual-use (military–civil) facilities.

Australia has a bilateral nuclear safeguards or nuclear transfer agreement with each NWS and 34 other countries plus Taiwan, as set out in ASNO's annual reports. The agreements with the UK, the US, France, Russia and China came into force in 1979, 1981, 1981, 1990 and 2007 respectively, so on a bipartisan basis Australia has been selling uranium for peaceful purposes to NWS for over 30 years. In 2007 a new bilateral agreement was negotiated with Russia to replace the limited existing 1990 agreement which came into force on 11 November 2010[iv].

Safeguards

All five NWS have ratified the NPT, negotiated a safeguards agreement with the IAEA, and ratified an AP. IAEA activities at safeguarded facilities (in NWS) are essentially the same as those at any nuclear facility in a NNWS with an IAEA safeguards agreement in force. In accordance with its safeguards methodology and objectives, the IAEA decides whether or not to conduct inspections at declared facilities. The IAEA does conduct inspections in NWS.

Nonetheless, in general terms, safeguards in NWS are different to those in NNWS. In accordance with the NPT (Art III), NNWS agree to accept IAEA safeguards. There is no similar requirement for NWS and, thus, NWS safeguards agreements with the IAEA are termed Voluntary Offer Agreements.

Broadly, safeguards are designed to prevent (detect and deter) the proliferation of nuclear weapons and detect undeclared nuclear material or activities in all states other than NWS. Clearly under the NPT, NWS have nuclear weapons, so it follows that they have undeclared nuclear material and activities. Therefore, in NWS, safeguards are used to achieve an objective different from safeguards in NNWS, namely, the non-diversion of nuclear material from peaceful purposes (declared civil nuclear activities and programs) to military or unknown purposes.

Nuclear materials accounting and control

Australia has a safeguards agreement with the IAEA that requires Australia to ‘establish and maintain a system of accounting for and control of all nuclear material subject to safeguards under the agreement’[v].

27.1.2 AUSTRALIAN DEFENCE WHITE PAPER

Issue:

It was suggested that the Australian Defence White Paper 2009 states China is a threat. On this basis, it was questioned why Australia is selling uranium to China that could be diverted to nuclear weapons.

Submission: 125

Response:

The 2009 Australian Defence White Paper (White Paper)[vi] recognises that China is a significant, rising regional and world power.[vii] It does not categorise China as a specific threat to Australia.

The Australian Government took all strategic issues into consideration when ratifying the 2007 Agreement between the Government of Australia and the Government of the People’s Republic of China on the Transfer of Nuclear Material. The Government gave similar consideration to strategic issues when granting a licence to export uranium to China in 2008 and 2009. Australian uranium is sold for exclusively peaceful purposes, specifically the production of electricity through nuclear energy. Australian uranium is subject, among other things, to each recipient country’s safeguards agreement with the IAEA and a bilateral safeguards agreement between Australia and the recipient country.

27.1.3 EFFECTIVENESS OF BILATERAL AGREEMENTS

Issue:

It was suggested that Australian controls on Australian Obligated Nuclear Material (AONM) in the international NFC are weak because Australia does not conduct inspections and in some countries there is no separation between military and civil nuclear fuel cycles.

Submissions: 7, 12, 13, 65, 216 and 218

Response:

Australian safeguards requirements are based on IAEA safeguards that provide the basic assurance that nuclear material is not being diverted from peaceful to non-peaceful purposes and that there are no undeclared nuclear programs and materials in NNWS receiving or involving Australian uranium. The IAEA reports on the findings of its verification activities in its annual report. In each of the NWS there is a clear separation between military and civil nuclear fuel cycles. AONM can only be stored, processed or used at facilities subject to each NWS safeguards agreement with the IAEA (i.e. at civil or peaceful use only facilities; dual use facilities are excluded).

The IAEA reports on the findings of its verification activities in its annual Safeguards Implementation Report, a summary of which is contained in the IAEA annual report. In turn, that part of the Safeguards Implementation Report relevant to the application of safeguards in Australia is reproduced by ASNO in its annual report. The Director General of ASNO reports annually to the Australian Parliament on the status of AONM in the international fuel cycle. In 2009–2010, as in earlier reports, the Director General confirmed all relevant statutory and treaty requirements were met. The Director General also reported that all AONM was satisfactorily accounted for.

27.1.4 EFFECTIVENESS OF THE IAEA

Issue:

It was suggested that the IAEA is unable to effectively undertake its role and is an ineffective international organisation.

Submissions: 7, 16, 37, 141, 204, 206, 216, 218, 247 and 346

Response:

The IAEA is an effective international organisation with a good record of detecting safeguards violations. Strengthening safeguards is an ongoing activity of the IAEA and its member states.

The IAEA is controlled by a 35-member Board of Governors, on which Australia has held a seat uninterrupted since 1957. The Board regularly reviews IAEA performance, programs and resources to ensure the organisation remains effective. The Board and the IAEA General Conference (an annual meeting of the 151 member states) review and debate the IAEA annual report.

27.5.5 OLYMPIC DAM URANIUM AND THE SPREAD OF NUCLEAR WEAPONS

Issue:

It was suggested that greatly expanding exports of uranium from Olympic Dam would inevitably fuel military programs worldwide.

Submission: 65

Response:

With the IAEA and its bilateral partners, Australia has in place adequate safeguards measures to prevent AONM being used in military programs. Worldwide demand for uranium as an energy source is expected to increase significantly over the next few decades and Olympic Dam will be seeking to satisfy this expanding market.

As explained in detail in Sections 27.1.1 and 27.1.6 of this chapter (refer also Draft EIS Appendix E3), Australia sells its uranium exclusively for peaceful use and has in place a network of bilateral safeguards agreements which, taken with other measures such as safeguards activities conducted by the IAEA, ensure AONM remains in peaceful use.

27.2 NPT AND DISARMAMENT

27.2.1 THE EFFECTIVENESS OF NPT

Issue:

It was suggested that the NPT is not a strong barrier to the spread of nuclear weapons and cannot be relied on to deter nation states from their acquisition, with one submission noting that some states will cheat and find ways around the treaty to obtain nuclear weapons.

Submissions: 65, 361, 216, 85, 318, 37, 204, 245, 247, 218 and 205

Response:

There is little doubt that the NPT with its attendant verification regime (IAEA safeguards) has (a) limited the spread of nuclear weapons and (b) created an international legal framework in which the overwhelming majority of countries judge that it is in their national security interests to reject nuclear weapons. Since the NPT came into force in 1970, IAEA safeguards have steadily been strengthened leading, in 1996, to the Additional Protocol.

Overall, there have been significant reductions in nuclear arsenals since 1991 (nominally the end of the Cold War).

27.2.2 FAILURE OF STATES PARTY TO THE NPT TO MEET THEIR TREATY OBLIGATIONS

Issue:

It was suggested that many states that are party to the NPT are not abiding by their non-proliferation obligations and, specifically, NWS are not meeting their NPT disarmament obligations.

Submissions: 44, 8, 85, 302, 335, 300, 116 and 141

Response:

The five NWS are committed to their disarmament obligations: this was reaffirmed at and acknowledged by the NPT Review Conference in 2010. From the IAEA's 2009 annual report it can be understood that of its 151 member states the IAEA has ongoing 'safeguards issues' with only three states: North Korea, Iran and Syria.

The five NWS are committed to their disarmament obligations. This was noted in the 2010 NPT Review conference Final Document (paragraph 79)[viii]; although the document also acknowledged there was still a lot of work to do before total disarmament was achieved.

The Final Document recognised many efforts made by the NWS towards meeting their disarmament obligations, including (paragraphs 89-95)[ix]:

- the closing and dismantling of nuclear weapons-related facilities
- reductions in the operational status of nuclear weapons and announced measures related to de-targeting
- declared moratoria by some NWS on the production of fissile material for nuclear weapons
- increased transparency of some NWS with respect to the number of nuclear weapons in their national inventories
- efforts towards the development of nuclear disarmament verification capabilities that will be required to provide assurance of compliance with nuclear disarmament agreements for the achievement and maintenance of a nuclear-weapon-free world; specifically the cooperation between Norway and the United Kingdom of Great Britain and Northern Ireland in establishing a system for nuclear warhead dismantlement verification.

While the IAEA annual reports acknowledge the AP is not yet universal, it is noted that, as of 10 March 2011, of the 62 NNWS NPT parties with significant nuclear activities, 47 (76%) had an AP in force and a further 10 (17%) had signed an AP or had an AP approved by the IAEA Board of Governors. An AP is in force in Taiwan. All five NWS have an AP in force. Even though it is a non-NPT party, India has ratified an AP. Latest details of AP status may be found at <http://www.iaea.org/OurWork/SV/Safeguards/sg_protocol.html>.

Issue:

It was suggested that many countries have not signed the NPT.

Submission: 388

Response:

The NPT has 189 signatory states, including the five nuclear-weapon states[x], only India, Israel and Pakistan have not signed. North Korea gave notice of its withdrawal from the NPT in 2003.

More countries have ratified the NPT than any other arms limitation and disarmament agreement – a testament to the Treaty's significance.

