ISSUES PAPER 4 – MANAGEMENT, STORAGE, DISPOSAL OF NUCLEAR AND RADIOACTIVE WASTE

Submission from the World Nuclear Association to the South Australian Nuclear Fuel Cycle Royal Commission

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Introduction

The World Nuclear Association is grateful for this opportunity to answer the Commission's questions regarding the management, storage and disposal of radioactive wastes in South Australia. There is considerable international experience in handling radioactive material and wastes, which it may be noted are neither particularly hazardous nor hard to manage relative to some other toxic industrial wastes.

The storage and handling of civil nuclear wastes has been safely undertaken for more than 50 years.

The aim in radioactive waste management is to protect people and the environment utilising three general principles – concentration and containment, dilution and dispersal, delay and decay. The first two principles are also used in the management of other, non-radioactive, wastes. The third principle works by storing the waste long enough until radioactive decay renders the waste no longer radiologically hazardous.

Unlike some other toxic wastes, such as heavy metals, the principal hazard associated with nuclear waste – radioactivity – diminishes with time.

The pillar of any national waste management plan is the responsible implementation of an institutional framework. Authoritative international organisations provide advice on institutional frameworks for the management of nuclear wastes. These include the International Atomic Energy Agency (IAEA), the Nuclear Energy Agency (NEA) of the Organisation for Economic Co-operation and Development (OECD), the European Commission (EC) and the International Commission on Radiological Protection (ICRP). International agreements in the form of conventions under the auspices of the IAEA have also been established, such as the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management.

Nuclear waste can be separated broadly into three categories, requiring different treatment and disposal.

<u>Low-level wastes</u> comprise about 90% of the volume of civil radioactive wastes but only about 1% of the radioactivity. They are often incinerated in a closed environment to reduce volume before disposal. In many countries, low-level waste disposal facilities are established and operating without contention.

<u>Intermediate-level wastes</u> require some shielding and comprise sludges, resins and reactor components. They make up about 7% of the volume and 4% of the radioactivity of all civil radioactive wastes. Before disposal, it is common practise to incorporate intermediate-level waste into concrete or bitumen. Repositories are operating in Sweden, Finland, Spain, South Korea and the USA.

<u>High-level wastes</u> comprise about 3% of the volume and 95% of the radioactivity of all civil radioactive wastes. They may consist of separated fission products and actinides from used fuel, or the used fuel itself where national policies preclude reprocessing. National policies typically require high-level waste to be stored for about 50 years so that its radioactivity has decayed by two or three orders of magnitude before it is ready for disposal. A typical composition for used fuel is shown in Figure 1. It should immediately be apparent that the vast majority (~95%) of material is in fact unused uranium and plutonium which can be recycled if desired.

Upon being unloaded from a reactor, used fuel is initially stored under water in pools inside the reactor building, and it may then be transferred to central pool storage on site or to an offsite storage facility. Fuel pools are 7-12 metres deep to allow ample water coverage of the fuel assemblies, and to act as a shield and coolant for the fuel. The pools are robust, constructed from reinforced concrete with steel liners and are often designed to hold all of the used fuel for the operational life of the reactor. Of the world's 230,000 tonnes of used fuel, most is currently held in storage pools.

After about five years cooling under water, used fuel may optionally be transferred to dry storage. Most dry storage capacity is at reactor sites, but centralised facilities are being built in Ukraine and are proposed in the USA. Dry storage for used fuel can exist in the form of sealed steel casks, concrete cylinders, or vaults with air circulation inside concrete shielding. There is a variety of possible dry storage arrangements, either above ground or largely buried.

There is international consensus that deep geological disposal is the solution for high-level

radioactive wastes.

While no facilities for civil high-level wastes are yet operating in the world, there is no reason to doubt that South Australia could safely dispose of high-level wastes in either small or large quantities. As indicated in Figure 2, the radioactivity of waste continues to fall with time, although the rate depends upon the composition of the waste.

The overwhelming lesson from attempts to construct waste facilities and repositories around the world is that public support and resolute political will are the critical elements of success.

