6

The safety of the nuclear fuel cycle

Despite popular misconceptions, nuclear power has an unmatched safety record relative to all base load fuels. It is far safer per megawatt hour generated than hydrocarbon fuels …[1]

… as a comparative figure, between 10 000 and 15 000 coal miners are killed per annum around the world. China contributes largely to that, with over 6 000 deaths per annum in their coal mines. In comparison, in power stations, coal-fired power stations since 1997 have killed 6 500 people; natural gas, 1 200 people; hydro, 4 000 and maybe more … the nuclear industry has killed 31 people.[2]

If you stood on the boundary of Lucas Heights for 24 hours a day, 365 days a year and breathed it all in, you would get about the same [radiation] dose as flying from Sydney to Melbourne …[3]

The new millennium will see the increasing use of nuclear science and technology in every field of human endeavour. The immense benefits far outweigh the risks. And the risks of radiation must be assessed on a scientific basis and with informed realism … The manipulative assessment of nuclear risk must not deprive humanity of these immense benefits.[4]

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1 Professor Leslie Kemeny, *Exhibit no. 9, Power to the people*, p. 2.

2 Mr Alan Eggers (Summit Resources Ltd), *Transcript of Evidence*, 3 November 2005, p. 3.

3 Dr Ron Cameron (Australian Nuclear Science and Technology Organisation), *Transcript of Evidence*, 13 October 2005, p. 16.

4 Professor Leslie Kemeny, *Exhibit no. 43*, *Pseudo-Science and Lost Opportunities*, p. 6.

Key messages —

- **The nuclear power industry has by far the best safety record of all major energy industries, including coal, oil, natural gas, liquefied petroleum gas and hydro.**
- **In the 20 years since the Chernobyl nuclear accident there have been some 60 deaths directly attributed to the accident—not all of which have been due to radiation exposure. In contrast, there are more than 10 000 deaths from coal mining accidents worldwide every year. This ignores the other deleterious health effects of burning fossil fuels, including through the ingestion of toxic gases and particulates. Even in Australia, which is said to have the safest mining industry in the world, 112 coal miners have died in NSW mines alone since 1979.**
- **Claims by some submitters that many thousands of people have already died as a result of the Chernobyl accident are massively exaggerated and are possibly intended to generate fear and further opposition to nuclear power. Whatever the motive, such claims are irresponsible and reflect poorly on the credibility of those individuals and groups making such claims.**
- **Among its other findings, a major multi agency UN report by the Chernobyl Forum concludes that the most pressing health problems for areas most affected by the Chernobyl accident is not radiation exposure but poor diet and lifestyle factors associated with alcohol and tobacco use, as well as poverty and limited access to health care.**
- **The Chernobyl Forum states that the largest public health problem caused by the accident has been the mental health impact, in part due to the trauma associated with the resettlement of large numbers of people from the most affected areas. The Chernobyl Forum states that 'misconceptions and myths' about the threat of radiation persist, promoting a 'paralysing fatalism' among residents.**
- **Notwithstanding the tragedy of Chernobyl, which has been the only accident to a commercial nuclear power plant that has resulted in loss of life, nuclear power's safety record is unrivalled by any other major energy source.**
- **The total average effective dose received by the world population from natural sources of radiation (i.e. 'natural background radiation') is 2.4 millisieverts (mSv) per year. In contrast, the total average effective dose to monitored workers across the whole nuclear fuel cycle (including uranium mining and milling) is 1.75 mSv per year.**

Aircrew in civil aviation are exposed to an average 3.0 mSv and radon exposure in some above-ground workplaces is estimated to average 4.8 mSv.

- **The maximum average annual radiation dose allowed for a uranium miner is currently set at 20 mSv. The actual dose received by workers at Australian uranium mines is well under half this level. The radiation exposure for the public in the vicinity of the mines is a small fraction of the prescribed limit for members of the public, which is 1 mSv.**
- **To provide greater assurance to uranium industry workers and the public at large, and also to definitively answer claims—which the Committee is confident are entirely mistaken—that current radiation exposures are harming workers, the Committee recommends the establishment of:**
  - ⇒ **a national radiation dose register for occupationally exposed workers; and**
  - ⇒ **a system of long-term monitoring of the health outcomes for workers occupationally exposed to radiation in uranium mining, associated industries and nuclear facilities.**
- **Occupational exposure, discharges from the nuclear industry and fallout from former atmospheric nuclear weapons tests accounts for approximately a quarter of one per cent of the total world average radiation exposure.**
- **The benefits of nuclear energy far outweigh the very small risks associated with radiation exposure from the routine operations of fuel cycle facilities, including uranium mining operations.**
- **In any case, health risks from the expanded use of nuclear power must be considered in the broader context of the risks associated with climate change and the certain health consequences of expanded use of fossil fuels.**
- **There is a clear need for improved public understanding of the nature of radiation and the actual exposures to the public from the nuclear industry's operations.**

Introduction

6.1 In this chapter the Committee examines the second key concern raised in opposition to the civil nuclear power industry—the safety of nuclear fuel cycle facilities, and particularly the health risks to workers and to the public from exposure to radiation from uranium mining and nuclear power plants.

6.2 The chapter presents evidence in relation to the following themes in turn:

- the health effects from exposure to ionising radiation and the current international standards for control of radiation exposure;
- regulation for radiation protection in Australia;
- safety and health issues associated with the uranium mining industry in Australia, specifically:
  - ⇒ radiation exposure to workers and the public from uranium mining operations;
  - ⇒ risks associated with the transport of uranium oxide in Australia;
  - ⇒ proposals for a national radiation dose register and long-term health monitoring of uranium industry and nuclear workers;
  - ⇒ safety at Australia's uranium mines;
- radiation exposure from the whole nuclear fuel cycle, including:
  - ⇒ exposures to nuclear industry workers;
  - ⇒ exposures to the public;
- nuclear safety, including:
  - ⇒ safety of nuclear reactors;
  - ⇒ global nuclear safety regime;
  - ⇒ fatalities associated with the Chernobyl accident;
  - ⇒ the safety record of the nuclear power industry compared to other energy sources;
  - ⇒ terrorism and the safety of nuclear facilities;
  - ⇒ use of depleted uranium munitions; and
- radiation and public perceptions.

Health effects of ionising radiation and international standards for control of exposure

6.3 The Committee introduced the concepts of ionising radiation and radiation exposure (or 'dose') at the beginning of the previous chapter. It was explained that ionising radiation, to which all living organisms are constantly exposed, has energy capable of causing chemical changes damaging to living tissue. Ionising radiation is of four types (alpha and beta particles, gamma rays and neutrons) and includes x-rays and the radiation from the decay of both natural and artificial radioactive substances.

6.4 Exposure measures the effect of radiation on substances that absorb it and is expressed in several ways, to account for the different levels of harm caused by different forms of radiation and the different sensitivity of body tissues. Among these measures is the 'equivalent dose', which refers to the effect of radiation exposure on human tissue and is measured by the 'Sievert' (Sv). The 'effective dose' takes into account what part of the body was exposed to radiation, because some organs are more sensitive to radiation than others. The effective dose is also measured by the Sievert.[5]

6.5 The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) reports that the total average effective dose received by the world population from all sources of radiation (natural and artificial) is 2.8 millisieverts (mSv—one thousandth of a Sievert) per year. Over 85 per cent of this total is from natural sources (primarily from buildings/soil, cosmic radiation, radon gas from the Earth and present in the air, and food). Of the sources of ionising radiation arising from human activities (i.e. artificial sources), the largest contributor is medical exposure from x-rays (0.4 mSv or 14 per cent of the total dose). Occupational exposure, discharges from the nuclear industry and fallout from former atmospheric nuclear weapons tests accounts for approximately a quarter of one per cent of the total world average radiation exposure (0.0072 mSv).[6] The contributions of natural and artificial sources to the world average annual effective radiation dose are listed in table 6.1.

6.6 The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) explained that it is well known that doses of ionising radiation can cause harm. Extreme doses of radiation to the whole body (around 10 Sv and above), received in a short period, will cause so much damage to internal organs and tissues of the body that vital systems cease to function and death may result within days or weeks. Very high doses (between 1 Sv and 10 Sv), received in a short period, will kill large number of cells, which can impair the function of vital organs and systems. Acute health effects, such as nausea, vomiting, skin and deep tissue burns, and impairment of the body's ability to fight infection may result within hours to weeks. The extent of damage increases with dose. These types of radiation effects are referred to as 'deterministic' effects.[7]

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5 See: International Atomic Energy Agency, *Radiation, People and the Environment*, IAEA, Vienna, 2004, viewed 5 September 2006, <http://www.iaea.org/Publications/Booklets/RadPeopleEnv/pdf/radiation_low.pdf>.

6 *ibid*., pp. 13, 14, 30; Professor Leslie Kemeny, *Exhibit no. 9, Power to the people*, p. 2.

7 ARPANSA, *Submission no. 32*, p. 7.

Table 6.1 Worldwide average annual effective radiation doses from natural sources and human activities in year 2000

Source	**Worldwide average annual effective dose (mSv)**
Natural background	2.4
Artificial sources (from human activities)	
Diagnostic medical examinations	0.4
Previous atmospheric nuclear weapons tests	0.005
Chernobyl accident	0.002
Nuclear power production	0.0002
Total from natural and human sources (rounded)	2.8

Source UNSCEAR, *Sources and Effects of Ionizing Radiation, Report to the UN General Assembly*, *2000*, *Volume I*, pp. 5, 8.

6.7 The International Atomic Energy Agency (IAEA or 'the Agency') explains that deterministic effects can be identified clinically to be the result of radiation exposure. They only occur if the dose or dose rate is greater than some threshold value, and the effect occurs earlier and is more severe as the dose and dose rate increase.[8]

6.8 While high radiation doses such as those mentioned above can cause harm, ARPANSA explained that there is continuing uncertainty about the effects at low doses. Doses below the thresholds for deterministic effects may cause cellular damage, but this does not necessarily lead to harm to the individual: the effects are said to be probabilistic or 'stochastic' in nature.[9]

6.9 The IAEA explains that stochastic effects are not certain to occur, but the likelihood that they will occur increases as the dose increases, whereas the timing and severity of any effect does not depend on the dose. Because radiation is not the only known cause of most of these effects, it is normally impossible to determine clinically whether an individual case is the result of radiation exposure or not.

6.10 The most important of the stochastic effects of radiation exposure is cancer. Ionising radiation is known to play a role in inducing certain types of cancer, for example by introducing mutations in the DNA of normal cells in tissues. These mutations can allow a cell to enter a pathway of abnormal growth that can sometimes lead to the development of a

8 IAEA, *op. cit.*, p. 15.

9 ARPANSA, *loc. cit.*

malignancy. Apart from cancer, the other main late effect of radiation is hereditary disease caused by genetic damage.[10]

6.11 It is known that doses above 100 mSv, received in a short period, lead to an increased risk of developing cancer later in life. Epidemiological evidence from survivors of the atomic bombs in Japan shows that, for several types of cancer, the risk of cancer increases roughly linearly with dose, and that the risk factor (which is the lifetime risk or radiation detriment assumed to result from exposure per unit dose) averaged over all ages and cancer types is about one in 100 for every 100 mSv dose.[11]

6.12 ARPANSA stated that at doses below 100 mSv the evidence of harm is not clear cut. It was observed that while some studies indicate evidence of radiation-induced effects, epidemiological research has been unable to establish unequivocally that there are effects of statistical significance at doses below a few ten of millisieverts. Given that no threshold for stochastic effects has been demonstrated, and in order to be cautious in establishing health standards, the proportionality between risk and dose observed at higher doses is presumed to continue through all lower levels of dose down to zero. This is called the linear, no-threshold (LNT) hypothesis and it is made for radiation protection purposes only.[12]

6.13 There is evidence that a dose accumulated over a long period carries less risk than the same dose received over a short period. Except for accidents and medical exposures, doses are not normally received over short periods, so that it is considered appropriate in determining standards for the control of exposure to use a risk factor that takes this into account. While not well quantified, a reduction of the high-dose risk factor by a factor of two has been adopted internationally, so that for radiation protection purposes the risk of radiation-induced fatal cancer (the 'risk factor') is taken to be about 1 in 20 000 per mSv of dose for the population as a whole.[13]

6.14 If the LNT hypothesis is correct, any radiation dose carries some risk. Therefore, measures for control of exposure for stochastic effects seek to avoid all reasonably avoidable risk, which is referred to as 'optimising protection'. The optimisation approach is underpinned by applying dose limits that restrict the risk to individual to an 'acceptable' level.[14]

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10 IAEA, *op. cit.*, pp. 16, 10.

11 ARPANSA, *op. cit.*, p. 8.

12 *ibid.*

13 This risk is usually expressed as five per cent per sievert. Recent data gathered by the ICRP would put the risk calculated on the same basis as 4.4 per cent per sievert.

14 *ibid.*

6.15 The International Commission on Radiological Protection (ICRP) has established recommended standards of protection (both for members of the public and radiation workers) based on three principles:

- Justification—no practice involving exposure to radiation should be adopted unless it produces a net benefit to those exposed or to society generally;
- Optimisation of protection—radiation doses and risks should be kept as low as reasonably achievable (ALARA), economic and social factors being taken into account; and
- Limitation of individual dose—the exposure of individuals should be subject to dose or risk limits above which the radiation risk would be deemed unacceptable.[15]

6.16 ARPANSA noted that determining what constitutes an 'acceptable' risk for regulatory purposes is a complex judgement. However, the ICRP's recommendations, which have in part been derived from studies of the Japanese survivors of the atomic bombs, have in general been internationally endorsed.

6.17 The *International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources* (BSS), published in 1996, are sponsored by the IAEA and five other international organisations including the World Health Organisation (WHO) and the International Labour Organisation (ILO).[16] The BSS, which are based primarily on the ICRP system of radiological protection described above, set out detailed requirements for occupational, medical and public exposures, and specify dose limits and exemptions. They also specify requirements for ensuring the safety of radioactive sources and for dealing with nuclear emergencies. IAEA Safety Guides give more detailed guidance on how the requirements should be met in particular situations.[17]

6.18 The BSS specifies that the additional effective dose above natural background and excluding medical exposure, should be limited to the following prescribed levels:

- 1 mSv in a year for members of the public; and
- 20 mSv per year averaged over five years for occupationally exposed persons, with no more than 50 mSv in any year.[18]

6.19 Citing a report by the 'European Committee on Radiation Risk', which is an organisation established by the Green Group in the European

15 Uranium Information Centre (UIC), *Submission no. 12*, p. 46; ARPANSA, *op. cit.*, p. 9.
16 ARPANSA, *op. cit.*, p. 9.
17 IAEA, *op. cit.*, p. 28.
18 ARPANSA, *loc. cit.*

Parliament, the Australian Conservation Foundation (ACF) argued that the dose limits prescribed by the ICRP were 'unacceptable' and that the total maximum permissible dose to members of the public arising from all practices should not be more than 0.1 mSv, with a value of 5 mSv for nuclear workers.[19]

The LNT hypothesis and radiation hormesis

6.20 Several submitters, including the Public Health Association of Australia (PHAA), Mr Justin Tutty and Dr Helen Caldicott argued that there is 'no known safe level at which radiation does not damage DNA and initiate cancer.'[20]

6.21 The MAPW (Victorian Branch) cited an article entitled *Risk of cancer after low doses of ionising radiation*, published in the British Medical Journal in June 2005. The article published the results of a study which sought to provide estimates of the risk of cancer after protracted low doses of ionising radiation, and involved a retrospective study of cohorts of workers in the nuclear industry (excluding uranium mining) in 15 countries. The study claimed to have been the largest ever conducted of nuclear workers, involving some 407 000 monitored workers. The report found that 1–2 per cent of deaths from cancer among the workers may be attributable to radiation. The results were said to indicate that there is a small excess risk of cancer, even at low doses and dose rates typically received by nuclear workers in the study. However, it was concluded that these estimates are higher than, but statistically compatible with, the risk estimates used for current radiation protection standards.[21]

6.22 In contrast, some submitters argued strenuously that very low doses of radiation may in fact have beneficial consequences for human health and questioned the appropriateness of the LNT hypothesis for radiation protection policies at these lower doses. Professor Ralph Parsons, a former President of the Australian Institute of Nuclear Science and Engineering (AINSE), former Member of the Uranium Advisory Council and past Chairman of the Australian Ionising Radiation Advisory Council, argued that there is evidence that low doses of radiation may in fact be beneficial to human health, an effect known as radiation hormesis:

> There is strong evidence to suggest that the estimated risks associated with low doses of ionising radiation have been grossly

19 ACF, *Submission no. 48*, p. 16.

20 Mr Justin Tutty, *op. cit.*, p. 5; Mr John Schindler, *Submission no. 10*, p. 1; Mrs Judy Forsyth, *Submission no. 74*, p. 2.