27.3 NUCLEAR WEAPONS

27.3.1 ASSURANCE THAT AUSTRALIAN URANIUM IS NOT DIVERTED TO WEAPONS

Issue:

The question was asked: How can we be certain that AONM is not diverted to military programs?

Submissions: 7, 12, 44, 77, 144,180, 186, 211, 237, 246, 266, 312, 370 and 390

Response:

As noted in responses above and in Appendix E3 of the Draft EIS, Australia sells uranium only for peaceful purposes to states party to the NPT, which have implemented a safeguards agreement with the IAEA (and, additionally, for NNWS, those which have an AP in force). Further, to be eligible to receive (store, process or use) Australian uranium a country must have a bilateral safeguards agreement in force with Australia, which imposes conditions additional to IAEA safeguards. Australian safeguards requirements build on IAEA safeguards that provide the basic assurance that nuclear material is not being diverted from peaceful to non-peaceful purposes and that there are no undeclared nuclear programs and materials in NNWS receiving Australian uranium.

27.3.2 SUGGESTED LINK BETWEEN URANIUM SUPPLIED BY OLYMPIC DAM, THE NUCLEAR POWER INDUSTRY AND NUCLEAR WEAPONS

Issue:

It was suggested that nuclear power reactors are used to provide expertise and materials for nuclear weapons and, as such, AONM should not be sold for use in power reactors.

Submissions: 7, 35, 37, 44, 52, 65, 216, 220, 237 and 326

Response:

Nuclear weapons programs in the NWS and nuclear weapons capable states (North Korea, India, Israel and Pakistan) emerged from dedicated military programs, not nuclear power programs.[xi]

27.3.3 INFERRED CONNECTION BETWEEN NUCLEAR POWER AND NUCLEAR WEAPONS IN CHINA

Issue:

It was suggested that AONM sold to NWS, including China, could be used in nuclear weapons or at least would free up indigenous uranium for use in military programs either as highly enriched uranium (HEU) or depleted uranium (DU).

Submissions: 7, 35, 92, 180, 200, 279, 331, 343, 351, 363 and 373

Response:

Australian uranium is sold for use in nuclear power reactors under strict treaty-level legal agreements that specifically prohibit any military use. These bilateral agreements prohibit the use of AONM in direct military applications of nuclear energy and nuclear material for nuclear weapons, military nuclear propulsion, military nuclear reactors, production of tritium for military purposes, and direct military non-nuclear applications of nuclear material such as depleted uranium munitions.[xii]

Further, AONM can be stored, processed or used only at facilities subject to a country's safeguards agreement with the IAEA in the case of NWS – in NNWS, all nuclear facilities are subject to safeguards. In the first instance, this peaceful-use assurance is given by the IAEA through its safeguards program(s).[xiii]

27.3.4 MIXED OXIDE FUEL STOCKPILE IN JAPAN

Issue:

It was noted that Japan is stockpiling MOX (mixed oxide uranium fuel) for use in nuclear power reactors and it was questioned whether this could stimulate a regional nuclear arms race.

Submission: 65

Response:

MOX is unsuitable as a source of fissile material for use in nuclear weapons, but it is suitable for use as fuel in nuclear power plants (NPPs). The nuclear weapon programs in China and North Korea predate and are not influenced by Japan's stockpile of MOX.

For over 30 years Australia has implemented a strong peaceful-use-only policy in regard to exports of uranium. Therefore, it would appear successive governments have concluded the sale of Australian uranium does not contribute to a regional nuclear arms race.

For over 30 years Australia has implemented a strong peaceful-use-only policy in regard to exports of uranium (AONM); the term AONM includes irradiation products such as (reactor grade) plutonium. Australia allows AONM to be used in MOX fuel assemblies. Successive Australian governments have concluded MOX is not a significant proliferation threat when managed under IAEA safeguards and a bilateral safeguards agreement.

Australia appears to be satisfied about Japan's enduring commitment to its NNWS status and has been supplying uranium to Japan since 1982.

27.3.5 SOURCES OF NUCLEAR MATERIAL FOR WEAPONS

Issue:

It was suggested that nuclear material (fissionable depleted uranium) ultimately ends up in nuclear weapons and war. Certain submissions noted that this is a global issue.

Submissions: 37, 43, 45, 46, 97, 177, 185, 206, 218, 236, 239, 244, 255, 266, 318, 352 and 363

Response:

Through treaties and bilateral safeguards agreements, Australia proscribes the use of AONM in any military program. Clandestine nuclear weapon programs have relied on undeclared sources of material rather than diversion from declared civil programs.

Through its network of bilateral safeguards agreements, Australia proscribes the use of AONM in any military program or explosive device, which includes depleted uranium munitions, military propulsion systems and the production of tritium for military use (see Section 27.1.1 for further discussion). Safeguards and nuclear material accounting arrangements are in place to ensure these prohibitions – export conditions – are achieved and verified.

Issue:

BHP Billiton was asked to state the amount of plutonium that is produced from Olympic Dam uranium.

Submission: 306

Response:

ASNO publishes annually consolidated data on AONM (plutonium) holdings in the international nuclear fuel cycle; this data does not detail AONM by source (i.e. it does not differentiate material supplied by Olympic Dam, Beverly or Ranger mine, or any other Australian source).

In its annual reports, ASNO presents bulk figures for AONM in the international nuclear fuel cycle, including plutonium quantities. AONM is 'Australian uranium and nuclear material derived from [it]' (i.e. plutonium) (ASNO Annual Reports, Glossary). All AONM (including plutonium) is subject to IAEA safeguards and the conditions on peaceful uses only are set out in all bilateral safeguards agreements. While the ASNO figures differentiate between separated and irradiated plutonium, they are not attributed to source. The 2009–2010 annual report (extract Table 9 (with pertinent footnotes), page 61) gives the following information with respect to plutonium (AONM).

Extract Table 9 AONM

Category	Location	Tonnes (Footnote (FN) 19)
Irradiated plutonium (FN21)	Canada, European Union, Japan, Mexico, South Korea, Switzerland, United States	127
Separated plutonium (FN22)	European Union, Japan	1.7

Footnotes

19. All quantities are given as tonnes weight of the element uranium, plutonium or thorium. The isotope weight of U-235 is 0.711% of the element weight for natural uranium and from 1% to 5% for low-enriched uranium.

21. Almost all Australian-obligated plutonium is irradiated, i.e. contained in irradiated power reactor fuel or plutonium reloaded in a power reactor following reprocessing.

22. Separated plutonium is plutonium recovered from reprocessing, before return to reactors for reuse in reactors for further power generation. This plutonium is used for reactor fuel after being mixed with uranium – termed mixed oxide (MOX) fuel. A significant proportion of Australian-obligated separated plutonium is stored as MOX. Separated plutonium holdings fluctuate as plutonium is fabricated as MOX fuel and returned to reactors. On return to reactors the plutonium returns to the 'irradiated plutonium' category. During 2009, 0.5 tonnes of Australian-obligated plutonium was fabricated into MOX fuel and transferred to reactors.

27.4 SAFEGUARDS

27.4.1 ACCOUNTING FOR URANIUM IN CHINA

Issue:

It was questioned how Australia would hold China accountable for the peaceful use of AONM.

Submissions: 43, 46, 85, 159, 177, 185, 266, 291, 351 and 388

Response:

As discussed in Appendix A3 of the Draft EIS, the primary assurance about the peaceful use of AONM rests on safeguards applied by the IAEA. In accordance with the bilateral safeguards agreement, detailed administrative arrangements setting out procedures for accounting for and reporting on AONM have been concluded with China. These arrangements are very similar to those in force with other NWS.

27.4.2 EFFECTIVENESS OF SAFEGUARDS

Issue:

It was suggested that IAEA safeguards are ineffective, especially since there are no safeguards inspections in NWS and the IAEA is under-resourced. Also, it was suggested that safeguards are unable to prevent the diversion of uranium.

Submissions: 35, 52, 65, 85, 144, 216 and 289

Response:

The IAEA does conduct safeguards inspections in NWS. The fact that the IAEA, with assistance from its member states, has detected undeclared nuclear material, facilities and programs counters the argument that safeguards are not effective.

27.5 NUCLEAR MATERIALS ACCOUNTANCY AND CONTROL (NMAC)

27.5.1 ACCOUNTING FOR URANIUM IN COPPER CONCENTRATE

Issue:

Clarification was sought on how Australia and China would account for uranium extracted from copper ore concentrates in China to ensure it was not used in military programs.

Submissions: 44, 92 and 159

Response:

As discussed in Appendix E3 of the Draft EIS, a new bilateral agreement with China would be required before BHP Billiton could export copper concentrate containing uranium to ensure any uranium recovered (in China for peaceful nuclear power use) was subject to the bilateral Nuclear Materials Transfer (Safeguards) Agreement (2007) and its accounting requirements (Administrative Arrangements).

The Australian Government strictly controls the export and use of AONM, selling it only to countries that are parties to the NPT and where AONM is subject to a bilateral safeguards agreement. AONM includes uranium and its derived products, such as plutonium. Bilateral safeguards agreements control UOC exports, but not ores containing uranium

A new bilateral agreement would be required were BHP Billiton to export copper concentrate containing uranium for processing in China. A new agreement would ensure peaceful-use obligations would be applied to any uranium extracted, that uranium oxide produced by this means would be subject to the current bilateral Nuclear Materials Transfer Agreement and that contained uranium would be accounted for in full, whether in the form of concentrate, uranium oxide or waste.