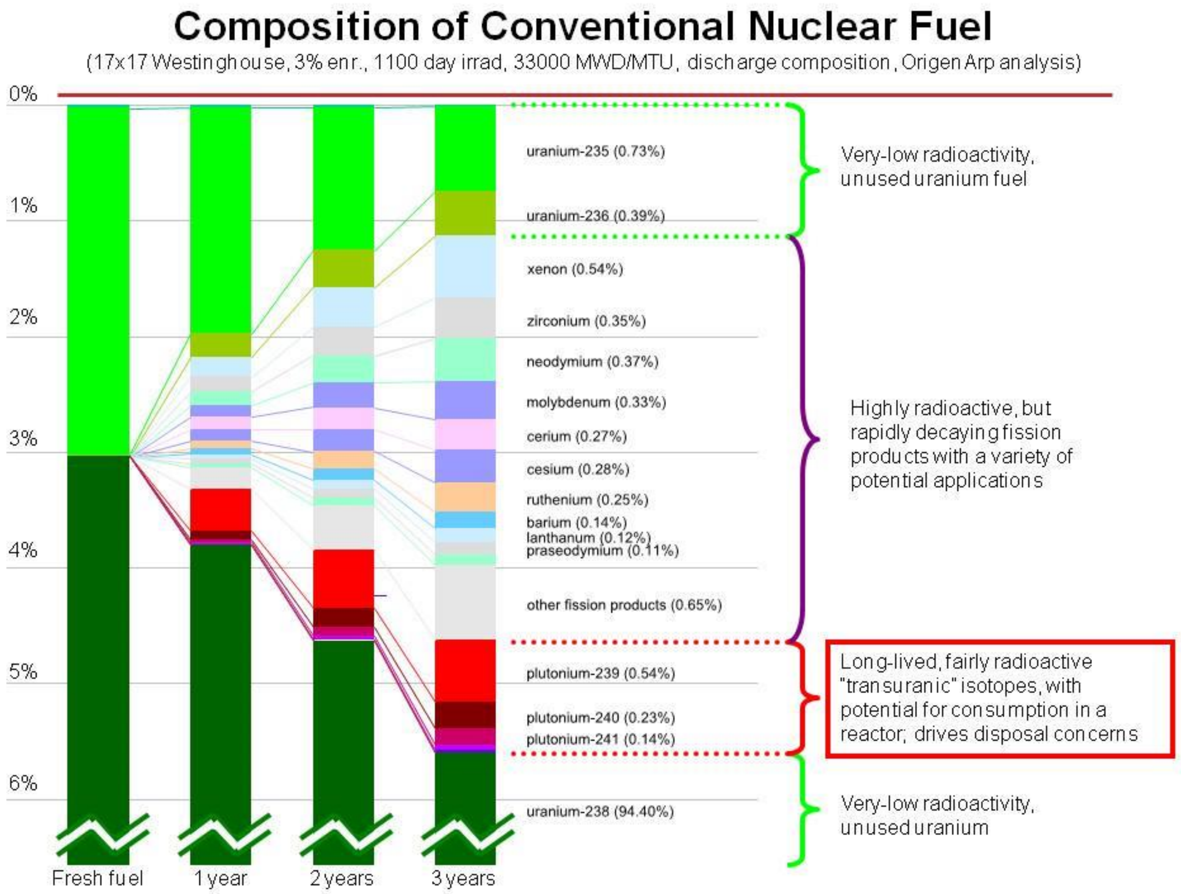

Figure 1: Typical composition of used nuclear fuel after several years of being in a reactor. Source: Westinghouse