21 MAPW (Victorian Branch), *Exhibit no. 50, Risk of cancer after low doses of ionising radiation: retrospective cohort study in 15 countries,* pp. 1, 5.

> in error. One of the bases of radiation protection adopted by the International Commission for Radiological Protection is that the risk rises linearly with the dose from zero and there is no dose below which there is no risk. This is known as the Linear / No-Threshold or LNT hypothesis. During the last two decades extensive epidemiological and other studies have shown that the risk–dose relationship follows a J-curve; low doses are indeed beneficial in direct contradiction to the LNT hypothesis. The effect is known as Radiation Hormesis. Hormesis is a general term which covers, inter alia, the beneficial effects of small doses of agents as diverse as red wine, aspirin, and sunshine, all of which are harmful at high doses. For radiation the risk does not exceed the benefit until the dose exceeds many tens of millisieverts per annum; by comparison, the natural background in much of Australia is approximately two millisieverts per annum.[22]

6.23 Emeritus Professor Peter Parsons, also a former President of AINSE, submitted that the LNT model does not accord with effects on human health since, it was claimed, low doses of radiation protect against the harmful health effects observed at high doses. Specifically, it was argued that a low dose of radiation may stimulate DNA repair and the immune system, leading to protection against the deleterious health effects of radiation at higher exposures.[23] Consequently, it was argued that the LNT hypothesis is not an appropriate basis for policies of radiation protection for low doses:

> … solid scientific evidence for radiation hormesis extends back for many years. In March 2005, the French Academy of Sciences and National Academy of Medicine issued a comprehensive report based upon extensive human and experimental data published over many decades. This clearly shows that the LNT model cannot be validly used for assessing risks to populations at very low doses of radiation. In fact, the report finds that the LNT model overstates the harmful effects of low dose radiation, and stresses the importance of this conclusion for radiation protection.[24]

6.24 It was noted that background radiation in Australia is around two mSv per year. In contrast, in geological outliers elsewhere in the world, background exposures can be over 50 times higher. It was argued that hormetic affects of ionising radiation extend over this elongated range,

22 Professor Ralph Parsons, *Submission no. 24*, p. 1. See also: Dr Clarence Hardy (Australian Nuclear Association), *Transcript of Evidence*, 16 September 2005, p. 60.

23 Professor Peter A Parsons, *Exhibit no. 23, Radiation Phobia and Phantom Risks*, p. 1.

24 Professor Peter A Parsons, *Submission no. 34*, p. 1.

although additional demographic research would help to quantify this conclusion. It was concluded that:

> Peaceful uses of radiation are therefore unlikely to be deleterious. While I do not have detailed knowledge of uranium mining and handling processes, radiation exposures are apparently towards the lower end of the hormetic range, implying no consequent biological or health reasons against the development of Australia's uranium resources.[25]

6.25 Professor Parsons also argued that the low risk associated with radiation exposure in nuclear power generation needs to be compared with the very serious health risks associated with global warming:

> This low-risk, or phantom-risk, situation should be viewed in the light of the progressive increase in greenhouse gases especially carbon dioxide, with their potential for climatic change and deleterious biological and health consequences.[26]

6.26 Despite these observations about radiation hormesis, ARPANSA stated that there is some epidemiological evidence that there are risks to health from lower doses of radiation, down to about 20 mSv. While the evidence of health effects from doses lower than this is uncertain, ARPANSA submitted that the 'safest view is that the effect is linear down to very low levels.'[27] That is, that the LNT hypothesis is the most prudent basis for radiation protection policy.

Australia's national regulatory framework

6.27 Established under the *Australian Radiation Protection and Nuclear Safety Act 1998* (ARPANS Act), ARPANSA is responsible for protecting the safety and health of people, and the environment, from the harmful effects of ionising and non-ionising radiation.

6.28 Among its other functions, ARPANSA seeks to:

- promote the uniformity of radiation protection and nuclear safety policy and practices across jurisdictions of the Commonwealth, the states and territories;
- provide advice to Government and the community on radiation protection, nuclear safety and related issues; and

25 *ibid.*, p. 2.

26 *ibid.*

27 Dr John Loy (ARPANSA), *Transcript of Evidence*, 16 September 2005, p. 77.

- undertake research and provide services in relation to radiation protection, nuclear safety and medical exposures to radiation;
- regulating radiation protection and nuclear safety aspects of all Commonwealth entities involved in radiation or nuclear activities and dealings; and
- lead the development of standards, codes of practice, guidelines and other relevant material to support radiation protection and nuclear safety throughout Australia.[28]

6.29 The ARPANS Act establishes the Chief Executive Officer (CEO) of ARPANSA (currently Dr John Loy) as the regulator of: the construction and operation of nuclear installations or prescribed radiation facilities; and dealings with radiation sources by 'controlled persons', which are Commonwealth entities (Commonwealth Department, agency or body corporate or Commonwealth controlled company) or Commonwealth contractors.

6.30 While ARPANSA does not have a direct role in regulation for radiation protection of current uranium mining in Australia, which is a responsibility of the state governments, it plays a major part in establishing the national framework for radiation protection applying, inter alia, to uranium mining and milling. Regulation for radiation protection in the mining and milling of uranium, as for radioactive waste management, takes place primarily through state/territory legislation. Radiation protection provisions are principally based upon national codes of practice and standards listed below, which in turn draw upon the international guidance described above.[29]

6.31 The ARPANS Act has established a Radiation Health and Safety Advisory Council and a Radiation Health Committee. The Council has the functions of identifying emerging issues and matters of major concern to the community and advising the CEO on them, while the Radiation Health Committee's functions are to:

- advise the CEO and the Council on matters relating to radiation protection;
- develop policies and to prepare draft publications for the promotion of uniform national standards of radiation protection;
- formulate draft national policies, codes and standards in relation to radiation protection for consideration by the Commonwealth, states and territories;

28 ARPANSA, *op. cit.*, p. 2.

29 *ibid.*, pp. 3, 4. Department of the Environment and Heritage, *Submission no. 55*, p. 22.

- from time to time to review national policies, codes and standards in relation to radiation protection to ensure that they continue to substantially reflect world best practice; and
- to consult publicly in the development and review of policies, codes and standards in relation to radiation protection.[30]

6.32 The members of the Radiation Health Committee are: the CEO of ARPANSA; a 'radiation control officer' from each state and territory; a representative of the Nuclear Safety Committee (also established under the ARPANS Act); a person to represent the interest of the general public; and up to two other members.

6.33 ARPANSA publishes a Radiation Protection Series to promote practices that protect human health and the environment from the possible harmful effects of radiation. The Series includes all radiation protection Codes of Practice, Safety Guides and Recommendations.

6.34 The Radiation Health Committee has recommended that the international radiation protection standards described above be adopted in Australia. The radiation protection principles and recommended standards for Australia are given in ARPANSA/National Occupational Health and Safety Commission (NOHSC) Radiation Protection Series Number One: *Recommendations for Limiting Exposure to Ionizing Radiation* and the *National Standard for Limiting Occupational Exposure to Ionizing Radiation* (republished 2002).[31]

6.35 In addition, a *Code of Practice and Safety Guide for Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing* (2005) provides a uniform framework for radiation protection in the mining and mineral processing industries in Australia, as well as for the management of radioactive waste arising from mining and mineral processing. Compliance with the Code is a requirement of authorisations issued by the NT Government or licences by the SA Government for the mining of uranium.[32] Dr Loy explained that the Code and Safety Guide refect the radiation protection principles outlined above:

> These are the need for justification of any practice involving exposure to ionising radiation; the optimisation of protection to ensure that exposures are as low as reasonably achievable, economic and social factors being taken into account—and this is

30 *ibid*., p. 3.

31 ARPANSA/NOHSC, *Recommendations for Limiting Exposure to Ionizing Radiation* and *National Standard for Limiting Occupational Exposure to Ionizing Radiation,* ARPANSA, Sydney, 2002, viewed 12 September 2006, <http://www.arpansa.gov.au/pubs/rps/rps1.pdf>.

32 ARPANSA, *Exhibit no. 67*, *Code of Practice and Safety Guide for Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing*.

called ALARA in the trade—and the limitation of individual doses.[33]

6.36 The transport of radioactive materials in Australia, including uranium, is addressed in a code of practice for the safe transport of radioactive material which adopts international transport requirements.

6.37 The UIC explained that responsibilities for administration of the Code are held by relevant agencies in the states and territories. This includes ensuring that the basic radiation exposure standards are complied with, day-to-day oversight of the general occupational health and safety requirements at mine sites, and regular reporting of monitoring results.[34]

6.38 In August 1999 the Australian Health Ministers' Conference (AHMC) endorsed the development of a *National Directory for Radiation Protection*, which is intended to provide an agreed overall framework for radiation safety, including both ionising and non-ionising radiation, together with clear regulatory statements to be adopted by the Commonwealth, states and territories. The Directory is intended to be the means for achieving uniformity in radiation protection practices between jurisdictions. The AHMC agreed that, following consideration and approval of the provisions, the regulatory elements of the Directory shall be adopted in each jurisdiction as soon as possible. The first edition of the Directory was approved by Ministers in July 2004. APANSA explained that it is hoped that the second edition of the Directory, planned for completion in 2006, will incorporate the new Code and deal with matters relevant to mining and minerals processing.[35] Dr Loy explained that:

> … it is hoped that the code and the safety guide will be adopted by states and territories through being included in … the National Directory for Radiation Protection, the second edition of which is being prepared.'[36]

33 Dr John Loy, *op. cit.*, p. 70.

34 UIC, *op. cit.*, p. 47.

35 See: ARPANSA, *National Directory for Radiation Protection – Edition 1.0*, ARPANSA, Melbourne, 2004, viewed 12 September 2006, <http://www.arpansa.gov.au/pubs/rps/rps6.pdf>; ARPANSA, *Submission no. 32*, pp. 6–7.

36 Dr John Loy, *loc. cit.*

Safety and health issues associated with the uranium industry in Australia

Radiation exposure to workers and the public from uranium mining

6.39 Mining and milling of uranium ores can lead to external and internal exposure of workers and the public to radiation. External exposure results from exposure to gamma rays from the radionuclides in the ore as it is mined and processed. Internal exposure arises from the inhalation of radon gas and its decay products and of radionuclides in the ore dust. ARPANSA explained that the extent of internal exposure will depend on the ore grade, the airborne concentrations of radioactive particles (which will vary with the type of mining operation and the ventilation) and the particle size distribution. The total internal exposure is generally of greater importance in underground mines than in open-pit mines.[37]

6.40 Several submitters opposed further uranium mining on the basis of radiation exposures and other health effects, with the MAPW (WA Branch) arguing that: 'The health consequences of uranium mining and nuclear power are on their own enough reason to spurn any increase in uranium mining/nuclear power.'[38] Mr Daniel Taylor claimed that: 'By allowing the mining and export of uranium, the Australian government is liberating vast quantities of radiation'.[39]

6.41 Dr Helen Caldicott claimed that, in the past, one third of uranium miners died of lung cancer:

> Uranium is radioactive. When you mine it, gamma radiation is emitted from the ore face. The men who mine uranium are exposed to gamma radiation, like X-rays, all the time, which can damage the ordinary bodies cells, to cause cancer, and damage the sperm. Uranium decays to a series of daughters, one of which is radon, which is an alpha emitter … If you inhale radon into your lung, it lands in the terminal air passage and can irradiate a few cells for many years—such that one-third of men who have, in the past, mined uranium around the world have died of lung cancer.[40]

6.42 Similarly, Ms Janet Marsh claimed that:

> The history of uranium mining is marked by a high incidence of lung cancer amongst miners, caused by unavoidable inhalation of

37 ARPANSA, *Submission no. 32*, p. 10. Dr G Mudd, *Exhibit no. 14, Uranium Mill Tailings Wastes in Australia*, p. 1.

38 MAPW (WA Branch), *Submission no. 8*, p. 2. See also: B K Daly-King, *Submission no. 3*, p. 1.

39 Mr Daniel Taylor, *Submission no. 85*, p. 17. See also: Mrs Judy Forsyth, *Submission no. 74*, p. 2.

40 Dr Helen Caldicott, *Transcript of Evidence*, 16 September 2005, pp. 2–3.

> radioactive radon gas, a highly radioactive gas given off by uranium deposits. There is no 'safe' dose of radon. Low dose ionizing radiation may well be the most single cause of cancer, birth defects and genetic disorders. There cannot be a 'safe' dose of radiation, there is no 'safe' threshold. Knowing this, then any permitted radiation is a permit to commit murder.
>
> Miners are also exposed to increased whole body radiation from the ore itself, causing cancers, sterility, and the genetic mutations which are detrimental to the species and passed on to countless future generations.[41]

6.43 The Public Health Association of Australia (PHAA) called for an end to uranium mining, stating that:

> The public health effects of radioactive (radon gas and air-borne radioactive particulates) and non-radioactive (eg molybdenum) contamination release from uranium mines has not been well studied yet … The PHAA has continuing concerns in the area of occupational health effects of uranium mining, including dose-related increase of risk of lung cancer (with no safe lower threshold of exposure), as this effect is synergistic with the effects of tobacco smoking. Non radiation related occupational health effects are similarly of concern. These are the same as for other mining in general and include injury, lung diseases and hearing loss.[42]

6.44 Similarly, Dr Gavin Mudd submitted that:

> … the release of radionuclides into the environment or changes in ionising radiation rates are still poorly quantified from uranium mining and milling, despite some improvements in recent years.[43]

6.45 The Gundjeihmi Aboriginal Corporation (GAC), representing the Mirarr people, Traditional Owners of the land on which the Ranger mine is located in the Northern Territory (NT), submitted that many of the Indigenous people near the mine are fearful that the bush food and land is being contaminated, and that people living downstream of the mine may face risks of contamination:

> A fundamental concern of the Mirarr is that uranium mining, both during operation and after rehabilitation, could lead to increased concentrations and loads of radionuclides released in the

41 Ms Janet Marsh, *Submission no. 2*, p. 1.

42 PHAA, *Submission no. 53*, p. 4.

43 Dr Gavin Mudd, *Exhibit no.18, Uranium mining in Australia: Environmental impact, radiation releases and rehabilitation*, p. 9.

> environment compared to pre-mining conditions, as well as possibly higher radiation rates due to the operations undertaken.[44]

6.46 In contrast, the Mr Ian Hore-Lacy, General Manager of the Uranium Information Centre (UIC), argued that:

> The industry has demonstrated that it can mine its uranium in a safe and environmentally responsible way, safe for the workers directly involved in the industry, and safe and with minimal environmental impact for the wider community.[45]

6.47 More specifically, the UIC argued that

- there have been more than 40 years of experience in applying international radiation safety regulations at uranium mines;
- Australian radiation safety regulations today are among the most comprehensive and stringent in the world;
- radiation doses at Australian uranium mines are well within regulatory limits; and
- uranium mining companies have taken active steps to reduce radiation doses wherever and whenever they can, and have voluntarily adopted the most recent international recommendations on dose limits long before they became a regulatory requirement.[46]

6.48 The UIC also argued that uranium mining does not discernibly increase the amount of radiation to which members of the public are exposed, including communities living near uranium mines.