In developing plans to manage uranium contained in copper concentrate, BHP Billiton has taken into account that a new bilateral agreement would need to be in force before concentrate exports could proceed.

27.5.2 MATERIAL UNACCOUNTED FOR (MUF)

Issue:

It was questioned how the public would know that MUF is not a cover for material diverted to military programs.

Submissions:

Response:

MUF is taken very seriously by national and international authorities (IAEA) and fully investigated. Diversion of material is only one possible cause of MUF.

To gain sufficient assurance of the non-diversion of nuclear materials, the IAEA supplements its verification of nuclear materials accountancy using techniques such as design information verification (to confirm that plant design and operation remains as declared) and the use of containment and surveillance, such as tamper-proof seals and cameras, and short-notice inspections.

A primary function of the IAEA safeguards AP is detection of undeclared nuclear material, facilities and programs[xiv], absence of which is a further assurance that MUF is not being used for proscribed or unknown purposes.

MUF issues, including diversion – were this proven to be the case – are included in IAEA safeguards judgements published in its Safeguards Implementation and Annual Reports.

27.6 NUCLEAR WASTE

27.6.1 NUCLEAR WASTE DISPOSAL

Issue:

It was questioned how states can continue to operate nuclear power reactors when there are no permanent waste repositories or long-term strategies to deal with high-level waste (HLW).

Submissions: 7, 8, 16, 52, 92, 97, 104, 177, 180, 185, 189, 229, 232, 255, 259, 260, 266, 300, 321, 352, 335, 363 and 380

Response:

Many governments (31 with about 440 power reactors operating in their countries) are satisfied with interim (short- to medium-term) and proposed long-term storage arrangements for used nuclear fuel, HLW and other radioactive materials. There is an international scientific consensus that disposal in geologic repositories can safely and securely store HLW for the periods of time required of the long-lived waste to decay to background levels. Finland and Sweden are constructing such repositories, the first of which is scheduled to be operational in 2020. These and associated issues were discussed in Appendix E3 of the Draft EIS.

The nuclear industry has over 50 years' experience in managing used fuel and radioactive waste, specifically HLW arising from the operation of nuclear reactors and 'back end' activities such as reprocessing. Many countries are examining and developing long-term strategies to manage used fuel and high-level radioactive waste[xv]. Internationally there is a broad, common understanding of the issues and possible options to achieve this safely. The UMPNER Report (2006) states;

> 'There is an international scientific consensus that disposal in geologic repositories can safely and securely store HLW for the periods of time required of the long-lived waste to decay to background levels.'[xvi]

Responsibilities

The Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (Joint Convention) is the main international instrument associated with the management of radioactive waste.[xvii] In most industrialised countries, in line with the Joint Convention, the regulation of and the requirements for regulation, safe handling and disposal of radioactive waste are enshrined in law. Management of radioactive waste is subject to regulatory control by the appropriate health and safety, environmental, security and transport authorities and with the applicable planning consent(s).

The nuclear power industry is the only large-scale, energy-producing industry that takes full responsibility for all its by-products and wastes – in this instance, radioactive materials – including whole-of-life-cycle costs in the market price of its product. Commonly national bodies are responsible for management of final (long-term) disposal of spent fuel and HLW (either directly or through reprocessing); for example, the DOE (US) and NDA (UK). In a number of countries, utility operators contribute to an account used to fund final disposal arrangements such as the Nuclear Liabilities Fund (UK), the Nuclear Waste Fund (US) and the National Nuclear Waste Management Fund (Finland).

Present arrangements

An accepted working principle of the international nuclear fuel cycle is that each country is ethically and legally responsible for its own radioactive wastes[xviii].

Safe management practices are implemented or planned for all categories of radioactive waste. LLW and most ILW, which make up 97% of the volume of waste produced, are being disposed of securely in near-surface repositories in many countries so as to cause no harm or risk in the long term. This practice has been carried out routinely for years in many countries.

HLW is currently safely contained and managed in interim storage facilities. The amount of HLW produced (including used fuel where this has been categorised as waste) is in fact small in relation to the quantities of toxic waste produced in other industries. Used nuclear fuel is normally stored in ponds at the site where it arises (i.e. the producing NPP). Used fuel may be handled in two ways: (1) through reprocessing or (2) by direct disposal.

Some countries reprocess used nuclear fuel after limited time in interim storage to recover reusable nuclear material and reduce the volume of HLW.

Interim storage at NPPs allows the radioactivity (and resultant heat) of the waste to decay before long-term geological disposal to about one thousandth its initial value after 40 years. Interim storage provides an appropriate means of managing used fuel until that country has sufficient fuel to make development of a repository economically viable.

In the long term, regardless of whether or not used nuclear fuel is reprocessed, disposal facilities, such as those being constructed in Finland and Sweden, will be necessary.

Issue:

It was suggested that nuclear waste cannot be handled, transported or stored safely and, as such, it was questioned why humans continue to produce it.

Submissions: 44, 116, 167, 206, 229, 244, 262, 289, 293, 315, 316 and 381

Response:

The good safety record of the nuclear transport industry was recognised by the international community at the NPT Review Conference in 2010. There is a significant body of evidence showing the health and safety costs of the nuclear industry (nuclear fuel cycle, including waste disposal) are much lower than fossil fuel-based energy generation systems, on the basis of unit of energy produced.

Related (and supplementary) information on these issues was provided in Appendix E3 of the Draft EIS (refer Section 2.2, 7.1, 7.4, 7.5, 7.7 and 7.8).

The nuclear industry has over 50 years' experience in managing used fuel and radioactive waste, specifically HLW arising from the operation of nuclear reactors and 'back end' activities such as reprocessing. These activities, including transportation, are closely regulated in each country and subject to significant international agreements (conventions) and standards. Many countries are examining and developing long-term strategies to manage used fuel and HLW. Internationally there is a broad, common understanding of the issues and options to achieve this safely.

The IAEA Regulations for the Safe Transport of Radioactive Material (IAEA Transport Regulations) address all categories of radioactive material, ranging from very low activity material, such as ores and ore concentrates, to very high activity material, such as used fuel and HLW. They establish requirements for the marking, labelling and placarding of conveyances, documentation, external radiation limits, operational controls, quality assurance, notification and the approval of certain shipments and package types.

Within the nuclear industry, safety audits and reviews are conducted routinely and rigorously. At an international level, the IAEA undertakes detailed annual industry-wide reviews, which are submitted to the Board of Governors and the results used to strengthen worldwide efforts on nuclear safety, radiation protection, transport safety and radioactive waste safety and emergency preparedness. The latest review, (Nuclear Safety Review for the Year 2007 GC(53)INF/2 (IAEA 2008))[xix] was published in 2009 and provides an overview of safety of the industry, identifying areas for improvement.

Nuclear materials have been transported safely (virtually without incident and without harmful effect on people) since even before the development of nuclear power over 50 years ago.

The Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (Joint Convention, in force 2001) – to which both Australia and China have acceded – establishes an international legal framework for harmonising national waste management practices and standards, and imposes obligations on contracting parties in relation to the trans-boundary movement of spent fuel and radioactive waste. These obligations would be based mainly on the concepts contained in the IAEA Code of Practice. The obligations imposed by the Joint Convention include a requirement to establish and maintain a legislative and regulatory framework to govern the safety of spent fuel and manage radioactive waste.

Further, the Joint Convention creates an obligation to ensure that individuals, society and the environment are adequately protected against radiological and other hazards through appropriate siting, design and construction of facilities and by making provisions for ensuring the safety of facilities both during their operation and after their closure.

There are also strict controls on the movement of radioactive waste to prevent one country disposing of it in another. One such control is the IAEA Code of Practice on the International Trans-boundary Movement of Radioactive Waste (IAEA Code of Practice), which was adopted by consensus at the IAEA General Conference in 1990.

The code recognises the sovereign right of every state to prohibit the movement of radioactive waste into, from or through its territory[xx].

Specifically with respect to radioactive wastes produced in an offshore processing facility, the Australian Government has required BHP Billiton to develop a detailed Uranium Accounting Report, among other things, to track waste streams containing AONM as part of the process for considering export approval. Under that regime Olympic Dam will develop a Waste Management Plan to ensure the waste containing AONM is properly accounted for and controlled.

Issue:

It was noted that the proposed Yucca Mountain repository has been rejected in the US and, as such, geological repositories are unsafe and there are no long-term solutions.

Submissions: 180, 185, 206, 216 and 389

Response:

The controversy in the United States over the proposed underground storage facility at Yucca Mountain in Nevada has not yet been resolved. Deep geological repositories for radioactive waste can be designed safely; they are being constructed in Finland and Sweden, and are under serious consideration by many other countries. Furthermore, the US already operates a small deep geological waste repository (the Waste Isolation Pilot Plant[xxi]) in New Mexico for the disposal of transuranic waste (long-lived ILW contaminated with military materials such as plutonium). The issue of the repository at Yucca Mountain was raised in the Draft EIS (refer Appendix E3, Section 2.2(g)), although the debate has shifted since early 2009.