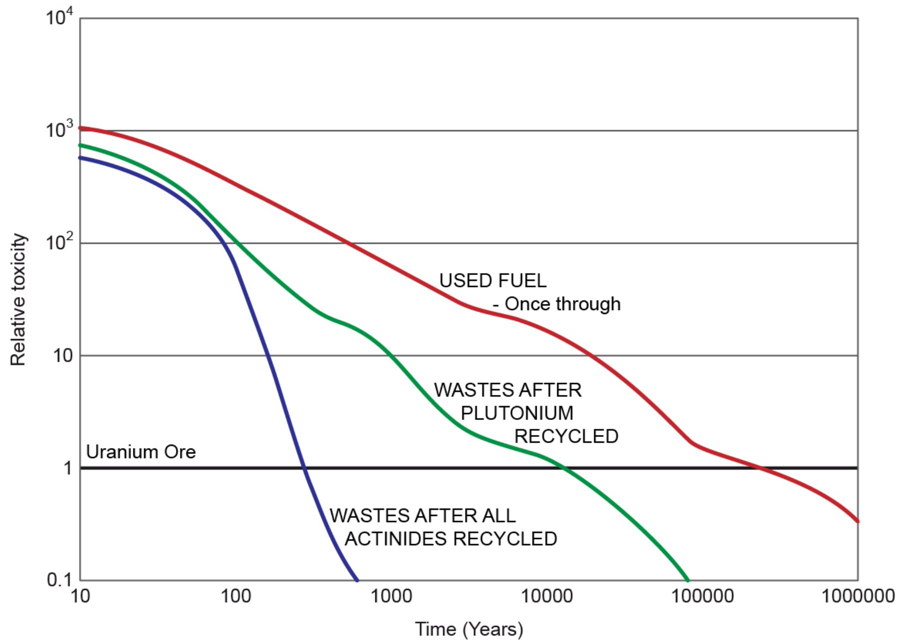

Figure 2: The radioactivity of high-level waste declines over time. Red line – used fuel if disposed of directly. Green line – leftover high-level waste (actinides and fission products) if plutonium and uranium is removed (via PUREX process). Blue line – high-level waste consisting only of fission products (via advanced reprocessing technique)

Question 4.5

a) *What are the specific models and case studies that demonstrate the best practice for the establishment, operation and regulation of facilities for the storage or disposal of nuclear or radioactive waste?*

Countries with power programs going back many decades all achieve safe storage and management of all kinds of civil nuclear wastes. A summary of national plans for radioactive waste management in many countries is maintained by the World Nuclear Association[1]. Some notes are provided below on Sweden, Finland, France, Canada, South Korea and the UAE.

Sweden

In Sweden SKB is the company responsible for managing and disposing of all radioactive waste resulting from nuclear power generation. It is entirely funded by regular contributions from nuclear operators. Used fuel from the country's ten operating reactors is transferred from the plants to a central interim storage facility (CLAB) near the Oskarshamn nuclear plant about a year after unloading. CLAB has operated since 1985, and the used fuel is stored for some 40-50 years in a pool constructed underground. It will then be encapsulated in copper canisters with cast iron internal structure for final emplacement packed with bentonite clay in a 500 metre deep repository in granite. Research at the Äspö Hard Rock Laboratory nearby identified the geological characteristics of this final deep repository. Site selection procedures from 2002 resulted in selection of Östhammar near the Forsmark nuclear power plant as the site for the final repository after two communities had bid to host it. SKB applied for a licence to construct the repository in March 2011. It plans to begin construction in 2020.

Finland

Supported by strong public acceptance, the government decided in December 2000 for a deep geological repository in Olkiluoto bedrock at Eurajoki for the disposal of high-level waste. Construction of the underground rock characterisation facility (ONKALO) to test the suitability of the site began in 2004. Once demonstrated, ONKALO will be extended to the final disposal depth of about 400 metres. Posiva is the company in charge of disposing of the waste. It is funded by industry in the same way as SKB. Posiva applied for a construction licence for the facility to hold 9000 tonnes of used fuel from Olkiluoto and Loviisa and the encapsulation plant in 2012, this was granted in 2015[2]. The operating licence application is expected in 2020, with a view to operation from 2022.

France

France has a policy of reprocessing used fuel, which radically reduces the final volume of wastes for disposal. The separated high-level waste is vitrified in borosilicate glass. The management of radioactive waste in France is governed by the 2006 Nuclear Materials and Waste Management Program Act which established deep geological disposal as the reference solution for high-level and long-lived radioactive wastes (recoverable in the short term and potentially retrievable for at least 100 years). In 1999, the national waste management agency, ANDRA, was authorised to build an underground research laboratory in clay at Bure to prepare for disposal of vitrified high-level wastes and long-lived intermediate-level wastes. In 2012 plans for the Industrial Centre for Geological Disposal (CIGEO) deep repository at Bure were approved. The concept for CIGEO was decided after public consultation[3]. ANDRA expects to apply for a construction and operating licence for CIGEO in 2017. The pilot phase of CIGEO is expected to operate from 2025. Two further repositories are envisaged by ANDRA and CEA.