6.49 The Association of Mining and Exploration Companies (AMEC) submitted that:

> Uranium mining companies have taken active steps to reduce possible radiation risk below international standards. Australian companies have voluntarily adopted the most recent international recommendations on safe radiation levels, published by the International Commission on Radiological Protection (ICRP), without waiting for a revision of the 1987 Health Code in Australia. Maximum actual exposure levels at Australian mines are about half those specified, and average levels are little more than from natural background.[47]

6.50 Similarly, Summit Resources submitted that:

44 GAC, *Submission no. 44*, p. 36.
45 Mr Ian Hore-Lacy (UIC), *Transcript of Evidence*, 19 August 2005, p. 89.
46 UIC, *Submission no. 12*, p. 45.
47 AMEC, *Submission no. 20*, p. 4.

> There is no evidence of safety as an issue. With over 50 years of uranium mining in Australia, and currently large underground mines operating, there has been full compliance with international radiation safety regulations and standards. Constant monitoring shows maximum actual exposure levels at Australian mines about half those specified and, average levels, little more than natural background.
>
> Importantly, to our knowledge, there has been no exposure of any mine or process plant personnel to unsafe radiation levels reported from Australia's uranium mines, or ongoing issues related to the health of current or former uranium mine workers.[48]

6.51 In terms of the actual radiation doses received by uranium mine workers, ARPANSA submitted that Australian data reported to the UNSCEAR for 1991–1994 and reported in UNSCEAR's report to the UN General Assembly in 2000, shows that the average annual effective dose to measurably exposed workers from uranium mining was 1.43 mSv, down from 4.11 mSv reported for 1985–1989. The world average reported for 1990–1994 was 5.39 mSv. The average annual effective dose to measurably exposed workers from uranium milling in Australia was 0.55 mSv for 1991–1994, down from 3.36 mSv for 1985–1989. The average dose reported worldwide for 1990–1994 was 1.25 mSv [49]

6.52 ARPANSA's Personal Radiation Monitoring Service (PRMS) has published the annual photon (i.e. external) doses monitored by the PRMS during 2004 for uranium mining, as listed in table 6.2. These results show that most uranium mine workers are receiving external radiation doses below 2 mSv with a maximum dose of 7.7 mSv for miners and 2.9 mSv for mill workers.

Table 6.2 Annual external radiation doses received by Australian uranium mine workers in 2004

Occupational Classification	**Quartile doses in microsieverts* (µSv)**			**Maximum dose (µSv)**	**Average dose (µSv)**	**No of wearers**
	Q1	**median**	**Q3**			
Uranium mine workers	260	900	1 710	7 770	1 125	583
Uranium mill workers		740	1 780	2 950	977	49
Miscellaneous		60	310	2 600	302	89

Source ARPANSA, *Submission no. 32*, p. 10.
* A micosievert (µSv) is one millionth of a Sievert.

48 Summit Resources Ltd, *Submission no. 15*, p. 33.
49 ARPANSA, *loc. cit.*

6.53 The UIC likewise submitted that radiation dose records compiled by mining companies have shown consistently that mining company employees are not exposed to radiation doses in excess of the regulatory limits. It was argued that the maximum dose received in Australia is about half the 20 mSv per year limit.

6.54 Radiation monitoring at the three operating uranium mines and in the surrounding areas shows the following radiation exposures for 2005:

- Ranger—the company's 250 designated employees (i.e. those employees in work categories that have the potential to exceed 5 mSv per year) received an average dose of 1.0 mSv during 2005. Non-designated employees received a maximum dose of 0.9 mSv in 2005. The exposure of residents of the Jabiru township and surrounding communities attributable to the mine was assessed as 0.04 mSv in 2005. The natural background radiation in the area is 2–3 mSv.[50]
- Olympic Dam—for the year 2005–06 the average dose to all designated employees in the mine was 3.5 mSv, while the highest dose received by an individual was 7.7 mSv. The exposure of residents of the Roxby Downs township attributable to the mine was calculated to be 0.018 mSv.[51]
- Beverley—the company's 247 employees received an average effective dose of 0.48 mSv in 2005, with the maximum dose received being 3.84 mSv. The dose to members of the public, who reside temporarily at the North Mulga Homestead and at the Beverley Accommodation Camp, was calculated at less than 0.01 mSv in 2005.[52]

6.55 The lower dose figures for Beverley are largely explained by the nature of the mining operation. Heathgate Resources, owners of the Beverley mine, explain that because Beverley is an in-situ leach (ISL) operation, the reduced dust and absence of exposure to ore means greatly reduced radiation exposure to workers and the public. Radon, the gas released into the atmosphere in underground and open cut mines is less prevalent in an ISL mine. This is because the ore is left in-situ and not exposed. There is no dust associated with the mining process and the ore is not crushed or

50 Energy Resources of Australia Ltd (ERA), *Social and Environmental Report 2005*, ERA, Darwin, 2006, p. 15, viewed 13 September 2006, <http://www.energyres.com.au/corporate/ERA_SE_Rep05ART.pdf>.

51 Information provided by Mr Richard Yeeles (BHP Billiton Ltd), 13 September 2006. Information available in the *Olympic Dam Radiation Protection Annual Report* (August 2006) provided to the South Australian Government.

52 Information provided by Ms Nicole Allen (Heathgate Resources Pty Ltd), 13 September 2006. See also: Heathgate Resources Pty Ltd, *Annual Environmental Report 2005*, Heathgate Resources Pty Ltd, Adelaide, 2005, p. 32, viewed 13 September 2006, <http://www.heathgateresources.com.au/contentsustainability.jsp?xcid=452>.

ground in processing. There are no tailings dams or waste rock-piles, nor are there any ore stockpiles at Beverley.[53]

6.56 The results for Australia's uranium mines indicates that, based on current data, exposure for workers is well under half the prescribed annual (average) limit for workers of 20 mSv. Furthermore, the radiation exposure for the public in the vicinity of the uranium mines is also far below the prescribed level of 1 mSv. Indeed, at Beverley, the nearest members of the public received a dose less than one hundredth the prescribed limit in 2005.

6.57 Furthermore, the UIC argued that doses are minimised by programs of eduction and training, as well as engineering design of mining and processing operations. Among the exposure management techniques to protect workers, UIC and the Minerals Council of Australia (MCA) pointed out that:

- dust is controlled, so as to minimise inhalation of gamma or alpha-emitting minerals. In practice, dust is the main source of radiation exposure in an open cut uranium mine and in the mill area;
- radiation exposure of workers is minimal in an open cut mine because there is sufficient natural ventilation to remove the radon gas. At Ranger (an open cut mine in the Northern Territory), the radon level seldom exceeds one percent of the levels allowable for continuous occupational exposure. In an underground mine, as at Olympic Dam in South Australia, a good forced-ventilation system is required to achieve the same result; and
- strict hygiene standards are imposed on workers handling uranium oxide concentrate (UOC). If UOC is ingested it has a chemical toxicity similar to that of lead oxide. In effect, the same precautions are taken as in a lead smelter, with use of respiratory protection in particular areas identified by air monitoring. At Olympic Dam, packing uranium oxide concentrate is automated, so no human presence is required.[54]

6.58 The Committee notes that in relation to the hazards associated with mining and milling uranium, the seminal Ranger Uranium Environmental Inquiry (the Fox Inquiry report) also concluded that:

> … we are quite satisfied that, if properly regulated and controlled according to known standards, those operations do not constitute

53 See: Heathgate Resources Pty Ltd, *Occupational Health and Safety*, viewed 13 September 2006, <http://www.heathgateresources.com.au/contentsustainability.jsp?xcid=356>.

54 UIC, *op. cit.*, p. 46; MCA, *Submission no. 36*, p. 18.

> any health hazard which is greater in degree than those commonly accepted in everyday industrial activities.[55]

6.59 Mr Andrew Crooks argued that the Australian Government should seek the adherence to international safety and environmental standards by those countries with uranium resources, so that the competitiveness of Australian producers is not threatened by an 'uneven playing field' in these matters.[56]

Risks associated with transport of uranium in Australia

6.60 As noted in the previous chapter, the transport of radioactive material in Australia, including uranium oxide, is conducted according to the Australian *Code of Practice for the Safe Transport of Radioactive Material* (2001), which effectively adopts international transportation requirements established by the IAEA.[57] The Code has been adopted by all the states and territories with the exception of Victoria, which ARPANSA notes is now moving to adopt the Code. Among other elements, the Code establishes: provisions about a radiation protection program; emergency response; quality assurance; compliance assurance; requirements for packages (e.g. transportation casks) and definitions of package types.[58]

6.61 Responsibility for enforcement of requirements for the physical protection (PP) of nuclear materials in Australia is the responsibility of the Australian Safeguards and Non-Proliferation Office (ASNO) under the *Nuclear Non-Proliferation (Safeguards) Act 1987*.

6.62 It was explained that under the *Convention on the Physical Protection of Nuclear Materials (1979)* (CPPNM), the IAEA has issued detailed guidance on the physical protection of nuclear materials and nuclear facilities. This guidance aims: 'To establish conditions which would minimize the possibilities for unauthorised removal of nuclear material and/or for sabotage.'[59] ASNO explained that Australia applies these requirements domestically and, through its bilateral safeguards agreements, requires customer countries to do the same. In July 2005 major amendments to the CPPNM were agreed that will strengthen the Convention and these amendments make it legally binding for States Parties to protect nuclear

55 Mr R W Fox, *Ranger Uranium Environmental Inquiry First Report*, AGPS, Canberra, 1976, p. 176.

56 Mr Andrew Crooks, *Submission no. 84*, p. 10.

57 See: ARPANSA, *Code of Practice for the Safe Transport of Radioactive Material,* 2001, viewed 29 August 2006, <http://www.arpansa.gov.au/pubs/rps/rps2.pdf>.

58 ARPANSA, *Submission no. 32*, pp. 5–6.

59 Cited in the Hon Alexander Downer MP, *Submission no. 33*, p. 9.

facilities and material in peaceful domestic use, storage as well as transport.[60]

6.63 It was explained that maintaining effective control over uranium requires that uranium is available only to authorised persons and that there are appropriate levels of PP at the mines themselves and the UOC stored there. ASNO sets out specific PP requirements and inspects the mines annually. ASNO also requires the uranium mines to adopt and report on specific procedures to ensure appropriate levels of physical protection for shipments of UOC from Australia to the port of unloading overseas. These procedures include checking on the physical condition of the containers and verifying the container and seal numbers at each port of unloading or transhipment.[61]

6.64 ASNO also submitted that it commissioned a thorough security risk review of uranium and its transport in Australia, the final report of which was expected in mid-2005. By virtue of its role as the provider of protective security advice to the Australian Government, ASIO was selected to conduct this work which included a National Security Threat Assessment. While it was expected that the ASIO report would bring forward some recommendations to further strengthen the protective security arrangements at the mines and during transport against currently perceived threats, the review identified no significant shortcomings. This result was said to be expected given that the current (terrorist) threat to UOC infrastructure remains (very) low and because UOC is weakly radioactive, meaning there would be minimal radiological consequences arising from any incident occurring during transport.[62]

6.65 Similarly, while the issue of the possible use of UOC in so-called 'dirty bombs' (radiological dispersal devices) is addressed more fully in chapter eight, ARPANSA and the Australian Nuclear Science and Technology Organisation (ANSTO) argued that because of the low levels of radioactivity in uranium oxide, use of natural uranium in such a device would not present any hazard to human health:

> … it is considered that the use of natural uranium, such as is processed and transported by the uranium mining industry, would not present any hazard to persons or the environment if used by terrorists with malicious intent.[63]

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60 IAEA, *States Agree on Stronger Physical Protection Regime*, Press Release, 8 July 2005, viewed 26 July 2006, <http://www.iaea.org/NewsCenter/PressReleases/2005/prn200503.html>.

61 The Hon Alexander Downer MP, *op. cit.*, p. 8.

62 *ibid*.

63 ARPANSA, *Submission no. 32*, p. 11; ANSTO, *Submission no. 29*, p. 20.

6.66 Furthermore, in relation to the hazards associated with transporting uranium oxide in Australia, Eaglefield Holdings submitted that:

> Yellowcake is actually about the least hazardous of all commodities that you can put on the back of a truck. By way of analogy, countless truck loads of sodium cyanide are shipped to the [Western Australian] goldfields each year. Each one of those truck loads of sodium cyanide would be 1,000 times more dangerous than a truck load of yellowcake … All it goes to show is that those who would oppose uranium mining in Western Australia have succeeded in the public relations war up until now. Yellowcake is almost entirely benign. It emits alpha radiation in very small quantities.[64]

6.67 Eaglefield went on to argue that:

> … moving a truck load of uranium around Western Australia is far safer than moving a truck load of smoke detectors … The active product in the smoke detector is an isotope called americium-241. Americium-241 was discovered during the Manhattan Project, which is why it is called americium. Americium-241 is a decay product of plutonium-241. Plutonium-241 is a product that is recovered from the reprocessing of high-level nuclear waste. Plutonium-241 can only be produced in a nuclear reactor.[65]

National radiation dose register and long-term health monitoring

6.68 Despite the radiation dose evidence presented above, which shows that doses received by uranium mine workers in Australia are well below the prescribed limit, some concern was expressed that Australia does not monitor the long-term health outcomes for uranium industry workers and other occupationally exposed persons. For example:

- MAPW (WA Branch) argued that Australia does not have a 'proper system of monitoring the long-term health of miners. The result is that we do not really know how much damage is being done.'[66]
- Dr Caldicott remarked that:

> None of our uranium miners have ever been followed up—from Rum Jungle, Mary Kathleen or anywhere else—to see,

64 Mr Michael Fewster (Eaglefield Holdings Pty Ltd), *Transcript of Evidence*, 23 September 2005, p. 32.

65 *ibid*., p. 34.

66 Dr Peter Masters (MAPW – WA Branch), *Transcript of Evidence*, 23 September 2005, p. 44.

> epidemiologically, if they have an increased incidence of cancer, and that is irresponsible on the part of our governments.[67]

- Mr John Schindler argued that 'no long-term health studies of workers who have been employed in uranium mining have been undertaken.'[68]

6.69 The Construction, Forestry, Mining and Energy Union (CFMEU), which noted that it does not represent any uranium mining workers, called for long-term monitoring of the health of uranium mine workers.[69] Similarly, the PHAA called for the establishment of a:

> … national register of all uranium industry workers who have been exposed to radiation to enable appropriate medical care and study of the occupational health effects of uranium mining and milling.[70]

6.70 Likewise, Friends of the Earth–Australia (FOE) argued that:

> There remains no government collection of records to assess long-term health impacts to workers. Given the health impacts now associated with asbestos mining, long-term health assessment should be a public duty of care.[71]

6.71 In relation to the monitoring of doses received by radiation workers, including designated uranium mine and mill workers, the *National Standard for Limiting Occupational Exposure to Ionising Radiation* states that:

> Records of doses assessed to have been received by an employee, including details of monitoring results and dose calculation methods, as required by the appropriate authority, shall be kept during the working life of the employee and afterwards for not less than 30 years after the last dose assessment and at least until the employee reaches, or would have reached, the age of 75 years. When an operation terminates, the employer shall pass to the appropriate authority the retained records of doses assessed to have been received by employees and any other records specified by the appropriate authority.[72]

6.72 ARPANSA explained that regulatory agencies in each state and territory accord with the national standard, requiring uranium mining companies

67 Dr Helen Caldicott, *op. cit.*, p. 3.

68 Mr John Schindler, *Submission no. 10*, p. 1. See also: MAPW (Victorian Branch), *Submission no. 30*, p. 15. See also: Alice Action Executive Committee, *Submission no. 79*, p. 1.