The Obama Administration has terminated the Yucca Mountain proposal, although it could yet be included in recommendations arising from a new review of long-term disposal options set up by the President in 2010.

The USA maintains a long-standing policy of not reprocessing used nuclear fuel and, thus, has a significant quantity of used nuclear fuel stored at nuclear power plant sites. This has been done safely for nearly 50 years and is likely to continue until a new long-term storage and disposal plan is agreed and implemented. In the long term, regardless of whether or not used nuclear fuel is reprocessed, disposal facilities, such as those being constructed in Finland and Sweden, will be necessary. Deep geological repositories are under serious consideration by many countries[xxii].

27.6.2 DISPOSAL PRACTICES

Issue:

The question was asked why tailings produced from a uranium mine are not treated as nuclear waste.

Submission: 189

Response:

The term 'nuclear waste' and 'radioactive waste' have quite specific meanings. While tailings from uranium mining and processing are generally considered a low-level radioactive waste, they are not defined as a 'nuclear waste'. The reason for this is that tailings have relatively low levels of radioactivity; they are placed into facilities at the mine site for which there are well-defined storage and disposal measures.

The tailings from the Olympic Dam mining and processing facility are radioactive and are required to be stored in an appropriate facility. The requirements are outlined in the Mining Code 2005 and are consistent with the disposal criteria for near-surface disposal of radioactive wastes (<http://www.arpansa.gov.au/radiationprotection/FactSheets/is_waste.cfm>).

'Nuclear waste' invariably refers to radioactive material that is a waste from a nuclear power plant or waste from a weapons program.

27.6.3 OBLIGATIONS ON AUSTRALIA

Issue:

It was questioned whether the expansion of Olympic Dam would lead to the establishment of a nuclear waste dump there. Also, whether used nuclear fuel or waste, derived from AONM, would be received back and stored in Australia.

Submissions: 126, 216, 247, 255, 338 and 363

Response:

As discussed in Appendix E3 (Sections 2.2(g), 7,7, 7.8 and 7.9) of the Draft EIS, the expansion of Olympic Dam will not result in the requirement for a 'nuclear waste dump' in Australia. In accordance with international practice and custom, Australia does not store any radioactive waste arising from the use of AONM in the international nuclear fuel cycle (i.e. offshore). Australia's only obligation to receive radioactive waste from overseas arises from the reprocessing in Europe (the UK and France) of used fuel from the former HIFAR research reactor at Lucas Heights[xxiii]. Return of this radioactive waste is likely around 2013 to 2015.

The expansion of the Olympic Dam site would result in additional tailings storage facilities. However, there will be no additional requirement for nuclear waste sites (repositories).

Issue:

It was questioned whether the construction of a nuclear waste repository in the Northern Territory would lead to the establishment of a HLW store in Australia.

Submissions: 35, 216 and 247

Response:

Australia does not produce HLW because it has no nuclear power plants. Furthermore, in accordance with international practice and custom, Australia does not store any radioactive waste arising from the use of AONM in the international nuclear fuel cycle (i.e. offshore, nuclear power plants). As discussed in Appendix E3 of the Draft EIS (Sections 2.2(g), 7,7, 7.8 and 7.9), establishing a Commonwealth radioactive waste storage facility is not a precursor to building a high-level-waste (HLW) repository in Australia. (See Endnote xxiii)

27.2 NUCLEAR INDUSTRY

27.7.1 OPERATION OF NUCLEAR POWER PLANTS

Issue:

The question was raised: What lessons have been learnt from the Chernobyl accident in Ukraine in 1986, and are we at risk from another similar event?

Submissions: 67, 293 and 379

Response:

The international community has learnt many lessons from the Chernobyl accident in Ukraine in a reactor which, by Western standards, was intrinsically an unsafe design. Given that only a small number of Chernobyl-type reactors are still operating (in Russia), the likelihood of a repeat accident is remote and getting lower each year. This topic was the subject of discussion in Sections 7.4 and 7.5 of Appendix E3 of the Draft EIS.

Many lessons have been learnt from the Chernobyl accident, not least the need to replace this type of reactor as quickly as possible. This accident was caused by poor design and negligent operational practice.

As summarised in Appendix E3, Section 7.5 of the Draft EIS, the Chernobyl accident was, by a significant margin, the world's most damaging nuclear reactor accident, with 31 direct fatalities[xxiv]. It is important to recognise that this type of Russian-designed reactor (RBMK1000) was built and operated only in Russia and former Soviet bloc states. Although many RBMK reactors have been decommissioned in the past 20 years, a limited number still operate in Russia. While some safety features have been updated since the Chernobyl accident, the RBMK reactor will never be as safe as Western designs, which employ containment buildings among other enhanced safety features.

By comparison, no deaths were attributable to the nuclear accident at Three Mile Island in the USA in 1979, due significantly to the use of an effective containment building. The Three Mile Island and Chernobyl plants were both power reactors of similar capacity but very different design.

The World Association of Nuclear Operators (WANO) was formed in 1989, in response to the Chernobyl accident, to improve safety at every nuclear power plant. Its mission is to maximise the safety and reliability of nuclear power plants worldwide by working together to assess, benchmark and improve performance through mutual support, exchange of information and emulation of best practices.

All the operators of the world's 439 (mid-2010) nuclear plants in 31 countries are represented in WANO's membership. Members share operational experience using an online database and contribute experts to peer reviews of one another's plants. WANO also holds technical courses and workshops, as well as conducting support missions to solve specific issues at its members' facilities. All these programs take place under a strict code of confidentiality that WANO considers essential to information exchanges that are fully open and honest.

The peer review program was formally adopted by WANO in 1993 and provides plant operators with an opportunity to share and learn from worldwide experience on safe and reliable plant operation. Carried out at the request of an operator, a typical peer review involves in-depth observation of all aspects of plant operation during a two-week visit by a team of experts from other WANO members, culminating in a frank – and confidential – report identifying strengths and areas for improvement.

By the end of 2009, WANO had achieved its goal of completing peer reviews at every operating nuclear power plant in the world, with many plants having been reviewed more than once. WANO aims to review each plant at least once every six years, and encourages each to host an outside review (not necessarily by WANO) at least once every three years.

Issue:

It was questioned why nuclear power plants are built in earthquake zones.

Submissions: 67 and 141

Response:

Worldwide, about 20% of nuclear power plants operate in areas of significant seismic activity; Japan and California are two well-known regions. In some countries that choose nuclear power as part of their energy mix, such siting is unavoidable.

Nuclear facilities, including NPPs, are designed to withstand earthquakes and they are designed to shut down safely under prescribed conditions. It is noted that safety assessments for NPPs take into account a wide range of internal and external events which are not limited to possible seismic activity.

Issue:

It was suggested that the cost of decommissioning nuclear power plants has not been considered by the industry.

Submissions: 44 and 113

Response:

The nuclear power industry is the only large-scale energy-producing industry that takes responsibility for whole-of-life costs, including waste disposal and decommissioning of facilities. These costs are reflected in the market price of its product. Most NPP have a lifespan of around 40 years, and life extension programs to 60 years are becoming common. Decommissioning activity itself is likely to take several years, which means decommissioning costs are spread over a significant period and actual sums involved may not be huge in comparison with public expenditure on defence, health or even transport infrastructure.

In most countries today the operator or owner is responsible for decommissioning costs[xxv]. Provision for future costs is achieved through a range of financing mechanisms, with costs generally recovered by the utility levying a percentage charge on consumers and 'sinking' that into a special fund. While some nuclear sites, mostly those dating from the 1950s and 1960s and now on the cusp of decommissioning, are not so well placed, that fault cannot be attributed to the commercial nuclear power industry today[xxvi].

Issue:

It was suggested that the nuclear industry has a long history of incidents that have not been considered.

Submissions: 44 and 67

Response:

An overview of the safety of nuclear power reactors is made by the World Nuclear Organisation at <http://www.world-nuclear.org/info/inf06.html>. Also, the IAEA regularly publishes a safety report; the latest is the Nuclear Safety Review for the Year 2009 (GC(54)/INF/2)[xxvii].

Regulation embraces physical protection (security) of materials and facilities, safeguards and safety, all of which are covered by international standards and compliance regimes supported by national control arrangements.

Governments and the nuclear industry, certainly in the developed world, are aware and responsible in regulating and managing nuclear fuel cycle activities. One reason so much is known about 'incidents' at nuclear facilities is the rigorous reporting requirements and the intention of most governments to be transparent about the industry. Even minor events, their impact – often inconsequential – remedial action and long-term implications (consequences, changes to process, procedures, equipment, design, testing etc) are, in many countries and at various levels of detail, most commonly made public by the operators, governments and regulatory authorities.

The International Nuclear and Radiological Event Scale (INES)[xxviii], is used to communicate the significance of all events associated with the transport, storage and use of radioactive material and radiation sources.

All major nuclear incidents, including in Russia since the Cold War era, are now public knowledge. These incidents have been thoroughly analysed; their causes are well known and corrective actions have been set on the public record.