Canada

The Nuclear Waste Management Organization (NWMO) was set up under the 2002 Nuclear Fuel Waste Act by the nuclear utilities operating in conjunction with Canadian Nuclear Laboratories (CNL - known formerly

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[1] See World Nuclear Association, National Policies – Radioactive Waste Management, http://www.world-nuclear.org/info/Nuclear-Fuel-Cycle/Nuclear-Wastes/Appendices/Radioactive-Waste-Management-Appendix-3--National-Policies/

[2] See World Nuclear News, Finnish regulator approves Posiva's waste repository plan, http://www.world-nuclear-news.org/WR-Finnish-regulator-approves-Posivas-waste-repository-plan-12021501.html

[3] See World Nuclear News, Designing the CIGEO disposal site, http://www.world-nuclear-news.org/WR-Designing-Cigeo-disposal-site-0206141.html

as AECL). Its mandate is to explore options for storage and disposal, to then make proposals to the government and to implement what is decided. NWMO, working with CNL, is also required to maintain trust funds for used fuel management and disposal. Canada uses pressurised heavy water reactors with low- or un-enriched nuclear fuel and used fuel quantities are therefore relatively higher than light-water reactors operating on enriched fuel. In 2007 the government selected the retrievable deep geological disposal option recommended by NWMO, and communities were invited to volunteer to host the repository. At the end of 2014, NWMO announced that partly on geological grounds the focus had narrowed to two communities: the municipality of South Bruce, and the township of Huron-Kinloss in Bruce County, Ontario. The facility is expected to begin operations by around 2035. Meanwhile, there is extensive use of dry storage by the country's nuclear operators. Fuel is typically transferred to casks after spending five to ten years in cooling pools.

South Korea
The Korea Radioactive Waste Management Co. Ltd was set up early in 2009 under the Radioactive Waste Management Act as an umbrella organisation to resolve South Korea's waste management issues, and particularly to forge a national consensus on high-level wastes. In 2013 its name changed to the Korea Radioactive Waste Agency (KORAD)[4]. While progress on high-level wastes has stalled pending approval from USA for reprocessing, or other arrangements, a $1.5 billion facility for low- and intermediate-level wastes is now in operation.

The Wolseong Low- and Intermediate-Level Radioactive Waste Disposal Centre is close to Wolsong nuclear power plant. In 2005, Gyeongju in North Gyeongsang province on the east coast was designated as the site for this following approval by almost 90% of its voters (compared with alternatives: Gunsan, 84%; and Yeongdeok, 79%). It has a number of silos and caverns about 80 metres below the surface, initially with capacity for 100,000 drums, and construction of a second, near-surface stage for low-level wastes is under way. Over 5000 drums of low-level waste are now stored on site and the first intermediate-level wastes were placed in a silo in July 2015. Ultimately, the facility will be used to dispose of a total of 800,000 drums of waste.

UAE
Australia's situation will be more analogous to that of an emerging nuclear power nation such as the United Arab Emirates (UAE), which has made an admirable start. Initially publishing a comprehensive policy regarding nuclear energy, they swiftly followed this with the creation of a regulatory framework and selection of a site. With advice from the IAEA, the UAE then established a Nuclear Energy Program Implementation Organization which launched the Emirates Nuclear Energy Corporation (ENEC). This public entity is used to develop and implement nuclear power plans within UAE. It has moved to begin development of a national storage and disposal program in parallel with exploring regional cooperation options – a dual track strategy. It intends to manage fuel using storage pools, with the option of transferral to dry storage after six years, and the possibility of reprocessing abroad. The regional cooperation options are under consideration by Arius for Gulf Cooperation Council countries, encouraged by the Federal Authority for Nuclear Regulation (FANR) of the UAE since 2012.

b) *What are the less successful examples?*

Japan
Despite Japan's Final Disposal Law of 2000 and the establishment of the Nuclear Waste Management Organisation (NUMO)[5] later that year, the open solicitation process to find communities interested in hosting a repository has not yielded results and from 2013 the government has become more proactive. Having short-listed possible locations with Atomic Energy Commission oversight, the government will seek local government consent to pursue plans for a deep geological repository for separated, vitrified high-level wastes. NUMO now expects site selection from about 2025, with repository operation from about 2035. A fuller description is in the World Nuclear Association information paper on Japan Nuclear Fuel Cycle[6].