69 CFMEU, *Exhibit no. 11, Submission by CFMEU to Senate Environment Committee*, p. 7.

70 PHAA, *Submission no. 53*, p. 4.

71 FOE, *Submission no. 52*, p. 9.

72 ARPANSA/NOHSC, *op. cit.*, p. 75.

to keep dose records for employees for not less than 30 years. For example, in jurisdictions with operating mines:

- In South Australia, Regulation 26(4) of the Ionizing Radiation Protection and Control (Ionising Radiation) Regulations 2000 (made under the *Radiation Protection and Control Act 1982*) provides that a specified employer must not destroy or dispose of any records kept under the regulation (which includes records of the personal radiation exposure for each radiation worker) except with the approval of the Minister. The South Australian regulator advised that to date, the Minister has not received an application from any specified employer to destroy such records.
- In the Northern Territory, section 26 of the *Radiation (Safety Control) Act 1999* requires employers of radiation workers to keep records of radiation doses received by each of its radiation workers. Employers of radiation workers must also comply with the *National Standard for Limiting Occupational Exposure to Ionizing Radiation*, requiring that records of doses received by employees must be kept during the working life of the employee and afterwards for not less than 30 years after the last dose assessment and at least until the employee reaches the age of 75.[73]

6.73 ARPANSA stated that collection of up-to-date data for total radiation doses received by uranium mine workers is complicated by the fact that the dose a miner receives is made up the direct dose from the gamma rays from the radioactive material and, second, the internal dose from the inhalation of radon gas and from inhaling or ingesting dust. The internal doses are difficult to measure. However, this data is collected by the companies concerned and ARPANSA's practice is to approach the companies 'every five years or so' to collate the data.[74]

6.74 BHP Billiton noted that it has 'quite an extensive program of monitoring employees' at Olympic Dam, particularly those designated employees exposed to radiation in the course of their duties.[75] The company provides relevant information to government every quarter for the designated employees.

6.75 However, BHP Billiton stated that regular monitoring of workers' health was not necessary:

> The radiation limits are set at a point that that is not required. If you are below those limits, the risk factor is equivalent to being a

73 ARPANSA, *Submission no. 32.1*, p. 2.

74 Dr John Loy, *op. cit.*, p. 75.

75 Dr Roger Higgins (BHP Billiton Ltd), *Transcript of Evidence*, 2 November 2005, p. 19.

> bricklayer or a painter. The same would apply if you were a bricklayer and you ceased employment with a construction company. Would the construction company then follow you for the rest of your life? The same theory applies. I think the discussions come up every two to five years, but there has been no recent discussions on that.[76]

6.76 In addition, BHP Billiton argued that it would be administratively very complex to track former employees:

> It is quite an administrative nightmare to try and track people, even while they are working with us … For them to be tracked when they leave employment and disappear to wherever in the world would be very difficult exercise.[77]

6.77 For its part, the MCA submitted that the minerals industry is working closely with the Minerals Industry Safety and Health Centre (MISHC) in determining the practicality of tracking the health of workers in the minerals industry.[78]

6.78 The Committee notes that the establishment of a national radiation dose register for occupationally exposed persons has previously been proposed to the Federal Government and not implemented. Dr Loy explained that the states opposed the establishment of such a register:

> … the states recommended through the Radiation Health Committee that we not proceed with such a register. I think fundamentally their view was based upon the fact that what we know of the doses is such that they are not likely to lead to any further knowledge of the effects of radiation on human health because the level of dose is low and the number of workers is relatively small.[79]

6.79 ARPANSA submitted that the Radiation Health Committee did not support the development of such a register but agreed with the collection and supply of data to UNSCEAR:

> The Committee's view was formed on the basis that the level of doses being received and likely to be received in Australia, together with the number of exposed workers, meant that there was no value in a register from the point of view of any study of health effects.[80]

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76 Mr Steve Green (BHP Billiton Ltd), *Transcript of Evidence*, 2 November 2005, p. 19.
77 *ibid*., pp. 19–20.
78 MCA, *op. cit*., p. 17.
79 Dr John Loy, *op. cit*., p. 76.
80 ARPANSA, *op. cit*., p. 10.

6.80 ARPANSA noted, however, that a radiation dose register could have merit and may be worth revisiting:

> On the other hand, you could argue that, for a sense of security and support for workers in the uranium mining industry, a dose registry would be something that would be appropriate. We would certainly be open to the suggestion that we should go back and revisit that, focusing on mining workers and perhaps some other workers who receive small but measurable doses, rather than having a national dose register for people who work very briefly with radiation and do not get very much exposure at all. I think we need to narrow down the terms of reference a little bit to make it manageable.[81]

6.81 The Committee notes the various views put to it in relation to the need for, and potential merits of, establishing a national radiation dose register and long-term health monitoring of occupationally exposed persons in Australia. The Committee accepts that the doses received by occupationally exposed workers in Australia are small and are highly unlikely to be injurious to health. However, there remains the important issue of public perceptions of the safety of the industry and its impacts on workers exposed to radiation. The matter of providing assurance to workers themselves is also important.

6.82 In view of the potential expansion of the industry and the claims, however erroneous, that the health of workers' is being compromised by uranium mining and the nuclear industry more generally, the Committee recommends that a national radiation dose register be established. The Committee further recommends that the long-term health outcomes of occupationally exposed workers, or an appropriate sample of such workers, be monitored. Such a monitoring regime could involve periodic medical assessments over the lives of cohorts of occupationally exposed workers. In this way, the Committee hopes not only to provide assurance to workers and the public at large, but also to definitively answer claims—which the Committee is confident are entirely mistaken—that current radiation exposures are harming workers.

6.83 The Committee accepts that the scope of the register and health monitoring program would need to be carefully considered in order to ensure manageability. For example, the Committee's intention is not to include workers engaged in medical uses of radiation. However, the Committee urges that all uranium mine workers and other occupationally exposed workers, including workers at Lucas Heights and any other

81 Dr John Loy, *loc. cit.*

nuclear facilities that may be established in Australia over time, be included in the monitoring program. It is hoped that these initiatives can build on monitoring currently undertaken.

6.84 The Committee notes the observation by BHP Billiton that a long-term health monitoring program could be administratively complex. The Committee wishes to minimise any additional burdens on industry and therefore recommends that the monitoring program be funded jointly by governments and industry. The Committee also urges that industry be closely consulted as to the operation of the program.

Recommendation 3

To provide greater assurance to workers and the public at large, and also to definitively answer claims—which the Committee is confident are entirely mistaken—that current radiation exposures are harming workers, the Committee recommends that the Australian Government, in conjunction with state governments and industry, establish:

- **a national radiation dose register for occupationally exposed workers; and**
- **a system of long-term monitoring of the health outcomes for workers occupationally exposed to radiation in uranium mining, associated industries and nuclear facilities.**

The Committee further recommends that the Australian Government:

- **jointly fund the health monitoring program with industry; and**
- **periodically publish the monitoring data, indicating any link between radiation exposures and health outcomes for these workers.**

Incidents at Australia's uranium mines

6.85 Some submitters drew the Committee's attention to two incidents that took place at Ranger during 2004, where the health of workers and members of the public may have been affected. One incident related to the exposure of some workers to contaminated drinking water (potable water contamination incident) and the other involved earth moving equipment with contaminated material leaving the mine site (radiation clearance incident).[82]

82 ACF, *op. cit.*, p. 20.

6.86 The GAC, ACF and others argued that such incidents are indicative of 'systematic underperformance and non compliance' by the company concerned, Energy Resources of Australia Ltd (ERA).[83] Mr Justin Tutty further alleged that the level of monitoring and compliance at Ranger is 'vastly unsatisfactory' and the CFMEU submitted that the union is concerned about negligence and health and safety practices at uranium mines more generally.[84]

6.87 The Australian Government Department of the Environment and Heritage (DEH) submitted that monitoring of radiation exposure to workers has shown that at Ranger dose levels have been generally decreasing with time and typical levels are less than 10 per cent of the statutory limit, with only three incidents of any note over the life of the mine. In 1982 a product packing incident created a dust hazard where the radiation dose may have exceeded the limit for one or both of the affected workers in the area. However, such exposure did not result in any detectable injury to either worker but elevated exposure levels are interpreted as possibly contributing to a statistical increase in lifetime risk of contracting cancer. During the water contamination incident in 2004 a number of Ranger workers were exposed to contaminated water through ingestion and/or showering. However investigations concluded that resultant radiological doses were below statutory limits.[85]

6.88 DEH further submitted that, generally, doses to members of the public have been very small, approaching the limits of detection of monitoring equipment. However, as noted above, in 2004 earthmoving equipment left the Ranger site without adequate radiation clearance checking, resulting in contamination of the workplace of a member of the public and exposure of that person and his children to radiation doses that were conservatively estimated to be at or near the statutory dose limit for members of the public. This incident was of concern from a regulatory perspective. However, DEH argued that the radiation doses received by members of the public did not represent a significant health risk.[86]

6.89 Mr Harry Kenyon-Slaney, Chief Executive of ERA, explained that while the accidents were unacceptable, they did not result in any negative impacts to human health:

> In both cases, it has been confirmed and accepted that there has been no impact on anybody's health as a consequence of those

83 *ibid.*, p. 21; GAC, *op. cit.*, p. 58.
84 Mr Justin Tutty, *op. cit.*, pp. 5–6; CFMEU, *op. cit.*, p. 2;
85 DEH, *Submission no. 55*, pp. 22–23.
86 *ibid.*

> incidents, but we took them extremely seriously. Frankly, they were unacceptable.[87]

6.90 The two incidents were investigated by the Supervising Scientist, the NT Department of Business, Industry and Resource Development and the mining company. The reports of the Supervising Scientist's investigations were tabled in the Senate on 30 August 2004. The Australian Government Minister for Industry, Tourism and Resources subsequently wrote to ERA requiring it to fulfil a series of conditions. Progress towards compliance with the conditions was assessed during audits by ANSTO and ARPANSA in September 2004, November 2004 and January 2005. Those audits have indicated satisfactory progress. ERA voluntarily shutdown operations following the tabling of the reports to allow it to focus on implementation of the Minister's requirements.[88]

6.91 The Supervising Scientist's *Annual Report 2004–2005* states that in March 2005 the Minister wrote to ERA to advise that, on the basis of the audit reports by ANSTO and ARPANSA, ERA had, with the exception of the implementation of the workplace safety standard AS4801, complied with all of the Minister's conditions.[89] ERA's *2005 Annual Report* states that in September 2005 the company achieved certification of its health and safety management system to AS4801.[90]

6.92 In relation to the audit findings and conditions to which ERA was asked to comply, Mr Kenyon-Slaney noted that:

> We went through a process of audits that were set up by the Commonwealth government after the reports by the Supervising Scientist were issued. It was a very comprehensive audit process, with which we were happy to comply and, by the end of last year, we had met all three of the audits that were set up by the Department of Industry, Tourism and Resources. As part of the audit process and as confirmation of a lot of work we were already doing, we put in place a whole series of new procedures and practices which strengthened our compliance with our water systems in the plant and the radiation clearance procedures. Those have been signed off and given a ringing endorsement by ARPANSA.[91]

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87 Mr Harry Kenyon-Slaney (ERA), *Transcript of Evidence*, 24 October 2005, p. 53.

88 DEH, *loc. cit.*

89 Supervising Scientist, *Annual Report 2004–2005*, DEH, Darwin, 2005, pp. 34–35.

90 ERA, *2005 Annual Report*, ERA, Darwin, 2006, p. 13, viewed 26 September 2006, <http://www.energyres.com.au/corporate/era-ar-2005.pdf>.

91 Mr Harry Kenyon-Slaney, *loc. cit.*

Radiation exposure from the nuclear fuel cycle

6.93 Several submitters expressed intense opposition to the nuclear power industry on the basis of the risks to public health and the alleged health effects of the industry's operations, and particularly the claimed hereditary mutagenic and carcinogenic effects of nuclear materials. For example, Dr Helen Caldicott argued that the nuclear industry causes cancer and that exporting uranium is tantamount to 'exporting disease':

> The nuclear industry is about cancer. We are talking about nuclear waste that lasts for up to half a million years, which at the moment is seeping out of containers all over the United States … The incidence of cancer in those areas is increasing. You cannot cure cancer, generally—not adult cancer … That is the legacy that this industry will bequeath to all future generations, and we are not the only creatures that have genes. All creatures have genes, all creatures get cancer and all creatures get genetic disease … We inhabit the planet with 30 million other species … We should not be mining uranium, because what we are actually doing is exporting disease.[92]

6.94 As noted in the previous chapter, Dr Caldicott also submitted that:

> Nuclear reactors consistently release millions of curries of radioactive isotopes into the air and water each year. These releases are unregulated because the nuclear industry considers these particular radioactive elements to be biologically inconsequential. This is not so.[93]

6.95 The Uniting Church in Australia (Synod of Victoria and Tasmania) asserted that risks from nuclear power and the fuel cycle to workers and the public are 'too high' and that:

> Workers in nuclear facilities (including mines, mills and storage sites), and the public in close proximity to these facilities, are experiencing serious health problems such as cancers, leukaemia, and genetic defects.[94]

6.96 The MAPW (Victorian Branch) argued that nuclear power produces radioactive materials that require long time frames to lose their toxicity

92 Dr Helen Caldicott, *op. cit.*, pp. 4–5.
93 Dr Helen Caldicott, *Exhibit no. 24, Nuclear power is the problem, not the solution*, p. 1.
94 Uniting Church in Australia (Synod of Victoria and Tasmania), *Submission no. 40*, p. 12.

and 'these are … simply materials that should not be added to the human environment where they can pose such a long-term risk.'[95]

6.97 Mr Justin Tutty, Dr Caldicott and others also claimed that routine releases of radioactive gases into the air and water from nuclear reactor operations, which were discussed in the previous chapter, pose an unsustainable burden on public health:

> … it must be recognised that nuclear power stations represent an unsustainable burden on both public health and the immediate environment due to the deliberate release of radiation into the skies and surrounding waters.[96]

6.98 In contrast, other submitters argued that the amount of radiation exposure to the public from uranium mines and the nuclear power industry as a whole is insignificant when compared to natural radiation exposure. For example, Dr Clarence Hardy of the Australian Nuclear Association (ANA) argued that:

> I would say that there is so much radiation coming from the sun—and from the whole universe, not just the sun … to the earth. There is a radiation field entering the earth. There is also basic radiation coming from the earth, from all of the radioactive materials in the earth. That amount of radiation on the earth is so significant that any tiny amount from the uranium industry is absolutely insignificant. You are getting all of this solar radiation … from the sun, plus all of the cosmic radiation and gamma radiation, as well as visible radiation. That flux on the earth is so enormous that the amount that any uranium mine or nuclear power plant is generating is totally insignificant. I do not think it is a factor to be taken into account at all.[97]

6.99 The MCA submitted that: 'It is recognised by government authorities that the major exposure to radiation for members of the public arises in the medical and dental sectors.'[98]

6.100 In a report to the UN General Assembly in 2000, UNSCEAR reviewed the worldwide doses from nuclear power production for the period of the mid 1990s. This followed similar studies conducted over previous assessment periods back to the early 1970s. Exposures were modelled for each stage of

95 Associate Professor Tilman Ruff (MAPW–Victorian Branch), *Transcript of Evidence*, 19 August 2005, p. 25.

96 Mr Justin Tutty, *Submission no. 41*, p. 5; Uniting Church in Australia (Synod of Victoria and Tasmania), *loc. cit.*; Dr Helen Caldicott, *Exhibit no. 24, Nuclear power is the problem, not a solution*, p. 2.