27.7.2 LIFE CYCLE OF URANIUM

Issue:

It was suggested that nuclear energy is dangerous, expensive and, because the nuclear fuel cycle is energy-intensive, nuclear energy is a significant source of greenhouse gases.

Submissions: 10, 92, 205, 216, 307 and 338

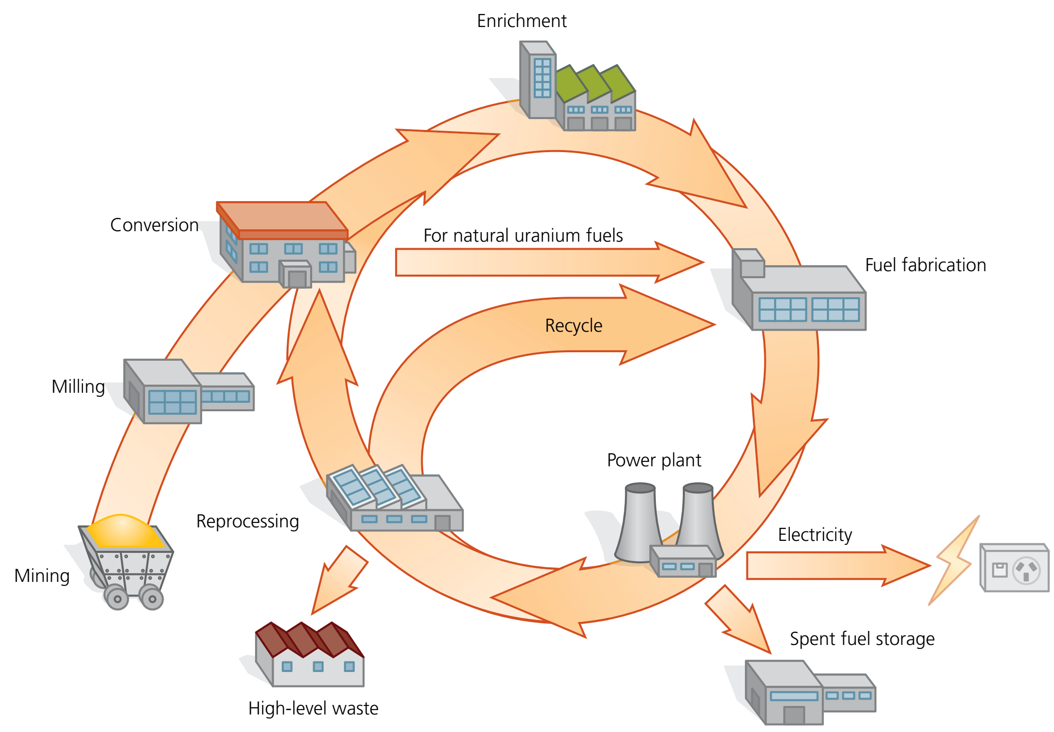
Response:

Review of the facts and the science around nuclear energy does not support these assertions.

Given there are some 440 nuclear power reactors operating in 31 countries, producing about 16% of the world's electrical energy, it is clear that many governments are satisfied nuclear energy is a safe, clean, low-carbon and efficient energy source. France, for example, generates over 70% of its electricity using nuclear power.

Figure 27.1 of the Supplementary EIS is a schematic of the nuclear fuel cycle.

The regulatory and economic playing fields for nuclear versus other primary sources of power generation are not level. First of all, the nuclear industry is given greater scrutiny and must meet a much higher level of accountability. Then, this industry is required to internalise many factors 'ignored' or omitted by other segments of the power generation industry. Such factors include future financial liabilities arising from decommissioning and dismantling nuclear facilities, health and environmental impacts of radioactivity releases in routine operation, radioactive waste disposal and effects of severe accidents. In turn, associated costs are reflected in the prices paid by consumers of nuclear-generated electricity. This situation will be (or is being) redressed, at least in part, through a range of carbon pricing mechanisms, with the EU leading the charge.



Source: UMPNER 2006

Figure 27.1 Schematic of the nuclear fuel cycle

Health impact, pollution

In its ExternE study[xxix], the European Commission examined 'external costs' of electricity generation using a whole-of-life-cycle model (i.e. for nuclear the whole fuel cycle of mining, processing, enrichment, fuel fabrication, nuclear fuel use, reprocessing, spent fuel storage and waste management). The study provided information on material and energy flows (inputs or consumption) for each process step, including their side-effects ('burdens') of pollution, emissions and waste. The study used this data to estimate and cost health and environmental impacts arising from these burdens. (For summary report, Externalities of Energy Methodology 2005 Update, see <http://www.externe.info/>; for Volume 5 (nuclear energy) see <http://www.nea.fr/ndd/reports/2003/nea4372-generation.pdf>)

ExternE results show the health and safety costs of the nuclear fuel cycle are lower than for fossil fuel-based energy generation systems, on the basis of unit of energy produced[xxx]. This work by Dones and others (2005) shows the nuclear fuel cycle produces much lower levels of greenhouse gas emissions and other pollutants, including air pollutants of major health concern such as sulphur dioxide, particulates and a range of nitrogen oxides.

Health impact, radiation doses

People receive radiation doses from both natural and man-made sources. The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) has reported[xxxi] worldwide average annual radiation doses as: 2.4 mSv from natural sources; 0.4 mSv from medical sources; 0.005 mSv from nuclear testing[xxxii] (mostly from above-ground tests which ceased in 1980); 0.002 mSv from Chernobyl; and 0.0002 mSv from nuclear power production[xxxiii] – which is clearly a dose several orders of magnitude less than average doses from natural sources.

To put this in context (quoting UMPNER, p76):

> '... a person taking a return flight from Sydney to London would receive the same dose (approx. 0.25 mSv)

While occupational radiation exposures are higher, so too are the applicable limits and the intensity of monitoring for these workers. UNSCEAR reports:

> '[the] worldwide collective effective dose to workers from man-made sources for the early 1990s... is lower by a factor of about 2 than that made by the Committee for the late 1970s. A significant part of the reduction comes in the nuclear power fuel cycle, in particular in uranium mining. However, reductions are seen in all the main categories: industrial uses, medical uses, defence activities and education.'[xxxiv]

Nuclear energy is expensive

The joint report by the International Energy Agency (IEA) and the OECD Nuclear Energy Agency (NEA), Projected Cost of Generating Electricity (2010), shows that, on a whole-life-cycle basis, nuclear energy is competitive with other baseload generating systems, especially where the cost of carbon is included. The report uses a concept called levelised costs of electricity (LCOE) per MWh, based on plant operating lifetime data, focusing on the expected plant-level costs of baseload electricity generation (for power plants that could be in commission at 2015), but includes the generating costs of a wide range of renewable energy sources. For OECD countries, a carbon price of US$30 per tonne of CO_2 is used; a figure which falls in the range, which UMPNER[xxxv] has determined could make nuclear energy competitive in Australia[xxxvi].

Although the IEA-NEA report states,

> 'There is no technology that has a clear overall advantage globally or even regionally' (page 21),

and,

> 'The study suggests that no single electricity generating technology can be expected to be the cheapest in all situations. The preferred generating technology will depend on a number of key parameters and the specific circumstances of each project' (page 25),

and, notwithstanding its caveats and thoughtful sensitivity analysis (Part 2, Chapter 6), the report shows nuclear energy is competitive and often a leader (lowest median cost) in each of its scenarios.

The report shows the cost of electricity in the coming years will depend on a number of key parameters, foremost among which are the costs of raising financial capital and the price of carbon. (Related to the cost of raising financial capital is the extended time needed for construction of a nuclear power plant.) Nuclear energy is particularly susceptible to these specific criteria, although it is interesting to note that both are within the direct control of governments, which could, therefore, create investment conditions (with respect to raising finance and the cost of carbon) that make nuclear energy more (or less) attractive.

The NEA-IEA report is a whole-of-life study which makes it clear that care must be taken when applying the results of its case studies to a different fuel cycle in another part of the world. This is well illustrated by the sensitivity analysis (Part 2, Chapter 6).

In the case of the special study completed for UMPNER by the University of Sydney in 2006, that was exactly the intention. While hypothetical, this fuel cycle analysis was conducted for Australia and yielded results consistent with the NEA-IEA report, albeit with very slightly higher costs.

Dones and others (2005)[xxxvii] determined, 'Emissions of greenhouse gases from the nuclear cycle are mostly from the upstream chain [where diffusion enrichment dominates], and the total is small and decreasing with increasing share of centrifuge enrichment.' Diffusion enrichment, which is being phased out, uses around 10 times more electrical power than centrifuges, so greenhouse gas emissions from the nuclear fuel cycle are expected to decrease over time. In the next five to 10 years, it is quite likely that the third-generation Australian laser enrichment technology, SILEX, currently under development jointly by General Electric (GE)[xxxviii] in partnership with Hitachi and Cameco, will be available for commercial-scale enrichment. A decision on this could be made in 2012. Due to its low power requirements, SILEX technology would lead to a further reduction in greenhouse gas emissions during enrichment, possibly by up to 75% compared to centrifuges[xxxix].