[4] http://www.korad.or.kr
[5] https://www.numo.or.jp/en See also WNA Japan Fuel Cycle paper http://www.world-nuclear.org/info/Country-Profiles/Countries-G-N/Japan--Nuclear-Fuel-Cycle/
[6] http://www.world-nuclear.org/info/Country-Profiles/Countries-G-N/Japan--Nuclear-Fuel-Cycle/

USA
In the USA all used fuel is treated as high-level waste and none has been reprocessed, increasing the need for a large geological repository. Yucca Mountain[7] in Nevada was initially designated as the sole repository for this as well as high-level military wastes, but the process was derailed by political opposition and interference. The future of the Yucca Mountain repository is uncertain, and meanwhile there are moves to establish long-term storage facilities in Texas and New Mexico. The whole situation is described in the latter half of World Nuclear Association information paper on US Nuclear Fuel Cycle[8].

c) *Where have they been implemented in practice?*

Low-level waste and intermediate-level waste disposal is currently achieved by all countries with nuclear power programs, as well as other countries without any such program. No geologic repositories for high-level waste have yet been commissioned. The closest nations to implementation are Finland, Sweden and France, as outlined above.

The USA has a deep geological repository in New Mexico for intermediate-levels wastes from military sources. This is the Waste Isolation Pilot Plant (WIPP) in a salt formation.

d) *What new methods have been proposed?*

Reference has been made above to the distinction between used fuel and separated high-level wastes arising from reprocessing used fuel in order to recycle its uranium and plutonium. At present, the only commercial reprocessing technology is PUREX, a hydrometallurgical process originally developed in the 1940s. There is however strong interest in electrometallurgical processes for the future (also known as pyroprocessing) so as to separate all actinides together for burning in fast neutron reactors[9].

Whether reprocessing is undertaken or not, the current international consensus is that deep geological disposal provides the most pragmatic and safe solution for high-level wastes. While proposals have emerged such as neutron bombardment in accelerator-driven systems (ADS) to transmute high-level waste into a non-radioactive material, this technology is far from mature.

Specialised forms of ANSTO's 'Synroc' technology with hot isostatic pressing can provide an effective and durable means for the immobilization of certain intermediate and high-level radioactive wastes for disposal[10], although the vitrification of separated high-levels wastes into borosilicate glass sealed into stainless steel casks is a proven and viable technology.

e) *What lessons can be drawn from them?*

The overwhelming lesson to be learned from these case studies is that public support and resolute political will are the critical elements for the success of a high-level waste disposal strategy – more so than appropriate geology. For this reason, internationally agreed standards and effectively structured institutional frameworks for countries embarking on nuclear power should be embraced. Public consultation is clearly crucial for building acceptance.

It was concluded from the major research program undertaken by Pangea Resources in the 1990s that Australia, amongst southern Africa, Argentina and western China had the best credentials worldwide for a deep geological repository, with Australia being favoured on economic and political grounds. The Pangea proposal, as analysed by a major economic consultancy, showed that there is considerable economic potential involved in a multinational waste disposal facility[11]. That will not have diminished since the 1990s.

[7] http://www.epa.gov/radiation/yucca/background.html
[8] http://www.world-nuclear.org/info/Country-Profiles/Countries-T-Z/USA--Nuclear-Fuel-Cycle/
[9] More information on reprocessing can be found here http://www.world-nuclear.org/info/Nuclear-Fuel-Cycle/Fuel-Recycling/Processing-of-Used-Nuclear-Fuel/
[10] http://www.world-nuclear.org/info/Nuclear-Fuel-Cycle/Nuclear-Wastes/Synroc/
[11] http://www.world-nuclear.org/info/Nuclear-Fuel-Cycle/Nuclear-Wastes/International-Nuclear-Waste-Disposal-Concepts/

If South Australia needs to dispose of high-level radioactive wastes in either small or large quantities, there is no reason to doubt that this can be undertaken safely. It need have no significant impact on people or the environment.

Question 4.6

a) What are the security implications created by the storage or disposal of intermediate or high level waste at a purpose-built facility? Could those risks be addressed?

b) If so, by what means?

Two aspects of security can be raised for the storage and disposal of nuclear waste: theft with the intention of terrorism, and environmentally secure containment of the waste over the long-term.