97 Dr Clarence Hardy (ANA), *Transcript of Evidence*, 16 September 2005, p. 59.

98 MCA, *loc. cit.*

the nuclear fuel cycle (including uranium mining and milling) and estimates of the doses were made for workers and for the public. The material below summarises the report's findings for exposures to employees and to the public from fuel cycle industries and their effluents.

Occupational exposures

6.101 UNSCEAR examined doses to workers at each stage of the nuclear fuel cycle and reported doses for the following categories of workers: uranium mining, uranium milling, uranium enrichment and conversion, fuel fabrication, reactor operations, fuel reprocessing, waste handling and disposal, and research and development activities associated with the nuclear fuel cycle.

6.102 There were 800 000 workers in the nuclear industry monitored in the most recent UNSCEAR study and the average doses received by these workers are listed in table 6.3. The total average annual effective dose to monitored workers was 1.75 mSv. This continued a downward trend evident in employee exposures reported by UNSCEAR in previous assessments. The total annual average effective dose to monitored workers in 1977–1979 was 4.1 mSv, in 1980–1984 it was 3.7 mSv, and in 1985–1989 it was 2.9 mSv.[99]

Table 6.3 Worldwide occupational exposures from nuclear power production (1990–1994)

Category	Number of workers	Average annual effective dose to monitored workers (mSv)
Uranium mining	69 000	4.5
Uranium milling	6 000	3.3
Uranium enrichment and conversion	13 000	0.12
Fuel fabrication	21 000	1.03
Reactor operation	530 000	1.4
Fuel reprocessing	45 000	1.5
Research in the fuel cycle	120 000	0.78
Total	*800 000*	*1.75*

Source ARPANSA, *Submission no. 32*, p. 19.

99 See: UNSCEAR, *Sources and Effects of Ionizing Radiation, Report to the UN General Assembly, 2000, Volume I, Annex E,* UNSCEAR, Vienna, 2000, p. 584, viewed 14 September 2006, <http://www.unscear.org/docs/reports/annexe.pdf>.

6.103 Among its findings, UNSCEAR noted that there had been a significant reduction in the doses to uranium mining and milling workers, with doses falling by a factor of three over the previous 20 years. These results follow a worldwide decline in underground mining activity and more efficient mining operations. Similarly, the dose to workers in reactor operations, which varies significantly for different types of reactors, had likewise fallen by a factor of three over the previous 20 years to 1.4 mSv in 1990–1994.[100]

6.104 UNSCEAR calculated the average annual doses to workers in various other occupations exposed to ionising radiation, which are listed in table 6.4. The occupations are classified by whether workers are exposed to artificial sources of radiation, which arise from human activities (e.g. the nuclear power industry and medical uses of radiation), or natural sources (e.g. aircrew in civil aviation and radon exposure in workplaces). The data shows that, as noted above, the average annual effective dose for those employed in nuclear power production is 1.75 mSv. However, the average dose to workers exposed to natural sources of radiation is slightly greater at 1.8 mSv and, of these, aircrew in civil aviation are exposed to an average 3.0 mSv (from cosmic radiation) and radon exposure in some above-ground workplaces is estimated to average 4.8 mSv.[101]

6.105 In the Australian context, the Committee's attention was drawn to the findings of a study of mortality rates among nuclear industry workers at ANSTO's Lucas Heights Science and Technology Centre, published in the Australian and New Zealand Journal of Public Health in June 2005. The project, which was part of an international study on nuclear industry workers from 14 countries undertaken by the International Agency for Research on Cancer, involved 7 076 workers employed at ANSTO's Lucas Heights facilities between 1957–1998. The project's objective was to assess whether the Lucas Heights workers have different levels of mortality from the NSW and Australian populations. It was found that all-cause mortality was 31 per cent lower than the national rates and all-cancer mortality was 19 per cent below the NSW rate. Of 37 specific cancers and groups of cancers examined, statistically significant excesses relative to NSW mortality rates were observed only for one type of cancer (pleural cancer, which is strongly related to asbestos exposure and unrelated to ionising radiation).[102]

100 ARPANSA, *op. cit.*, p. 17.

101 UNSCEAR, *op. cit.*, p. 647.

102 Information provided by S Thorogood (ANSTO), 13 February 2006. ANSTO, *Media Release,* 'ANSTO Mortality Below National Level: Latest Report', 1 June 2005, viewed 22 September 2006, <http://www.ansto.gov.au/info/press/2005/anstomedia013_010605.pdf>.

Table 6.4 Worldwide occupational radiation exposures (1990–1994)

Source / practice	Average annual effective dose to monitored workers (mSv)
Artificial sources	
Nuclear fuel cycle (including uranium mining)	1.75
Industrial used of radiation	0.51
Defence activities	0.24
Medical uses of radiation	0.33
Education/veterinary	0.11
Total from artificial sources	*0.6*
Enhanced natural sources	
Air travel (aircrew)	3.0
Mining (other than coal)	2.7
Coal mining	0.7
Mineral processing	1.0
Above ground workplaces (radon)	4.8
Total from natural sources	*1.8*

Source UNSCEAR, *Sources and Effects of Ionizing Radiation, Report to the UN General Assembly*, *2000*, *Volume I*, p. 8.

6.106 ANSTO also notes that the average worker at Lucas Heights receives a dose of 1 mSv per year and those working in the most active areas receive less than 10 mSv, well below internationally accepted levels.[103]

Exposures to the public

6.107 The dose received by a whole population that is exposed to radiation is referred to as the 'collective effective dose' (or simply 'collective dose') and is calculated by adding the effective doses received by all of the people in the defined population. The unit of collective dose is the man Sievert (man Sv).[104] To evaluate the total impact of radionuclides released at each stage of the nuclear fuel cycle, UNSCEAR presents normalised collective effective doses per unit electrical energy generated, expressed as man Sv per gigawatt year $(GWa)^{-1}$.

6.108 The normalised collective doses to members of the public from radionuclides released in the various stages of the nuclear fuel cycle are

103 ANSTO, Media Release, *Largest Study of International Radiation Workers: Standards Meet the Mark*, 29 June 2005, viewed 22 September 2006, <http://www.ansto.gov.au/info/press/2005/anstomedia019_290605.pdf>.

104 IAEA, *op. cit.*, p. 12.

summarized in table 6.5. Doses to the public are divided into the local/regional component and a global component.

Table 6.5 Normalised collective effective dose to members of the public from radionuclides released in effluents from the nuclear fuel cycle (1995–1997)

Source	Normalised collective effective dose (man Sv(GWa)$^{-1}$)
Local and regional component	
Mining	0.19
Milling	0.008
Mine and mill tailings (releases over five years)	0.04
Fuel fabrication	0.003
Reactor operation Atmospheric Aquatic	 0.4 0.04
Reprocessing Atmospheric Aquatic	 0.04 0.09
Transportation	<0.1
Total (rounded)	*0.91*
Solid waste disposal and global component	
Mine and mill tailings (releases of radon over 10 000 years)	7.5
Reactor operations Low level waste disposal Intermediate level waste disposal	 0.00005 0.5
Reprocessing solid waste disposal	0.05
Globally dispersed radionuclides (truncated to 10 000 years)	40
Total (rounded)	*50*

Source UNSCEAR, *Sources and Effects of Ionizing Radiation, Report to the UN General Assembly, 2000, Volume I, Annex C*, p. 284.

6.109 The total local and regional collective dose in UNSCEAR's two most recent assessment periods is 0.9 man Sv (GWa)$^{-1}$. The largest part of this dose is received within a limited number of years after the releases and is mainly due to the normal operation of nuclear reactors and mining operations. The largest doses come from the continued use of some older reactors, with doses from modern Pressurised Water Reactors (PWR) about one fifth of those reported.[105]

105 UNSCEAR, *Sources and Effects of Ionizing Radiation, Report to the UN General Assembly, 2000, Volume I, Annex C,* UNSCEAR, Vienna, 2000, p. 190, viewed 15 September 2006, <http://www.unscear.org/docs/reports/annexc.pdf>; ARPANSA, *op. cit.*, p. 15.

6.110 The global dose, which is estimated for 10 000 years, amounts to 50 man Sv $(GWa)^{-1}$. After 100 years of nuclear power production, and assuming present generating capacity is maintained, the maximum annual *individual* dose to the global population would be less than 0.2 μSv (i.e. 0.0002 mSv, as listed in table 6.1). This dose combines both the local and regional component, and exposure to globally dispersed radionuclides. The dose is trivial in comparison to natural background radiation.[106]

6.111 According to UNSCEAR and submitted to the Committee by ARPANSA, the main contribution to the public dose is from globally dispersed carbon-14 (from reactor operations and reprocessing), due to its long half-life and the fact that it becomes part of the carbon cycle through the dispersion of carbon dioxide in the atmosphere.[107]

6.112 After carbon-14 emissions, the next largest contributor to the collective dose is attributable to radon emanating from uranium mine tailings. Tailings at uranium mines, which contain the long-lived radionuclides radium-226 and thorium-230, generate radon gas. The collective dose per unit energy produced is estimated to be 0.19 man Sv $(GWa)^{-1}$ during operation of the mine and the mill, and 7.5 man Sv $(GWa)^{-1}$ for an assumed 10 000 year period of constant, continued release from residual tailings piles.[108]

6.113 These estimates relate to mines operating in the mid 1990s and UNSCEAR notes that in an alternative study, site-specific data relating to currently operating mills in four countries (Australia, Canada, Namibia and Niger) were used. This study, which used a more detailed dispersion model than UNSCEAR and local and regional population densities applicable to the mines in question were much lower than those estimated by UNSCEAR, which take into account high population densities reported in areas surrounding mills in China. ARPANSA submitted that the tailings management practices employed at mines today are more rigorous than have been applied historically and soil covers to reduce radon emissions are more substantial than employed in the past. As a result, for currently-operating mines the alternative study found that the collective dose from radon emissions is five times lower at 1.4 man Sv $(GWa)^{-1}$ over a 10 000 year period. ARPANSA submitted that this value would be more representative of new and future mines operated in accordance with current international practice.[109]

106 UNSCEAR, *op. cit.*, pp. 190, 194.
107 ARPANSA, *loc. cit.*
108 *ibid.*, pp. 13, 20.
109 UNSCEAR, *op. cit.*, pp. 181–182.

6.114 UNSCEAR notes that the trends in collective doses per unit electrical energy generated show significant decreases since the 1970s, which is largely attributable to reductions in the release of radionuclides from reactors and fuel reprocessing plants. The components of normalized collective dose have decreased by more than an order of magnitude for releases from reprocessing plants, by a factor of seven for releases from reactors, and by a factor of two for globally dispersed radionuclides, compared to the earliest assessment period, 1970–1979.[110]

6.115 ARPANSA concluded that it is possible to estimate the future impact of nuclear power production for a PWR using uranium from a current uranium mine operating to international best practice. In this situation the contribution from mining and reactor operations would fall from 14 man Sv $(GWa)^{-1}$ to 7 man Sv $(GWa)^{-1}$. The overall effect of nuclear power production including fuel reprocessing would then be approximately 12 man Sv $(GWa)^{-1}$ in the hundredth year of practice. This would result in less than one additional fatal cancer from radiological exposures based on current risk factors. This would equate to an individual effective dose of approximately 0.3 µSv, or less than one thousandth of the dose received due to naturally occurring radionuclides.[111]

6.116 In sharp contrast, FOE made the allegation that some 80 000 fatal cancers will arise from the routine emissions from the nuclear fuel cycle.[112]

6.117 In response to the allegation that the emission of radioactive gasses from nuclear power plants is unregulated, ARPANSA noted that, internationally, regulatory agencies regulate in terms of the total dose to the public near to the facility and not necessarily by specific radionuclides, such as iodine-131. ARPANSA also argued that the discharge from Lucas Height exposes the people nearby to a trivial dose that is well below international best practice.[113]

6.118 Similarly, ANSTO stated that:

> If you stood on the boundary of Lucas Heights for 24 hours a day, 365 days a year and breathed it all in, you would get about the same dose as flying from Sydney to Melbourne … We have that data. It is measured data, and it has been around for years.
>
> The other issue—and the reason she [Dr Caldicott] makes that claim—is that nuclear power plants do not produce iodine because

110 *ibid*., p. 190.

111 ARPANSA, *op. cit*., p. 20.

112 FOE et. al., *Exhibit no. 71, Nuclear Power: No Solution to Climate Change*, section 5.2 Comparing alternative energy sources.

113 Dr John Loy, *op. cit*., pp. 73–74.

> they do not produce radioisotopes for medicine, and iodine is one of those. So it is a spurious type of argument. The key issue is: what dose might people receive? The whole concept of radiation protection takes into account where it comes from, and you can compare it dose for dose—and dose for dose Lucas Heights produces almost nothing.[114]

Nuclear safety

6.119 Some submitters pointed to alleged hazards of current nuclear reactors, evolutionary reactor designs and future reactor concepts. For example, the ACF pointed to a report commissioned by Greenpeace which asserted, inter alia, that:

- all operational reactors have very serious inherent safety flaws which cannot be eliminated by safety upgrading;
- a major accident in a light-water reactor could lead to catastrophic radioactive releases;
- new reactor lines are envisaged which are heralded as fundamentally safe. However, apart from having their own specific safety problems, those new reactors would require enormous sums for their development;
- life extensions to reactors leads to the degradation of critical components and the increase of 'severe' incidents;
- de-regulation of electricity markets has pushed nuclear utilities to decrease safety-related investments and limit staff; and
- reactors cannot be sufficiently protected against a terrorist threat.[115]

6.120 Mr Justin Tutty also alleged that the risk of catastrophic radioactive releases is an unavoidable feature of nuclear power generation.[116] Similarly, the Arid Lands Environment Centre (ALEC) argued that: 'The spectre of catastrophic failure still looms large' and there are hazards at all steps of the nuclear energy chain, particularly in reactors and reprocessing plants.[117] Likewise, Mr John Klepetko alleged that:

114 Dr Ron Cameron (ANSTO), *Transcript of Evidence*, 13 October 2005, p. 16.
115 ACF, *op. cit.*, p. 15.
116 Mr Justin Tutty, *op. cit.*, p. 5.
117 ALEC, *Submission no. 75*, p. 3.

The history of uranium's role in serious accidents and long lasting legacies of these accidents are a stark reminder of why widespread uranium use should not be pursued in the future.[118]

6.121 Mr David Addison argued that the potential damage a nuclear accident could cause is high enough in consequence for the burden of proof to be on those who promote nuclear energy to prove its safety:

I appreciate that safety technology and procedures supportive [of] nuclear energy has most likely improved over the last decade. At the same time I still believe that the potential damage of a nuclear accident and the release of radioactive materials are high enough in consequence for the burden of proof to be on those who advance nuclear energy as a solution to our energy requirements, rather than on those who oppose.[119]

6.122 MAPW (WA Branch) specifically pointed to the risks of reactors being built in Indonesia and the possibility of accidents 'with the prospect of the fallout from any meltdown being carried by the prevailing winds … towards Australia.'[120]

Reactor safety

6.123 In response to these concerns, other submitters emphasised that the risks from western nuclear power plants, in terms of the consequences of an accident or terrorist attack, are minimal compared with other commonly accepted risks.[121]

6.124 It was argued that nuclear power has proven to be an extremely safe form of power generation. In the 50-year history of civil nuclear power generation, which spans more than 12 000 cumulative reactor years of commercial operation in 32 countries, there have been two significant accidents to nuclear power plants:

- Three Mile Island (TMI) in the US in 1979, where the reactor was severely damaged but the plant design contained the radiation and there were no adverse health and environmental consequences; and

118 Mr John Klepetko, *Submission no. 86*, p. 1.
119 Mr David Addison, *Submission no. 59*, p. 1.
120 Dr Peter Masters (MAPW – WA Branch), *Transcript of Evidence*, 23 September 2005, p. 36.
121 UIC, *Safety of Nuclear Power Reactors*, Nuclear Issues Briefing Paper No. 14, viewed 19 September 2006, <http://www.uic.com.au/nip14.htm>.