Nuclear energy is a significant source of greenhouse gases

Throughout the past decade, the debate on 'global warming' has consistently categorised nuclear energy as 'low-carbon'[xl] technology widely regarded as most suitable for the production of baseload electricity.

A recent study by the Royal Academy of Engineering (UK)[xli] states a commonly held view (also acknowledged at the Copenhagen Summit in 2009) that:

> 'There is no single 'silver bullet' that will achieve [significant] cuts in greenhouse gas emission. The full suite of low-carbon energy supply technologies already available (or identified as credible) will be needed, including nuclear, renewables and carbon capture and storage brought together in a balanced way.'[xlii]

Dones and others (2005) would agree that nuclear energy can make a strong contribution to the reduction of carbon emissions for, as noted earlier, they have shown the nuclear fuel cycle produces much lower levels of greenhouse gas emissions etc than other power generating systems, on the basis of unit of energy produced.

As part of UMPNER's work in 2006, the University of Sydney conducted a hypothetical study on the cost and impact of nuclear energy in Australia[xliii] through analysis of the nuclear fuel cycle. Notwithstanding the caveats stated in the university report and the variables explored through sensitivity analysis, UMPNER draws a clear conclusion that the range of energy intensity of nuclear power[xliv] (nuclear fuel cycle) – which is related to greenhouse gas intensity – is in the same order of magnitude as hydro, wind and photovoltaics, noting the latter two technologies are not able to provide unsupported uninterrupted baseload power. In the university report, gas and coal are shown to be one to two orders of magnitude more polluting than nuclear energy.

27.8 NUCLEAR SECURITY

27.8.1 SECURITY OF NUCLEAR MATERIAL

Issue:
It was suggested that the IAEA database on illicit trafficking shows that a lot of uranium is loose in the world.

Submission: 44

Response:

The IAEA database on illicit trafficking contains very few items of nuclear material, which includes uranium. IAEA safeguards ensure that uranium in the international nuclear fuel cycle is controlled; material accounting discrepancies are investigated by the IAEA and national responsible authorities.

The majority of entries in the IAEA's Illicit Trafficking Database are related to radioactive sources, not nuclear material (uranium). This database does not support the assertion that it 'shows that a lot of uranium is loose in the world'. It its 2008 annual report[xlv] the IAEA states that safeguards

> 'provide credible assurance to the international community that nuclear material and other items placed under safeguards are not diverted or misused ...' page 77

Among other things, this report summarises Safeguards Conclusions and Safeguards Implementation Issues. It sets out how the agency seeks to detect undeclared nuclear material and activities, including improved technical capabilities and methods. At no point does it support the assertion that there is a lot of uranium loose in the world.

Specifically, with respect to the Illicit Trafficking Database, the IAEA's 2008 Annual Report states (page 73):

> 'The agency's Illicit Trafficking Database (ITDB) contains data on illicit trafficking and other unauthorised activities from 1993 onward. The membership of the agency's ITDB programme continued to expand, now numbering 103 member states and one non-member state. By 31 December 2008, states had reported, or otherwise confirmed, 1,562 incidents to the database; 222 incidents were reported by states in 2008, of which 119 had occurred during the year (the others had occurred earlier). Of those which had occurred during the year, 15 involved illegal or unauthorised possession and related criminal activities, 16 involved thefts or losses of material, and 86 incidents involved the recovery or discovery of uncontrolled or orphan material, unauthorised disposals and other unauthorised activities. In two cases, there was insufficient information to categorise the incident.'

Further, in a fact sheet (IAEA Illicit Trafficking Database (ITDB) Fact Sheet, available <http://www-ns.iaea.org/downloads/security/ITDB_Fact_Sheet_2007.pdf>), the IAEA states,

> 'The ITDB covers incidents, reported by national points of contact or otherwise confirmed by states, involving unauthorised acquisition (e.g. by theft), provision, possession, use, transfer or disposal of nuclear and other radioactive materials, whether intentionally or unintentionally, with or without crossing international borders, as well as unsuccessful or thwarted acts of the above type.
>
> It includes, therefore, but is not limited to, incidents involving illegal trade and movement of materials across borders. It also covers the loss of materials and the discovery of uncontrolled materials. The scope of the ITDB covers all types of nuclear materials (i.e. uranium, plutonium, thorium), all naturally occurring and artificially produced radioisotopes, and radioactively contaminated materials. No limitation is placed on the quantity of material, its activity level, and other technical characteristics.
>
> The ITDB incorporates strict information classification and dissemination guidelines. (i.e. some ITDB information is in the public domain).
>
> Of the 18 incidents involving HEU (highly enriched uranium) and Pu (plutonium) reported to the ITDB during 1993–2007, 15 incidents involved unauthorised possession of HEU and Pu; some of these incidents involved attempts to sell these materials and their smuggling across national borders. A few of these incidents involved seizures of kilogram quantities of weapons-usable nuclear material, but the most involved very small quantities. In some of these cases, however, there is a possibility that the seized material was only a sample of larger quantities available for illegal purchase or at risk of theft. These materials continue to pose potential security risks. Reported thefts and losses have primarily involved radioactive sources, such as ^{137}Cs, ^{241}Am, ^{90}Sr, ^{60}Co, ^{192}Ir and other radioisotopes.

Issue:

It was suggested that the prospect of uranium falling into the hands of terrorists is too great a risk and, as such, uranium should not be mined or traded.

Submissions: 302, 303, 306 and 381

Response:

Given there are about 440 nuclear power reactors operating in 31 countries, demonstrating that many governments worldwide have evaluated the benefits-cost-risk-environment equation and are satisfied with the safety and security arrangements pertaining to the use of nuclear energy.

The Australian Government has studied the risks and benefits of nuclear energy and the nuclear fuel cycle and has reported:

> 'While proliferation of nuclear weapons remains a critical global issue, increased Australian involvement in the nuclear fuel cycle would not change the risks.' (Department of Prime Minister and Cabinet. Uranium Mining, Processing and Nuclear Energy Review –Opportunities for Australia (UMPNER 2006. p2)

27.9 THE ROLE OF BHP BILLITON

27.9.1 BHP BILLITON AND THE NUCLEAR FUEL CYCLE

Issue:

Clarification was sought on BHP Billiton's involvement in the international nuclear fuel cycle.

Submissions: 10 and 205

Response:

Since entering the nuclear industry in 2005, BHP Billiton has given leadership to the development of national and international uranium stewardship working groups that assist global players in the life cycle of uranium to work together to minimise harm to people and the environment as a result of using uranium as a fuel source.

Although BHP Billiton is involved directly only in mining ores containing uranium and the production of UOC (and the newly proposed product of copper concentrate containing uranium), it is committed to the Uranium Stewardship Principles that have been developed to reduce, as far as practicable, any residual risk for harm to people and the environment from the nuclear industry, including to:

- support the safe and peaceful use of nuclear technology
- act responsibly in the areas that we manage and control
- operate ethically with sound corporate governance
- uphold and promote fundamental human rights
- contribute to social and economic development of the regions in which we operate
- provide responsible sourcing, use and disposition of uranium oxide and its by-products
- encourage best practice and responsible behaviour throughout the nuclear fuel cycle
- improve continually in all areas of our performance
- communicate regularly on progress
- review and update as necessary.

Applied to the export of concentrate, the Uranium Stewardship Program and the adoption of the Principles mean BHP Billiton has a direct responsibility in the areas and functions that it controls and operates, and a shared concern in those areas and functions where others have a direct responsibility.

While the verifiable standards for uranium stewardship are still being developed, several interim measures are in place that either reflect national and international regulation, or company (e.g. BHP Billiton's Health, Safety, Environment and Community (HSEC) Standards) or industry values (e.g. the International Council on Mining and Metals' (ICMM) Sustainable Development Principles and the Minerals Council of Australia's Enduring Value framework for sustainable development).

The performance criteria associated with the BHP Billiton HSEC standards are verified in a triennial audit and also verified by some BHP Billiton customers (e.g. Vattenfall's Ecologically Sustainable Development (ESD) questionnaire and site audit). The development of the stewardship principles and performance criteria will reflect the shared responsibility and shared concern by all participants in the uranium life cycle. These performance criteria will cover not only the primary sectors in the NFC (mining, conversion, enrichment, fuel fabrication, power generation and waste disposal) but also the links between the sectors, such as transport.

27.9.2 BHP BILLITON OBLIGATIONS

Issue:
It was questioned how BHP Billiton would be held accountable to comply with its nuclear obligations.

Submission: 44

Response:

In Australia, federal, state and territory governments regulate BHP Billiton for its management, safe handling, sale and export of radioactive material and uranium concentrates. This includes, but is not limited to, safeguards and security (ASNO), transport (land and sea – state and territory authorities, AMSA), OH&S, export permits (Department of Resources, Energy and Tourism). In China – with respect to the prospective offshore processing operation – the BHP Billiton partners would be subject to Chinese law under which criminal and civil penalties would apply.