Storage and disposal of wastes has been a priority since the inception of civil nuclear power. The risks are addressed by engineering practices which include multiple redundancy measures such as immobilisation of high-level wastes in an insoluble matrix, sealing the product inside a corrosion resistant metal container, if in wet rock surrounding the containers with bentonite clay to inhibit the mobilisation of any leaked radionuclides, and locating all this underground in a deep stable rock structure.

Hypothetical scenarios postulate terrorists breaching waste storage, or using high-level wastes to acquire materials for a dirty bomb. However, a purpose-built facility for nuclear wastes will be resistant to such plans, and the waste itself will be radiologically self-protecting. Indeed, once emplaced in a geologic disposal facility the waste is about as secure as it could conceivably be. To further decrease security risk, it has been proposed that only a limited number of storage locations be constructed, which will allow better financing for only the most secure engineering technologies and monitoring capabilities.

Question 4.10

a) What are the risks associated with transportation of nuclear or radioactive wastes for storage or disposal in South Australia?

b) Could existing arrangements for the transportation of such wastes be applied for this purpose?

c) What additional measures might be necessary?

Radioactive materials are defined as Class 7 in the UN model regulations and treated as dangerous goods, regardless of any particular characteristics such as the degree of chemical or radiological hazard. The risks are addressed by appropriate packaging. Nuclear materials have been transported safely, with few incidents, and without harmful effect on anybody that can be attributed to their radioactivity. Existing procedures for transport include movement by truck or rail on land, and by purpose-built ships, and these procedures are well-tested and fully adequate for any purposes which might arise for South Australia[12].

There are two types of packaging for radioactive wastes and used fuel, A, and B. Type A packages are designed to withstand minor accidents and are used for medium-activity materials such as medical or industrial radioisotopes. Type B packaging can be further categorized into more than 150 types depending on the material, but are designed to maintain shielding from gamma and neutron radiation, even under extreme accident conditions.

Since 1971 there have been some 7000 shipments of used fuel (over 80,000 tonnes) over many million kilometres with no property damage or personal injury, no breach of containment, and very low dose rate to the personnel involved, e.g. 0.33 mSv/yr per operator at France’s La Hague reprocessing facility. This includes 40,000 tonnes of used fuel shipped to La Hague, at least 30,000 tonnes of mostly UK used fuel shipped to UK's Sellafield reprocessing plant, 7040 tonnes of used fuel in over 160 shipments from Japan to Europe by sea and over 4500 tonnes of used fuel shipped around the Swedish coast. In the USA naval used fuel is routinely transported by rail to Idaho National Laboratory.

[12] Australian mining companies have shipped over 11,000 shipping containers with 200-litre drums of U_3O_8 for more than three decades. These have been moved from mines to ports without any incidents affecting public health.

From France to Japan, 12 waste shipments over 12 years involved 1310 canisters containing about 700 tonnes of vitrified high-level wastes in heavy steel shipping casks. Shipment of similar wastes from UK to Japan commenced in 2010 and will involve about 11 shipments to move about 900 canisters. Some 300 sea voyages have been made carrying used nuclear fuel or separated high-level waste over a distance of more than 8 million kilometres. The major company involved, International Nuclear Services[13], has transported over 4000 casks, each of about 100 tonnes, carrying 8000 tonnes of used fuel or separated high-level wastes. A quarter of these have been through the Panama Canal.

In Sweden, more than 80 large transport casks are shipped annually to CLAB containing used fuel that has been stored for about a year at the reactor, during which time heat and radioactivity have diminished considerably. Each 80 tonne cask has steel walls 30 centimetres thick and holds 17 BWR or 7 PWR fuel assemblies. Some 6000 tonnes of used fuel have been transported, much of it around the coast by ship.

Shipments of used fuel from Japan to Europe for reprocessing used 94-tonne Type B casks, each holding a number of fuel assemblies (e.g. 12 PWR assemblies, total 6 tonnes, with each cask 6.1 metres long, 2.5 metres diameter, and with 25 centimetre thick forged steel walls). More than 160 of these shipments took place from 1969 to the 1990s, involving more than 4000 casks, and moving several thousand tonnes of highly radioactive used fuel – 4100 tonnes to UK and 2940 tonnes to France.

Relative to petrol and chemical tankers on public roads or on railways, transport of any radioactive wastes as normally practiced poses trivial hazards.

[13] A wholly owned subsidiary of the UK Nuclear Decommissioning Authority, see http://www.internationalnuclearservices.com/