- Chernobyl in Ukraine in 1986, where the destruction of the reactor by explosion and fire killed 31 workers, with the death toll subsequently rising to about 56.[122]

6.125 While there have been other incidents at nuclear reactors, the Chernobyl accident, which is discussed further below, is the only accident at a commercial nuclear power plant that has resulted in fatalities. Furthermore, Chernobyl is said to be the only accident where radiation doses to the public were greater than those resulting from exposure to natural sources. Other incidents have been completely confined to the plants involved.

6.126 AMP Capital Investors Sustainable Funds Team (AMP CISFT), who oppose the use of nuclear power, observed that:

> The modern engineering design of nuclear reactors are designed to represent a very low risk to the public and therefore to date there has only been one major nuclear accident that led to death of [members of] the public.[123]

6.127 Areva submitted that safety at nuclear reactors is realised in the form of precautionary measures in design, construction and operation. Nuclear plants operate using a three-level 'defence in depth' concept: first, to prevent any accident; second, to monitor and protect safety; and third, to avoid unacceptable consequences.

6.128 In turn, safe reactor design relies on a 'three barrier principle', involving series of strong, leak-tight physical 'barriers' which form a shield against radiation and confine radioactivity in all circumstances:

- the metal cladding of the fuel rods;
- the metal enclosure of the reactor primary circuit; and
- the containment surrounding the reactor.[124]

6.129 The UIC further explains that these barriers in a typical plant are: the fuel is in the form of solid ceramic pellets, and radioactive fission products remain bound inside these pellets as the fuel is burned. The pellets are packed inside sealed zirconium alloy tubes to form fuel rods. These are confined inside a large steel pressure vessel with walls up to 30 cm thick, with the associated primary water cooling pipework also substantial. All

122 Nuclear incidents and accidents are classified according to an International Nuclear Event Scale (INES) developed by the IAEA and OECD in 1990. The scale runs from a zero event with no safety significance to a seven for a 'major accident' such as Chernobyl. TMI rated five, as an 'accident with off-site risks'.

123 AMP CISFT, *Submission no. 60*, p. 6.

124 Areva, *Submission no. 39*, p. 6.

this, in turn, is enclosed inside a reinforced concrete containment structure with walls at least one metre thick.

6.130 However, the UIC comments that the main safety features of most reactors are inherent—'negative temperature coefficient' and 'negative void coefficient'. The first means that beyond an optimal level, as the temperature increases the efficiency of the reaction decreases (this is used to control power levels in some new designs). The second means that if any steam has formed in the cooling water there is a decrease in moderating effect so that fewer neutrons are able to cause fission and the reaction slows down automatically.[125]

6.131 Beyond the control rods which are inserted to absorb neutrons and regulate the fission process, the main engineered safety provisions are the back-up emergency core cooling system (ECCS) to remove excess heat (though this is more to prevent damage to the plant than for public safety) and the containment structure.

6.132 The basis of design assumes a threat where, due to accident or malign intent (e.g. terrorism), there is core melting and a breach of containment. Nuclear power plants are also designed with sensors to shut them down automatically in an earthquake, as this is a vital consideration in many parts of the world (e.g. Japan).

6.133 Professor Leslie Kemeny submitted that nuclear reactors are highly robust:

> Fear of nuclear-risks is usually focused on accidental releases of nuclear radiation. Potentially, this can occur in incidents ranging from terrorist acts or geological instability to plant failure and human operator mistake. Nuclear plants are, however, incredibly robust: Japan's 54 nuclear power stations withstand earth tremors and will automatically shut down at the onset of a major quake.
>
> Reinforced concrete reactor containment domes are designed to withstand the impact of crashing aircraft …[126]

6.134 Investigations following the TMI accident led to a new focus on the human factors in nuclear safety. According to the UIC, no major design changes were called for in western reactors, but controls and instrumentation were improved and operator training was overhauled. In contrast, the Chernobyl reactor did not have a containment structure like those used in the West or in post-1980 Soviet designs.

6.135 One mandated safety indicator for reactors is the probable frequency of degraded core or core melt accidents. The US Nuclear Regulatory Commission (NRC) specifies that reactor designs must meet a 1 in 10 000

125 UIC, *Safety of Nuclear Power Reactors, loc. cit*.

126 Professor Leslie Kemeny, *Exhibit no. 9, op. cit*., p. 2.

year core damage frequency, but modern designs are said to exceed this. US utility requirements are 1 in 100 000 years, the best currently operating plants are about 1 in one million years and those likely to be built in the next decade are almost 1 in 10 million years. Regulatory requirements are that the effects of any core-melt accident must be confined to the plant itself, without the need to evacuate nearby residents.[127]

6.136 The UIC notes that the main safety concern has always been the possibility of an uncontrolled release of radioactive material, leading to contamination and consequent radiation exposure off site. It has been assumed that this would follow a major loss of cooling accident (LOCA) which resulted in a core melt. However, UIC argued that experience has proved otherwise in any circumstances relevant to Western reactor designs. Studies of material in a reactor core under extreme conditions, including the post-accident situation at TMI, have found that a severe core melt coupled with a breach of containment could not in fact create a major radiological disaster from any Western reactor design.[128]

6.137 Areva noted that some 12 000 reactor years of operation has contributed greatly to global experience in reactor design. This experience and extensive research and development programs are said to have had a significant impact, improving plant performance and enhancing safety.[129] ANSTO and others also emphasised technological developments in reactor and fuel cycle design which are focused on enhanced safety.

6.138 Mr Jerry Grandey, Chief Executive Officer of Cameco Corporation, explained that in Western Europe and the US a new generation of reactors are now being certified by regulatory agencies that are 'passively safe'; that is, they use gravity instead of depending on mechanical devices for the operation of safety features. Mr Grandey observed that, like any other industry, the nuclear power industry is continually striving to develop improved technology. Improved plants are already being deployed in some countries, such as Japan, Finland, France and China.[130]

6.139 Several generations of reactors are commonly distinguished. Generation I reactors were developed in the 1950–60s and outside the UK none are still operating today. Generation II reactors are typified by the present US fleet and most in operation elsewhere. Generation III (and III+) designs are known as 'Advanced Reactors' and are now being deployed, with the first in operation in Japan since 1996 and one each being built in France and Finland. Generation IV designs are still being developed, with some at an

127 UIC, *Safety of Nuclear Power Reactors*, *loc. cit*.

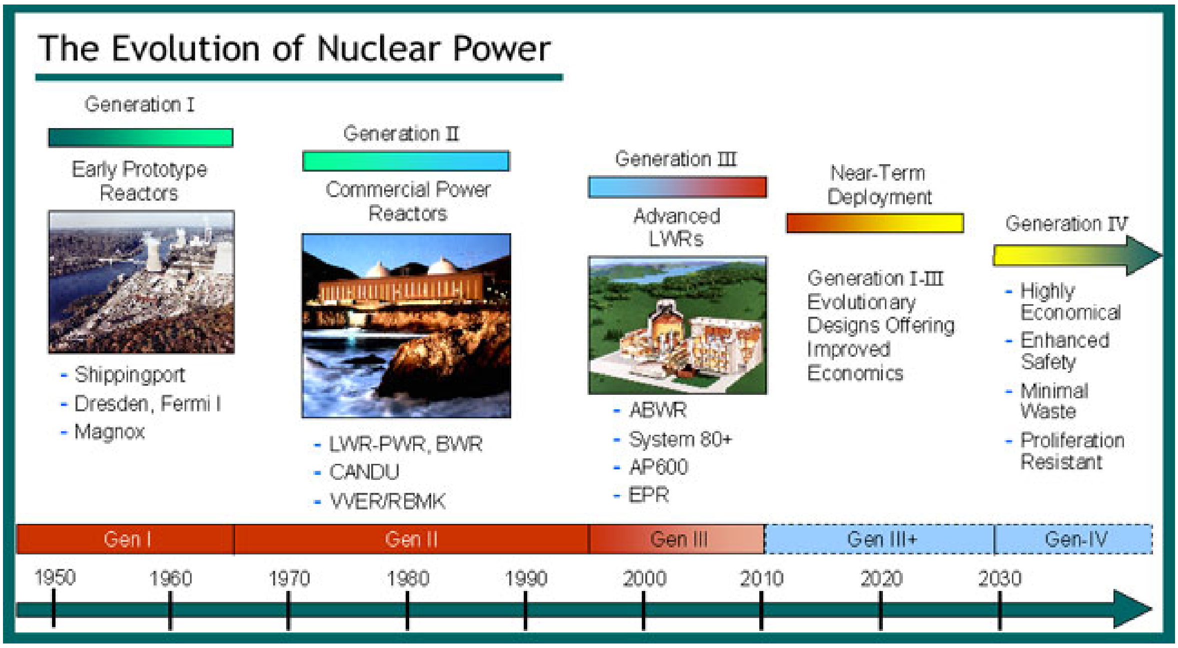
128 *ibid*.

129 Areva, *loc. cit*.

130 Mr Jerry Grandey (Cameco Corporation), *Transcript of Evidence*, 11 August 2005, p. 11.

advanced stage (such as the Modular Helium Reactor, mentioned in the previous chapter, which is now in advanced development by General Atomics in the US), and will not be operational before 2020 at the earliest.[131] Figure 6.1 depicts the evolution of nuclear reactor designs.

Figure 6.1 The evolution of nuclear reactor designs



Source US Department of Energy, *Generation IV Nuclear Energy Systems.*

6.140 The UIC explains that the most significant departure from second-generation designs is that many Advanced Reactors incorporate passive or inherent safety features which require no active controls or operational intervention to avoid accidents in the event of malfunction, and may rely on gravity, natural convection or resistance to high temperatures.[132] It is argued that these reactors are one or two orders of magnitude safer than second generation reactors in respect to the likelihood of core melt accidents.

6.141 Examples of third-generation reactors in the US include the advanced boiling water reactor (ABWR) derived from a General Electric design, which the NRC notes exceeds NRC safety goals by several orders of magnitude, and the Westinghouse AP-600 (AP = Advanced Passive). Both designs have been granted NRC design certification. The AP-600s

131 ANSTO, *Exhibit no. 74, Presentation by Dr Ron Cameron and Dr Ian Smith*, slide no. 46.

132 Traditional reactor safety systems are 'active' in the sense that they involve electrical or mechanical operation on command. Some engineered systems operate passively, eg pressure relief valves. Both require parallel redundant systems. Inherent or full passive safety depends only on physical phenomena such as convection, gravity or resistance to high temperatures, not on functioning of engineered components.

projected core damage frequency is nearly 1 000 times less than today's NRC requirements.[133]

6.142 One of four Advanced Reactor designs currently being developed to meet European utility requirements is the European pressurised water reactor (EPR) proposed by Areva, which is an example of a Generation III+ design. The first EPR is currently being built in Finland and a second is to be built in France. Areva noted that key design improvements are the total confinement of radioactivity even in the most serious accident scenarios and reinforced protection against external events. The reactor's safety systems have been simplified, diversified, more fully automated and a greater degree of redundancy has been incorporated.

6.143 Areva submitted that the EPR has several novel safety features and the design meets demands expressed by European electricity companies and safety authorities:

- according to safety margins compared with the other French reactors, the EPR has a ten times lower probability of a major accident (e.g. to provide emergency cooling of the reactor core, four independent sub-systems have been introduced);
- even in case of a severe accident with a core melt and piercing of the reactor vessel, leak tight containment ensures no external radioactive release and no consequence on neighbouring population;
- also in case of severe accident and core bleed through the vessel bottom, a special 'ash-tray' underneath would recover the melted material, preventing any radioactive intrusion underground (the containment building stands on a concrete base mat 6 m thick); and
- protection against external events (including fire, flood and falling aircraft) has been reinforced, including independent redundant systems to prevent common failure and a double containment of two 1.3 m thick walls (giving a total of 2.6 m of concrete).[134]

6.144 Beyond third-generation reactors, two international initiatives have been launched to define future reactor and fuel cycle technology. The Generation IV International Forum (GIF) is a US-led grouping of twelve countries established in 2001, which has identified six reactor concepts for further investigation with a view to commercial deployment between 2010 and 2030. The six systems are intended to offer increased safety, improved economics for electricity production and new products such as hydrogen

133 See also: UIC, *Advanced Nuclear Power Reactors*, Nuclear Issues Briefing Paper No. 16, August 2006, viewed 20 September 2006, <http://www.uic.com.au/nip16.htm>.

134 Areva, *op. cit.*, p. 7. See also: Areva, *EPR: A reactor for maximum safety*, viewed 20 September 2006, <http://www.areva-np.com/>.

for transportation applications, reduced nuclear wastes for disposal, and increased proliferation resistance.[135]

6.145 The other initiative is the IAEA's International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO), which has some 21 members and is focused more on developing country needs, and initially involved Russia rather than the US, though the US has now joined the Project. INPRO is intended to complement the GIF in promoting innovative concepts.[136]

6.146 Some of the Generation IV reactor designs will be inherently safe by virtue of being immune from the possibility of core melt accidents and passively safe. Among these designs are the very high-temperature gas reactors (one of the six GIF concepts), which includes pebble bed modular reactors (PBMR) under development in South Africa and China, and the gas turbine-modular helium reactor (GT-MHR) being developed by General Atomics. Among their other characteristics, these designs can accommodate the total loss of coolant without the possibility of a meltdown. The reactors' negative temperature coefficient inherently shuts down the core when it rises above normal operating temperatures. Furthermore, the helium (in which the core is bathed) which is used to transfer heat from the core to the turbines is chemically inert. It cannot combine with other chemicals and is non-combustible. Being passively safe, in the case of emergency no human intervention would be required in the short or medium term in these reactors.[137]

6.147 Silex Systems also argued that safety has been a top priority for the industry since reactors were first deployed commercially and that the current reactor fleet has been made safer by modifications over time. Third generation reactors, which are now being deployed, include inherent safety features and fourth generation designs, such as the PBMR and GT-MHR designs mentioned above, ensure that an event in the reactor core cannot even occur:

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135 Dr Ron Cameron (ANSTO), *Transcript of Evidence*, 13 October 2005, p. 11. See also: US Department of Energy, *Generation IV Nuclear Energy Systems*, viewed 20 September 2006, <http://gen-iv.ne.doe.gov/documents/geni.pdf>; Generation IV International Forum, *Fact Sheet*, viewed 20 September 2006, <http://www.gen-4.org/GIF/About/factsheet.htm>.

136 See: IAEA, *INPRO Status 2005*, viewed 20 September 2006, <http://www.iaea.org/OurWork/ST/NE/NENP/NPTDS/Downloads/Brochure/2005_INPRO_Brochure.pdf>.

137 Nova Energy Ltd, *Submission no. 50*, p. 14. See: MP LaBar, *The Gas Turbine – Modular Helium Reactor: A Promising Option for Near Term Deployment*, General Atomics, San Diego USA, 2002, pp. 7–8, viewed 20 September 2006, <http://gt-mhr.ga.com/2hieff_all.html>; Pebble Bed Modular Reactor Pty Ltd, *How safe is PBMR?*, viewed 20 September 2006, <http://www.pbmr.com/index.asp?content=5>.