BHP Billiton understands that before the Australian Government would allow it to export copper concentrates to China (or any other third party) for offshore processing to recover uranium for use in the civil nuclear fuel cycle, the Government would need to establish a new bilateral safeguards agreement. Such an agreement would ensure peaceful use obligations applied to any uranium recovered in China, that uranium oxide produced by this means would be subject to the current bilateral Nuclear Materials Transfer Agreement and that contained uranium would be accounted for in full (whether in the form of concentrate, uranium oxide or waste). BHP Billiton is committed to full and transparent compliance with Australian law, specifically Australia's uranium export regulations, international law and Chinese law as applicable.

Issue:
It was suggested that BHP Billiton has not obtained informed consent for the transport of radioactive material through Australia.

Submission: 205

Response:

BHP Billiton is legally authorised to mine ores containing uranium, and produce and transport UOC in Australia and internationally. If BHP Billiton implements the offshore processing option it would need new permits to transport radioactive copper concentrate.

BHP Billiton legally transports uranium oxide concentrate (UOC) from Olympic Dam to Adelaide by road and from Adelaide to the Port of Darwin by rail. UOC is shipped overseas from both ports in Adelaide and Darwin. If BHP Billiton implements the offshore processing option, it acknowledges it would need new permits to transport radioactive copper ore concentrates from Olympic Dam to a port of lading, most likely Darwin. Transportation would be by road and rail. These new approvals would be sought from federal, state and territory governments prior to the transport of copper concentrate.

Issue:
It was suggested that the integrity of China as a customer for uranium is questionable.

Submissions: 16, 35, 65, 116, 141, 159, 198, 204, 206, 311, 352, 379 and 388

Response:

Before negotiating and ratifying a bilateral safeguards agreement, the Australian Government considers a full range of issues, including strategic issues. Since 2007, the Government has granted licences to export UOC to China.

The Australian Government considers issues such as proliferation record and signature of relevant international treaties during its deliberations on (and the ratification process of) bilateral nuclear agreements. Recent Australian governments have chosen not to link directly bilateral nuclear negotiations with other matters such as human rights, or democracy issues.

When ratifying in 2007 the Agreement Between the Government of Australia and the Government of the People's Republic of China on the Transfer of Nuclear Material, the Government of Australia took all strategic issues into consideration.

The present Australian Government gave similar consideration when granting a licence to export uranium to China in 2008 and 2009.

Australian uranium is sold for exclusively peaceful purposes, specifically the production of electricity through nuclear energy. Australian uranium is subject, among other things, to each recipient country's safeguards agreement with the IAEA and a bilateral safeguards agreement. In 2010 Australia has already made multiple shipments of uranium to China, confirming that the Australian Government is satisfied that Australian uranium sold to China will remain exclusively in peaceful use and make no material contribution to that country's nuclear weapons program.

Issue:

BHP Billiton was asked to consider all aspects of the nuclear fuel cycle in the EIS.

Submissions: 35, 92, 97, 216, 290, 296, 315, 335 and 338

Response:

Even though the joint government EIS Guidelines for the Olympic Dam EIS noted that this issue was not a necessary requirement for the Draft EIS, BHP Billiton addressed all aspects of the nuclear fuel cycle in Appendix E3 of the Draft EIS and provided additional information in this chapter of the Supplementary EIS.

Issue:

It was suggested that BHP Billiton should provide a justification for the concentrate export scenario.

Submission: 265

Response:

BHP Billiton provided justification on the proposed copper concentrate export option in Section 4.5 of the Draft EIS and again in Section 4.2 of this Supplementary EIS.

Issue:

It was suggested that BHP Billiton should take responsibility for health impacts in China.

Submission: 44

Response:

BHP Billiton's operations in China and associated impacts would be subject to Chinese law.

BHP Billiton would have full visibility of implementation, operational standards and materials accounting in China. In accordance with its standards, BHP Billiton would make every effort to ensure sound international standards were implemented.

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[i] See Australian Safeguards and Non-Proliferation Office (ASNO) Annual Report 2008-2009 p100, at http://www.asno.dfat.gov.au/annual_report_0809/index.html.

[ii] http://www.aph.gov.au/house/committee/jsct/8august2006/treaties/chinatransfer_nia.pdf accessed 2 July 2010) and JSCOT Report 81 and http://www.aph.gov.au house/committee/jsct/8august2006/report.htm accessed 2 July 2010.

[iii] Administrative Arrangements are 'confidential between the parties' (and thus not in the public domain). See http://www.dfat.gov.au/security/nuclear_safeguards.html and http://www.dfat.gov.au/asno/annual_report_9899/documents.html (both documents accessed 29 June 2010)

[iv] http://www.pm.gov.au/press-office/australia-russia-nuclear-cooperation-agreement

[v] See (1) IAEA safeguards document INFCIRC/153(Corrected); (2) IAEA document IAEA/SG/INF/2; and, (3) Australian legislation, *Nuclear Non-Proliferation (Safeguards) Act* Schedule 3.

[vi] http://www.defence.gov.au/whitepaper/docs/defence_white _paper_2009.pdf

[vii] The 2009 Defence White Paper subtly nuances its judgements about China, as follows:

'11.15 As China assumes a greater role on the regional and world stage, the Government recognises that Australia must build a deeper understanding of China's security policies and posture. China is critical to stability in Northeast Asia and the wider region. Its approach to regional security in North Asia and the wider region, and how it interacts with our key strategic partners (the United States, Japan, and increasingly India), is fundamental to Australian interests. Along with these countries, China will be central to the development of a cooperative security community in the Asia-Pacific region. Closer to home, we need to engage China as a responsible stakeholder in support of our common desire to see stable, prosperous and well-governed nations in our immediate region.

11.16 Developing our defence relationship with China is therefore a priority. Greater engagement is essential to encourage transparency about Chinese military capabilities and intentions, understand each other's approaches and secure greater cooperation in areas of shared interest. To that end, in 2008 we upgraded our bilateral Defence Strategic Dialogue to talks at the Secretary of Defence and Chief of Defence Force level. At a practical level, we are committed to deepening our educational and professional exchanges with China, and to exploring opportunities for future joint activities.

The Strategic Implications of the Rise of China

4.23 Barring major setbacks, China by 2030 will become a major driver of economic activity both in the region and globally, and will have strategic influence beyond East Asia. By some measures, China has the potential to overtake the United States as the world's largest economy around 2020. However, economic strength is also a function of trade, aid and financial flows, and by those market-exchange based measures, the US economy is likely to remain paramount.

4.24 The crucial relationship in the region, but also globally, will be that between the United States and China. The management of the relationship between Washington and Beijing will be of paramount importance for strategic stability in the Asia-Pacific region. Taiwan will remain a source of potential strategic miscalculation, and all parties will need to work hard to ensure that developments in relation to Taiwan over the years ahead are peaceful ones. The Government reaffirms Australia's longstanding 'One China' policy.

4.25 China has a significant opportunity in the decades ahead to take its place as a leading stakeholder in the development and stability of the global economic and political system. In coming years, China will develop an even deeper stake in the global economic system, and other major powers will have deep stakes in China's economic success. China's political leadership is likely to continue to appreciate the need for it to make a strong contribution to strengthening the regional security environment and the global rules-based order.

4.26 China will also be the strongest Asian military power, by a considerable margin. Its military modernisation will be increasingly characterised by the development of power projection capabilities. A major power of China's stature can be expected to develop a globally significant military capability befitting its size. But the pace, scope and structure of China's military modernisation have the potential to give its neighbours cause for concern if not carefully explained, and if China does not reach out to others to build confidence regarding its military plans.

4.27 China has begun to do this in recent years, but needs to do more. If it does not, there is likely to be a question in the minds of regional states about the long-term strategic purpose of its force development plans, particularly as the modernisation appears potentially to be beyond the scope of what would be required for a conflict over Taiwan.'

[viii] http://www.reachingcriticalwill.org/legal/npt/revcon2010/FinalDocument.pdf accessed 3 July 2010

[ix] http://www.reachingcriticalwill.org/legal/npt/revcon2010/FinalDocument.pdf accessed 3 July 2010

[x] http://unhq-appspub-01.un.org/UNODA/TreatyStatus.nsf accessed 3 July 2010

[xi] See (1) Avner Cohen. *Israel and the Bomb*. 1998. Columbia University Press (2) David Albright, O'Neill K. *Solving the North Korean Nuclear Puzzle*. 2000. ISIS (3) T. C. Reed, Stillman, D. B. *The Nuclear Express*. 2009. Zenith Press (4) Joseph Cirincione et al. *Deadly Arsenals*. 2002. Carnegie Endowment for International Peace. Washington DC. Chapters 11-13.

[xii] By way of example and specific to this context see Agreement Between the Government of Australia and the Government of the People's Republic of China on the Transfer of Nuclear Material Articles I, III(a), V and Annex E. (http://www.info.dfat.gov.au/Info/Treaties/Treaties.nsf/AllDocIDs/B15237EE8463C30ECA2571460021455F accessed 17 July 2010)

[xiii] By way of example and specific to this context see Agreement Between the Government of Australia and the Government of the People's Republic of China on the Transfer of Nuclear Material Articles VI.2 and Annex B. (http://www.info.dfat.gov.au/Info/Treaties/Treaties.nsf/AllDocIDs/B15237EE8463C30ECA2571460021455F accessed 17 July 2010),

[xiv] New safeguards measures introduced by the *Additional Protocol* provide increased access for inspectors to information about current and planned nuclear programs, greater access to more locations on the ground and the right to take environmental samples more widely.