> The industry has made risk analysis a complete science from which many other industries have benefited. The current fleet of nuclear reactors has been improved steadily and is now operating very reliably and efficiently. There is no long-term safety issue with the current fleet.
>
> Third and fourth generation reactors are being developed. Some third generation reactors have already been built in Japan. These reactors have process-inherent safety features. If the reactor core has an excursion—if it misbehaves—automatically the reactor goes into a failsafe mode, natural forces take over and human intervention is cut out …
>
> Fourth generation reactors, which are being developed now—they have not been commercially deployed—go one step further. They are built so that inherently the fuel is configured so that an excursion—an event of misbehaviour in the reactor—cannot even occur in the first place. They shut down before the excursion manifests. Examples are the pebble bed reactor being developed in China and South Africa with some German interests, and the modular high temperature gas cooled reactor being developed by General Atomics in the USA. These reactors will become the future reactor of choice. Reactor safety, I believe, is now not a technical issue. There is a public perception issue, and the industry has to educate the public and governments alike.[138]

6.148 Nova Energy also argued that new and advanced reactor designs are now far safer than those that operated in previous decades:

> There is an acceptance that the new generation of reactors, of which pebble bed reactors are one, are considered safer, cheaper to build and environmentally a better option. The point we are trying to make is that the technology in terms of nuclear reactor development and nuclear power stations has advanced significantly over the last 20 to 30 years. That is often not recognised in the discussion about concerns around nuclear power and nuclear energy, which often go back to views based on 1970s technology.[139]

6.149 Areva commented that public perceptions of reactor designs are still shaped by the Chernobyl accident and fail to appreciate the technical developments that have occurred since:

138 Dr Michael Goldsworthy (Silex Systems Ltd), *Transcript of Evidence*, 9 February 2006, p. 4.

139 Mr Richard Pearce (Nova Energy Ltd), *Transcript of Evidence*, 23 September 2005, p. 71.

> Most of the public see reactor designs as being similar to the Chernobyl design and having the same problems … the designs are dramatically different now. Even the Chernobyl design, as has been commonly stated, would never have been built in the Western world. The technology was far greater in the Western world than what it was in Chernobyl at the time that it was built. We have moved on. Last year [Areva] spent €402 million on research and development. The company spends a lot of money continuously, year after year. Many other companies are also doing that and trying to improve the technology and to improve the safeguards.[140]

6.150 AMEC also argued that, as with developments in the design of ships or aircraft, the evolution of reactor technologies needs to be acknowledged:

> If I can give you an analogy, in 1912 the *Titanic* sank. What did we do? We did not say we were never going to build another ocean liner; we said we were going to have to build them better and safer. We have been saying since 1986 that we have decided we are not going to close down all nuclear reactors; we are going to build better and safer ones. In the same way, we have the situation with the hurricanes in the United States. We have not said we are going to close down New Orleans because of hurricanes; we are going to try and build a better New Orleans.[141]

6.151 Similarly, the Committee notes the observation by Dr Patrick Moore, co-founder of Greenpeace, that:

> Accidents do happen in newly emerging technologies, and nuclear is no exception, but it is one of the safer newly emerging technologies that we have in the world.
>
> The fact is over 5 000 people die every year in coal mines around this world. If you look at automobiles, 1.2 million people die in automobile accidents every year. Who's banning the automobile?
>
> I mean, if you really wanted to ban a technology that was causing death and destruction and injury, it would be the car.[142]

6.152 Notwithstanding technological advances, the AMP CISFT was not confident that passive or inherent safety features incorporated into modern reactor designs could adequately mitigate against the risk of accidents.[143] Pointing to a 'near miss' incident at the Davis-Besse plant in

140 Mr Stephen Mann (Areva), *Transcript of Evidence*, 23 September 2005, p. 10.

141 Mr Alan Layton (AMEC), *Transcript of Evidence*, 23 September 2005, p. 15.

142 Dr Patrick Moore, 'Greenpeace co-founder welcomes nuclear debate', *AM*, ABC Radio, 8 June 2006, transcript of interview with David Weber.

143 Dr Ian Woods (AMP CISFT), *Transcript of Evidence*, 16 September 2005, p. 30.

the US, and incidents at reprocessing plants in the US and UK, AMP CISFT asserted that 'good engineering' is not enough to ensure safety:

> … good engineering design is not sufficient to ensure appropriate control of nuclear facilities and … human factors and errors are key underlying causes of accidents and incidents. Improvements in employee training, maintenance and record keeping of all parts of the nuclear value chain, the independent verification of these systems and improved regulatory control, are all required to a level well beyond that which is required by existing safeguards.[144]

6.153 It was argued that strict adherence to maintenance and safety rules on the part of nuclear workers are critical in providing the required level of health and safety assurance. However, AMP CISFT argued that incidents at reactors, reprocessing plants and uranium mines 'cast doubt over whether it is possible for … companies to address health and safety concerns and ensure that systems and procedures will be followed or are adequate.'[145]

6.154 MAPW (Victorian Branch) argued that incidents at TMI, Tokai-mura in Japan and Davis-Besse in the US shows that risks of serious accidents are not confined to specific types of reactors or to particular countries.[146]

Global nuclear safety regime

6.155 The IAEA states that a global nuclear safety regime exists which is comprised of four elements:

- the widespread subscription to binding and non-binding international legal instruments such as safety conventions and codes of conduct;
- a comprehensive suite of nuclear safety standards that embody good practices as a reference point to the high level of safety required for all nuclear activities;
- a suite of international safety reviews and services, based on the safety standards; and
- the need to ensure strong national infrastructures and a global experts' community.[147]

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144 AMP CISFT, *Submission no. 60*, p. 6.

145 AMP CISFT, *Exhibit no. 65, The Nuclear Fuel Cycle Position Paper*, p. 16; Dr Ian Woods, *op. cit.*, p. 28.

146 MAPW (Victorian Branch), *op. cit.*, p. 12.

147 IAEA, *Nuclear Safety Review for the Year 2005,* IAEA, Vienna, 2005, p. 2, viewed 21 September 2006, <http://www.iaea.org/About/Policy/GC/GC50/GC50InfDocuments/English/gc50inf-2_en.pdf>.

6.156 The principal international legal instruments include the:

- *Convention on Nuclear Safety*;
- *Convention on Early Notification of a Nuclear Accident*;
- *Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency*;
- *Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management*; and
- *Convention on the Physical Protection of Nuclear Material*.[148]

6.157 The IAEA has also developed Codes of Conduct relating to research reactors and on the safety and security of radioactive sources. The IAEA is also charged with developing Safety Standards which embody best practice and serve as guides for national regulatory rules and guidelines.

6.158 In addition to the application of safety standards, international peer review is also said to bring broader expertise, perspective and transparency to national safety assessment and verification processes and ultimately to improve public confidence. The IAEA conducts safety and security peer reviews and safety appraisals upon Member State request, including Operational Safety Review Team (OSART) and Peer Review of Operational Safety Performance Experience (PROSPER) missions. In 2005 the Agency conducted some 120 safety review missions covering topics including nuclear power plant operational safety, radiation source safety and security, nuclear and radiation safety infrastructure, and transport safety.[149]

6.159 The IAEA states that a key to promoting safety culture is the exchange of knowledge. To this end, the IAEA is promoting and facilitating the establishment of regional nuclear and radiation safety networks, such as the Asian Nuclear Safety Network. The IAEA also seeks to preserve and maintain knowledge through an International Nuclear Information System.[150] Areva also noted that the IAEA and the OECD Nuclear Energy Agency (OECD-NEA) jointly manage an international Incident Reporting System (INS), which has been established to facilitate the exchange of experience for the purpose of improving the safety of nuclear power plants.[151]

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148 See: IAEA, *Nuclear Safety Review for the Year 2004*, IAEA, Vienna, 2004, p. 3, viewed 22 September 2006, <http://www.iaea.org/Publications/Reports/nsr2004.pdf>.

149 For an overview of the IAEA's activities in relation to nuclear safety and security in 2005 see: IAEA, *IAEA Annual report 2005*, viewed 22 September 2006, <http://www.iaea.org/Publications/Reports/Anrep2005/>.

150 IAEA, *Nuclear Safety Review for the Year 2004*, *op. cit.*, p. 6.

151 Areva, *op. cit.*, p. 6.

6.160 There are also a number of forums in which national regulators can exchange information and experience with their counterparts in other countries, such as the International Nuclear Regulators Association and the Network of Regulators of Countries with Small Nuclear Programs.[152]

6.161 In addition to these international activities, peer review and knowledge exchange is also undertaken by other organisations, such as the World Association of Nuclear Operators (WANO) which was formed in 1989. WANO, whose membership includes every organisation in the world that operates a nuclear power plant, was established following the Chernobyl accident specifically to improve safety at every nuclear power plant in the world. WANO seeks to achieve its mission of maximising the safety and reliability of the operation of nuclear plants by exchanging information and encouraging communication, comparison and emulation amongst its members. It conducts activities including peer reviews, technical support and exchange, and professional and technical development. WANO has also developed a series of performance indicators for plant safety and reliability which are now reported by practically all operating nuclear power plants worldwide.[153]

6.162 Among its other findings, the IAEA's *Nuclear Safety Review for the Year 2005,* which reports on worldwide efforts to strengthen nuclear, radiation, transport and radioactive waste safety, concluded that:

> Nuclear power plant (NPP) operational safety performance … remained high throughout the world in 2005. Radiation doses to workers and members of the public due to NPP operation are well below regulatory limits. Personal injury accidents and incidents are among the lowest in industry. There have been no accidents that have resulted in the unplanned release of radiation that could adversely impact the environment. This operational safety performance is a strong testimony to the attention to improving the engineering and human performance attributes of safety that have occurred over the past two decades.[154]

6.163 The IAEA noted, however, that there is a need to guard against complacency by the industry and regulatory authorities, particularly in relation to operational safety performance, and that a continuing challenge is to collect, analyse and disseminate safety experience and knowledge.[155]

152 IAEA, *Nuclear Safety Review for the Year 2005, op. cit.,* p. 3.

153 See: WANO, *What is WANO?*, viewed 21 September 2006, <http://www.wano.org.uk/WANO_Documents/What_is_Wano.asp>; Areva, *loc. cit.*

154 IAEA, *Nuclear Safety Review for the Year 2005, op. cit*., p. 5.

155 *ibid*., pp. i, 6.

In relation to the transport of radioactive material, the report found that the industry's good safety record continued in 2005.[156]

6.164 In a similar vein, the OECD-NEA's 2005 edition of *The Safety of the Nuclear Fuel Cycle* report reached the general conclusion that while more should always be done to enhance nuclear safety, for example in relation to human factors, nonetheless 'the fuel cycle industry has now reached a full maturity status and … nuclear safety is adequately mastered.'[157]

The Chernobyl accident

6.165 The Chernobyl accident occurred on 26 April 1986 at Unit 4 of the Chernobyl nuclear power plant in the former Ukrainian republic of the Soviet Union.

6.166 According to the US Nuclear Energy Institute (NEI), the four chernobyl reactors were PWRs of the Soviet RBMK design, which were intended to produce electrical power and plutonium. These reactors were said to be very different from standard commercial designs, employing a combination of graphite moderator and water coolant. The reactors were also highly unstable at low power, primarily owing to control rod design and a large positive void coefficient—factors that accelerated nuclear chain reaction and power output if the reactors lost cooling water.[158]

6.167 On the morning of 26 April 1986 the reactor crew at Chernobyl-4 began to prepare for a test involving a shut-down of the reactor (in order to determine how long turbines would spin and supply power following a loss of main electrical power supply). A series of operator actions, including the disabling of automatic shutdown mechanisms, preceded the attempted test. As the flow of coolant diminished, power output increased. When the operator sought to shut down the reactor from its unstable condition arising from previous errors, a peculiarity of the design caused a dramatic power surge.

6.168 The power surge caused a sudden increase in heat which ruptured some of the fuel elements. The hot fuel particles reacted with the water and caused a steam explosion which lifted off the cover plate of the reactor and released fission products to the atmosphere. The explosion ruptured the remaining fuel elements which caused a second explosion and exposed the reactor core to the environment. The second explosion threw out fragments of burning fuel and graphite from the core and allowed air to rush in, causing the graphite moderator to burst into flames. The graphite

156 *ibid*., p. 20.

157 OECD-NEA, *The Safety of the Nuclear Fuel Cycle*, OECD-NEA, Paris, 2005, pp. 300, 18.

158 NEI, *The Chernobyl Accident and Its Consequences*, NEI, Washington DC, April 2006, viewed 25 September 2006, <http://www.nei.org/doc.asp?catnum=3&catid=296>.

burned for the following nine days, causing the main release of radioactivity.[159]

6.169 The Chernobyl plant did not have a containment structure common to most nuclear power plants elsewhere in the world. Without this protection, radioactive material escaped into the environment. The explosions which ruptured the reactor vessel and the consequent fire resulted in large amounts of radioactive materials being released. The cloud from the burning reactor spreading numerous types of radioactive materials, especially iodine-131 (which has a half-life of eight days) and caesium-137 (which has a half-life of 30 years) over much of Europe. However, the greatest deposits of radionuclides occurred over large areas of the former Soviet Union, notably Belarus, the Russian Federation and Ukraine.[160]

6.170 In short, the UIC submitted that the Chernobyl accident resulted from a flawed Soviet reactor design that was operated with inadequately trained personnel and without proper regard for safety. The accident has led to a profound change in operational culture in the former Soviet Union.[161]

6.171 It was repeatedly emphasised that the Chernobyl plant would *never* have been certified for operation under regulatory regimes of western countries, due to reactor design shortcomings and the lack of safeguards. The UIC stated that all of the 13 remaining Soviet-designed RBMK reactors, identical to the Chernobyl reactor, have now been substantially modified, making them more stable and adding safety features like faster automatic shut-down mechanisms.[162]

6.172 Evidence presented to the Committee on the number of immediate fatalities caused by the accident and the possible number of eventual fatalities due to radiation exposure was strongly divided.

6.173 The MAPW (Victorian Branch) claimed in its submission that 'at least 6 000 deaths resulted' from the accident.[163] Dr Helen Caldicott claimed that, of the clean up workers alone, '5 000 to 10 000 are known to have died so far.'[164] Dr Caldicott also cited claims that the eventual number of fatal cancers caused by the accident will be between 140 000 and 450 000,

159 UIC, *Chernobyl Accident*, Nuclear Issues Briefing Paper No. 22, viewed 25 September 2006, <http://www.uic.com.au/nip22.htm>.

160 The Chernobyl Forum: 2003–2005, *Chernobyl's Legacy: Health, Environmental and Socio-economic Impacts* (Summary Report), IAEA, Vienna, 2006, p. 10, viewed 25 September 2006, <http://www.iaea.org/Publications/Booklets/Chernobyl/chernobyl.pdf>.

161 UIC, *Submission no. 12*, p. 12.

162 *ibid.*

163 MAPW (Victorian Branch), *Submission no. 30*, p. 12.

164 Dr Helen Caldicott, *Exhibit no. 25, Nuclear Madness*, p. 134.

with an equal number of non-fatal cancers. That is, there will ultimately be almost one million cases of cancer attributable to the Chernobyl accident.[165] The FOE estimated that there will be 24 000 fatal cancers attributable to the accident.[166]

6.174 In September 2005 a major multi-agency UN report was released, *Chernobyl's Legacy: Health, Environmental and Socio-Economic Impacts*, which represents the most comprehensive evaluation of the Chernobyl accident's consequences to date. The report was produced by the Chernobyl Forum, which is comprised of eight agencies—IAEA, WHO, UNSCEAR, United Nations Development Program, Food and Agriculture Organisation, United Nations Environment Program, United Nations Office for the Coordination of Humanitarian Affairs, the World Bank and the governments of Belarus, the Russian Federation and Ukraine. The report, which involved the contributions of some 100 recognised international experts, represents a consensus view of the eight UN organisations and the three governments.

6.175 In relation to cancer mortality due to radiation exposure from the accident, the Chernobyl Forum states that claims that tens or even hundreds of thousands of persons have died as a result of the accident are 'highly exaggerated.'[167]

6.176 The report states that it is impossible to assess reliably, with any precision, the latent cancer deaths that may be caused by radiation exposure due to the accident. Further, radiation-induced cancers are at present indistinguishable from those due to other causes. The WHO notes that that number of such deaths can only be estimated statistically using information and projections from the studies of atomic bomb survivors and other highly exposed populations. However, the atomic bomb survivors received high radiation doses in a short time period (i.e. high dose rates), while Chernobyl caused low doses over a long time. This and other factors, such as trying to estimate doses people received some time after the accident, as well as differences in lifestyle and nutrition, cause very large uncertainties when making projections about future cancer deaths. In addition, a significant non-radiation related reduction in the average lifespan in the three countries over the past 15 years caused by overuse of alcohol and tobacco, and reduced health care, have significantly increased the difficulties in detecting any effect of radiation on cancer mortality.