[xv] Radioactive Waste Management. World Nuclear Association. 2009. http://www.world-nuclear.org/info/inf04.html

[xvi] *Australia's uranium—Greenhouse friendly fuel for an energy hungry world*. House of Representatives Standing Committee on Industry and Resources. 2006. Page 212

[xvii] IAEA Annual Report 2008, page 66.

[xviii] International Nuclear Waste Disposal Concepts (2009). WNA. http://www.world-nuclear.org/info/inf21.html accessed 4 Jul 2010

[ix] http://www.iaea.org/About/Policy/GC/GC52/GC52InfDocuments/English/gc52inf-2_en.pdf

[xix] INFCIRC/386 (IAEA Code of Conduct) Basic principle 3.3

[xxi] http://www.wipp.energy.gov/ accessed 4 July 2010

[xxii] Radioactive Waste Management. World Nuclear Association. 2009. http://www.world-nuclear.org/info/inf04.html

[xxiii] 'Used fuel made from uranium originally enriched in the United Kingdom was sent to Scotland and France for reprocessing. During this process, the remaining enriched uranium in the fuel is extracted and recycled. What remains is intermediate-level waste which, under international agreements, will return to Australia.' http://www ansto.gov.au/__data/assets/pdf_file/0020/40259/Managing_Waste_and_Spent_Fuel.pdf Page 5. accessed 4 July 2010. Also, 'The contract between ANSTO and COGEMA states that the waste will be returned by 2015.' http://www.ansto.gov.au/__data/assets/pdf_file/0009/34758/ANSTO_Spent_Fuel_Shipment_150_2004.pdf accessed 3 July 2010

[xxiv] Department of Prime Minister and Cabinet. *Uranium Mining, Processing and Nuclear Energy Review*. 2006. Commonwealth of Australia. Chapter 6, Table 6.1

[xxv] Decommissioning Nuclear Facilities. World Nuclear Association. http://www.world-nuclear.org/info/inf19.html

[xxvi] Steve Kidd. *Core Issues: Dissecting Nuclear Power Today*. 2008. Nuclear Engineering International. Page 168

[xxvii] http://www.iaea.org/About/Policy/GC/GC54/GC54InfDocuments/English/gc54inf-2_en.pdf

[xxviii] see http://www.iaea.org/Publications/Factsheets/English/ines.pdf

[xxix] http://www.ier.uni-stuttgart.de/forschung/projektwebsites/newext/newext_final.pdf (New Elements for the Assessment of External Costs from Energy Technologies, 2004.) Accessed 22 July 2010.

[xxx] Life Cycle Inventories for the Nuclear and Natural Gas Energy Systems, and Examples of Uncertainty Analysis. Roberto Dones, Thomas Heck, Mireille Faist Emmenegger and Niels Jungbluth. See http://www.esu-services.ch/download/dones-2004-nuclear.pdf . Accessed 22 July 2010.

[xxxi] http://www.unscear.org/docs/reports/gareport.pdf (Report of the United Nations Scientific Committee on the Effects of Atomic Radiation to the General Assembly, 2000). Accessed 22 July 2010.

[xxxii] 'The main man-made contribution to the exposure of the world's population has come from the testing of nuclear weapons in the atmosphere, from 1945 to 1980. Each nuclear test resulted in unrestrained release into the environment of substantial quantities of radioactive materials, which were widely dispersed in the atmosphere and deposited everywhere on the Earth's surface. The Committee has given special attention to the evaluation of the doses from nuclear explosions in the atmosphere…' (http://www.unscear.org/docs/reports/gareport.pdf, paras 27-28). Accessed 22 July 2010.

[xxxiii] '35. Except in the case of accidents or at sites where wastes have accumulated, causing localized areas to be contaminated to significant levels, there are no other practices [other than those listed here] that result in important exposures from radionuclides released into the environment. Estimates of releases of isotopes produced and used in industrial and medical applications are being reviewed, but these seem to be associated with rather insignificant levels of exposure. Possible future practices, such as dismantling of weapons, decommissioning of installations and waste management projects, can be reviewed as experience is acquired, but these should all involve little or no release of radionuclides and should cause only negligible doses'. '37. There are several industries that process or utilize large volumes of raw materials containing natural radionuclides. Discharges from those industrial plants to air and water and the use of by-products and waste materials may contribute to enhanced exposure of the general public. Estimated maximum exposures arise from phosphoric acid production, mineral sand processing industries and coal-fired power stations. Although annual doses of about 100 μSv could be received by a few local residents, doses of 1-10 μSv would be more common.' (http://www unscear.org/docs/reports/gareport.pdf , paras 35, 37). Accessed 22 July 2010.

[xxxiv] http://www.unscear.org/docs/reports/gareport.pdf (para 44). Accessed 22 July 2010.

[xxxv] http://pandora.nla.gov.au/pan/79623/20080117-2207/dpmc.gov.au/umpner/index.html (pages 5, 55). Accessed 22 July 2010.

[xxxvi] UMPNER states, 'Cost additions to fossil fuel-based generation in the (low to moderate) range of AUD15-40 per tonne of carbon dioxide equivalent (CO2–e) would make nuclear electricity competitive in Australia' (p5, 55). The joint IEA/NEA study states (p132), 'CO2 prices or costs are explicit in the EU with the introduction of the European Union Emission Trading Scheme in 2005' and thus uses a carbon tax of USD 30 per tonne of CO2 which falls within UMPNER's range for competitive nuclear energy in Australia.

[xxxvii] Life Cycle Inventories for the Nuclear and Natural Gas Energy Systems, and Examples of Uncertainty Analysis. Roberto Dones, Thomas Heck, Mireille Faist Emmenegger and Niels Jungbluth. See http://www.esu-services.ch/download/dones-2004-nuclear.pdf . Accessed 22 July 2010.

[xxxviii] 'In May 2000, the US-Australian Agreement for Cooperation for the development of SILEX Technology was approved by the US Government. In June 2001, the SILEX Technology was officially Classified by the US and Australian Governments, bringing the project formally under the security and regulatory protocols of each country.

The Uranium application of SILEX is currently in the third and final stage of development—called the 'Test Loop'. In accordance with the SILEX-GE Agreement, the Test Loop program is being fully funded by Global Laser Enrichment (GLE), a subsidiary of GE (51%) formed in partnership with Hitach (25%) and Cameco (24%). The Test Loop, which is being built at GE's nuclear (Fuel Fabrication) facility in Wilmington, North Carolina, USA, will verify performance and reliability data for full scale (commercial-like) facilities. This key engineering demonstration program is scheduled to be completed at the end of 2009. [See http://www.silex.com.au/public uploads/announce/%28d%29%20UEP%2012%20April%202010%20ASX.pdf (accessed 22 July 2010) for Silex Ltd announcement on 12 April 2010 concerning the successful completion of Test-loop project initial measurement program.]

Following successful completion of the Test Loop Program, GLE will decide weather to proceed with a commercial production facility, potentially starting construction of the initial 'Lead Cascade' production facility after the receipt of the relevant licence from the US Nuclear Regulatory Commission (NRC), expected at the beginning of 2012. This plant which will have a significant production capacity, will also be built at the Wilmington site at GLE's cost.' (http://www.silex.com.au/ accessed 12 April 2010).

[xxxix] SILEX technology is undergoing commercial scale evaluation (2010). A decision about its commercial viability may be taken in 2012.

[xl] *Projected Cost of Generating Electricity* (2010), NEA-IEA; UMPNER (2006); Life-Cycle Energy Balance and Greenhouse Gas Emissions of Nuclear Energy in Australia (2006).

[xli] Generating the Future: UK energy systems fit for 2050 (2010).

[xlii] See, also, *Projected Cost of Generating Electricity* (2010). 'A core result of the scenario analysis is that not a single technology, but a portfolio of technologies is needed to achieve the CO2 reductions envisaged in the scenarios.' (page 178).

[xlii] Life-Cycle Energy Balance and Greenhouse Gas Emissions of Nuclear Energy in Australia (2006) (http://pandora.nla.gov.au/pan/79623/20080117-2207/dpmc.gov.au umpner/index.html). Accessed 22 July 2010.

[xliv] [*Life-Cycle Energy Balance and Greenhouse Gas Emissions of Nuclear Energy in Australia*, page 8 (extract)] Reading in three columns (technology//energy intensity kWhth/kWhel//GHG intensity gCO2–e/kWhel): LWR/0.18 (0.16–0.40)/60 (10–130); Black coal (supercritical)/2.62 (2.48–2.84)/863 (774–1046); Brown coal (new supercritical)/3.46 (3.31–4.06)/1175 (1011–1506); Natural gas (open cycle)/3.05 (2.81–3.46)/751 (627–891); Wind turbines/0.066 (0.041–0.12)/21 (13–40); Photovoltaics/0.33 (0.16–0.67)/106 (53–217); Hydro/0.046 (0.020–0.137)/15 (6.5–44).:

[xlv] http://www.iaea.org/Publications/Reports/Anrep2008/index.html Pages 77-89) accessed 4 July 2010