165 *ibid.*, p. 135.

166 FOE, *Exhibit no. 71, Nuclear Power: No Solution to Climate Change*, Section 5.3 Chernobyl.

167 The Chernobyl Forum, *op. cit.*, p. 14.

6.177 The estimates also make the LNT assumption described above; that risk continues in a linear fashion at lower doses. The Chernobyl Forum notes that small differences in the assumptions about the risks from exposure to low level radiation can lead to large differences in the predictions of the increased cancer burden, and hence 'predictions should be treated with great caution, especially when the additional doses above natural background radiation are small.'[168]

6.178 Among its other findings, the Chernobyl Forum concludes that:

- Of the 134 emergency workers (referred to as 'liquidators') diagnosed with acute radiation sickness after the accident, 28 persons died in 1986. Nineteen more died of various causes over the period 1987–2004; however, not all these deaths were directly attributable to radiation exposure. Two more persons died at Unit 4 from injuries unrelated to radiation, and one additional death was thought to have been due to a coronary thrombosis.
- Emphasising the caveats noted above, Chernobyl Forum projections for cancer mortality indicate that, among the most exposed populations (a population of 600 000 people comprised of liquidators, evacuees and residents of the most contaminated areas), total cancer mortality might increase by up to 3–4 per cent owing to Chernobyl-related radiation exposure. This might eventually represent up to 4 000 fatal cancers over the lifetime of the most exposed populations.[169]
- Among the six million persons residing in other contaminated areas of Belarus, Russia and the Ukraine, these people received whole body doses not much higher than doses due to natural background radiation (currently, the vast majority of these populations receive annual effective doses from Chernobyl fallout of less than 1 mSv). Projected mortality increases are more speculative, but are expected to make a difference of less than one per cent in cancer mortality.

  Predictions suggest that up to 5 000 additional cancer deaths may occur in this population from radiation exposure, or about 0.6 per cent of the cancer deaths expected in this population due to other causes. The WHO notes that this estimate is highly uncertain as 'it is based on an average dose of just 7 mSv, which differs very little from natural

168 *ibid*., p. 15. See also: WHO, *The Health Effects of Chernobyl: An Overview*, Fact Sheet No. 303, April 2006, viewed 28 September 2006, <http://www.who.int/mediacentre/factsheets/fs303/en/index.html>.

169 WHO, *Health effects of the Chernobyl accident and special care programs*, Report of the UN Chernobyl Forum Group 'Health', WHO, Geneva, 2006, p. 106, viewed 28 September 2006, <http://www.who.int/ionizing_radiation/chernobyl/who_chernobyl_report_2006.pdf >.

background radiation.'[170] The radiation-induced increases will also be difficult to detect with available epidemiological tools, given the normal variation in cancer mortality rates.[171]

The predictions of excess cancer deaths in populations exposed as result of Chernobyl accident are listed in table 6.6.

The WHO notes that the Chernobyl accident may also cause cancers elsewhere in Europe, outside Belarus, the Russian Federation and Ukraine. However, according to UNSCEAR, the average dose to these populations is much lower and so the relative increase in cancer deaths is expected to be much smaller. Predicted estimates are very uncertain and it is very unlikely that any increase in these countries will be detectable using national cancer statistics.[172]

- Among more than 4 000 cases of thyroid cancer diagnosed in 1992–2002 in persons who were children or adolescents at the time of the accident, some nine cancer deaths had been documented by 2002. However, the survival rate is almost 99 per cent.[173]
- Studies of residents in the contaminated areas of Belarus, Ukraine and Russia have not provided clear and convincing evidence for radiation-induced increase in general population mortality, and in particular, for fatalities caused by leukaemia, solid cancers (other than thyroid cancer) and non-cancer diseases.[174]
- Contrary to the assertions of some submitters, the Forum found that there is no evidence, or any likelihood of observing, decreased fertility, increases in congenital malformations or hereditary effects attributable to radiation exposure among the populations of the Chernobyl affected regions.[175]

170 *ibid*.
171 WHO, *The Health Effects of Chernobyl: An Overview*, *loc. cit*.
172 *ibid*.
173 WHO, *Health effects of the Chernobyl accident and special care programs*, *op. cit.*, p. 104.
174 The Chernobyl Forum, *op. cit.*, p. 16.
175 *ibid.*, p. 19. See for example: Mr Daniel Taylor, *Submission no. 85*, p. 6.

Table 6.6 Predictions of excess deaths from solid cancers and leukaemia over lifetime (up to 95 years) in populations exposed as a result of the Chernobyl accident

Population	Population size / average dose	Predicted excess cancer deaths
Liquidators, 1986–1987	200 000 100 mSv	2 200
Evacuees from 30 km highly contaminated zone surrounding the reactor	135 000 10 mSv	160
Residents of strict control zones	270 000 50 mSv	1 600
Sub total		*3 960*
Residents of other 'contaminated' areas	6 800 000 7 mSv	4 970
Total		8 930

Source Adapted from WHO, *Health effects of the Chernobyl accident and special care programs*, p. 108.

6.179 The MAPW (Victorian Branch) were critical of the Chernobyl Forum's estimates and claimed that they were 'incomplete and underestimate the health consequences of the disaster.'[176] Adding estimates for other groups, such as additional liquidators that the MAPW believes the Chernobyl Forum has not included in its analysis and estimates for deaths in future generations, MAPW arrived at an estimated death toll of 34 200 to 38 500.[177]

6.180 In research published by the International Agency for Research on Cancer (IARC) in April 2006, *Estimates of the Cancer Burden in Europe from Radioactive Fallout from the Chernobyl Accident*, it was concluded that cancer incidence and mortality in Europe do not, at present, indicate any increase in cancer rates—other than thyroid cancer in the most contaminated regions—that can be clearly attributed to radiation from the Chernobyl accident. However, the study found that for Europe up to 2065 (i.e. at end of the average life expectancy of Europeans born at the time of the accident in 1986) about 16 000 cancer deaths may occur that are attributable to Chernobyl. The study notes that the uncertainty associated with this prediction is large. As noted by the Chernobyl Forum, the study also found that because these possible deaths represent only a very small fraction of the total number of cancers seen since the accident and expected in the future in Europe, it is unlikely that the cancer burden from

176 MAPW (Victorian Branch), *Submission no. 30.1*, p. 11.

177 *ibid.*, p. 16.

the accident could be ever be detected by monitoring national cancer statistics.[178]

6.181 When asked by the Committee to explain the variance between the Chernobyl Forum's findings and claims that many thousands of deaths have occurred *already*, Dr Caldicott and the MAPW alleged that the Chernobyl Forum's report was a 'whitewash'.[179] It was also claimed that, due to an agreement entered into with the IAEA in 1959, the WHO has been prevented from undertaking any epidemiological studies of radiation victims from Chernobyl and has had diminished independence in relation to radiation health matters more generally.[180]

6.182 The Chernobyl Forum's conclusions were also disputed because the latency period before cancer reveals itself was said to be up to 70 years, and thus to have undertaken a study 'only 20 years post Chernobyl' was said to be too early.[181] Dr Caldicott also claimed that there had been 7 000 cases of thyroid cancer and disputed, without evidence, the Chernobyl Forum's findings that there have actually been between 4 000 and 5 000 cases and, of these, only 15 people have died to date with thyroid cancer having very high survival rates (almost 99 per cent).[182]

6.183 The ANA, among others, expressed frustration with Dr Caldicott's position and responded with the observation that:

> We know the results of the United Nations study by eminent experts. They are not all working for the IAEA. These eminent experts looked at all of the figures and said, 'We think the initial estimates have been grossly overestimated. This many have died, this many have had thyroid cancer and this many may die, but it is in the thousands, not the hundreds of thousands.' [Dr Caldicott] disputes that by saying that we have not waited long enough. If we wait another 20 years there will be many more. You cannot prove her wrong because we have not got there yet.[183]

6.184 However, the Chernobyl Forum states that for most solid cancers the latency period is likely to be longer than for leukaemia or thyroid cancer (some 10 to 15 years longer—i.e. about 20–25 years after the accident), and

178 E Cardis et. al, *The Cancer Burden from Chernobyl in Europe: Briefing Document,* WHO/IARC, April 2006, viewed 28 September 2006, <http://www.iarc.fr./chernobyl/briefing7.php>.

179 Dr Helen Caldicott, *Transcript of Evidence*, 16 September 2005, pp. 5, 6; Dr Stephen Masters (MAPW – WA Branch), *Transcript of Evidence*, 23 September 2005, p. 39.

180 MAPW (Western Australian Branch), *Submission no. 8*, p. 6; MAPW (Victorian Branch), *Submission no. 30.1*, pp. 12–14; Dr Helen Caldicott, *op. cit.*, p. 5.

181 Dr Helen Caldicott, *loc. cit.*

182 *ibid*.

183 Dr Clarence Hardy (ANA), *Transcript of Evidence*, 16 September 2005, p. 60.

hence it may be too early to evaluate the full radiological impact of the accident. Accordingly, the Forum recommends that medical care and annual examinations of highly exposed Chernobyl workers should continue.[184]

6.185 Rather than radiation exposure posing the greatest threat to the affected populations, the Chernobyl Forum clearly states that:

> The most pressing health concerns for the affected areas … lies in poor diet and lifestyle factors such as alcohol and tobacco use, as well as poverty and limited access to health care.[185]

6.186 The report also states that the largest public health problem caused by the accident has been the mental health impact, in part due to the trauma associated with the resettlement of some 330 000 people from the most affected areas. Populations in the affected areas are said to exhibit strongly negative attitudes in self-assessments of health and well-being, and a strong sense of lack of control over their own lives. This is said to have been exacerbated by widespread mistrust of official information and designation of the population as 'victims' rather than as 'survivors'.[186]

6.187 The report emphasises that exaggerated or misplaced health fears, a sense of victimisation and a dependency culture created by government policies is widespread in the affected areas:

> … misconceptions and myths about the threat of radiation persist, promoting a paralysing fatalism among residents. This fatalism yields both excessively cautious behaviour (constant anxiety about health) and reckless conduct …[187]

6.188 At the release of the report, the Chairman of the Chernobyl Forum, Dr Burton Bennett, stated that:

> This was a very serious accident with major health consequences, especially for thousands of workers exposed in the early days who received very high radiation doses, and for the thousands more stricken with thyroid cancer. By and large, however, we have not found profound negative health impacts to the rest of the population in surrounding areas, nor have we found widespread

184 The Chernobyl Forum, *op. cit.*, p. 19; WHO, *Health effects of the Chernobyl accident and special care programs*, *op. cit.*, p. 106.

185 The Chernobyl Forum, *op. cit.*, p. 37.

186 *ibid.*, pp. 21, 35.

187 *ibid.*, p. 41.

> contamination that would continue to pose a substantial threat to human health, with a few exceptional, restricted areas.[188]

6.189 Similarly, the Manager of the WHO's Radiation Program, Dr Michael Repachioli, stated that:

> … the health effects of the accident were potentially horrific, but when you add them up using validated conclusions from good science, the public health effects were not nearly as substantial as had at first been feared.[189]

6.190 The Director General of the IAEA commented that while the impacts of the accident were severe, nonetheless:

> … the situation was made even worse by conflicting information and vast exaggerations—in press coverage and pseudo-scientific accounts of the accident—reporting, for example, fatalities in the tens or hundreds of thousands.[190]

6.191 Dr Ron Cameron of ANSTO submitted that:

> People often ask, 'What about Chernobyl?' Chernobyl was a tragic accident in the nuclear industry. It occurred with a reactor which would never have been built in a Western country. I know that because when I was in the United Kingdom we did an assessment of the Chernobyl RBMK reactor. The conclusion in the report was that we could never license such a reactor in any Western country. The comparison between that and Three Mile Island, which was a Western design, is that they both had a meltdown but there were no injuries or deaths to go with Three Mile Island. That is because it had a strong containment building et cetera.
>
> The latest report on Chernobyl has just been produced, which is after 20 years. The estimate is now 56 deaths after 20 years. That was 31 immediate deaths and a number of people have died since. There have been 4,000 cases of thyroid cancer, but thyroid cancer is a very survivable cancer. Only nine people have died. So that takes the number up to 56 after 20 years. They say that the worst case they could predict—taking into account even the most conservative assumptions and people who got very small doses

188 Cited in IAEA, 'Chernobyl: The True Scale of the Accident', *Press Release*, 5 September 2005, viewed 25 September 2006, <http://www.iaea.org/NewsCenter/PressReleases/2005/prn200512.html>.

189 Cited in IAEA, 'Chernobyl: The True Scale of the Accident', *loc. cit*.

190 IAEA, 'The enduring lessons of Chernobyl', *Statement of the Director General*, 6 September 2005, viewed 25 September 2006, <http://www.iaea.org/NewsCenter/Statements/2005/ebsp2005n008.html>.

> but have a certain probability of dying—would be that you might get 4,000 over the whole lifetime.[191]

6.192 ANSTO also sought to place the 56 fatalities to date from the Chernobyl accident in the context of fatalities in other industries, which have far outnumbered those that have or may be attributed to Chernobyl:

> If you compare that with Bhopal, which was the chemical accident in 1984, just two years before Chernobyl, that killed 4,000 people immediately and 15,000 people within two years. In 1996, nearly 3,500 people died in China as a result of mining accidents. If you take Australia, which probably has the safest mining industry in the world, 281 coalminers have died since 1902; in New South Wales, 112 have died since 1979.[192]

6.193 As noted by the UIC and ANSTO, Mr Jerry Grandey also pointed out that the accident involved a Soviet designed reactor which would never have been licensed in the West. Mr Grandey also observed that the TMI and Chernobyl accidents have affected public perceptions of the safety of nuclear power and 'we have been living with that and responding to it as an industry since they occurred in 1979 and 1986.'[193]

6.194 In particular, Mr Grandey noted that in Eastern Europe, where similar reactors to those that operated at Chernobyl are still being used, considerable effort has been put into retrofitting the reactors to enhance safety and bring them up to Western standards. These activities have occurred under the oversight of the IAEA and Euratom, with the result that:

> … those that remain operating—and a number of them have been shut down—are as safe as those Western style reactors that are operating in Europe. A number of them, however, are scheduled to be phased out and shut down as a condition of accession to the European Union. In Lithuania, Bulgaria and Hungary these phase-outs will occur between now and 2007. So the technology that would be viewed as Soviet technology that cannot meet Western standards will be largely phased out, but in the interim it has been upgraded considerably.[194]

6.195 Although retrofitting of reactors in Russia has not had the same degree of international oversight, upgrades of Russian reactors have been carried out by the country's ministry of atomic energy. Mr Grandey argued that

191 Dr Ron Cameron (ANSTO), *Transcript of Evidence*, 13 October 2005, pp. 9–10.

192 *ibid.*, p. 10.

193 Mr Jerry Grandey, *op. cit.*, p. 11.

194 *ibid.*

within the nuclear industry the 'conventional view of Russian technology today is that it is as safe as, if not more robust than, some of the Western technology'.[195]

6.196 The UIC confirms these observations, noting that modifications have been made to overcome deficiencies in the 12 RBMK reactors still operating in Russia and Lithuania. Among other modifications, these have removed the danger of a positive void coefficient response, as occurred at Chernobyl. Automated inspection equipment has also been installed in these reactors. Later Soviet-designed reactors are said to be very much safer and the most recent ones have Western control systems or the equivalent, along with containment structures.[196]

6.197 More generally, the UIC notes that the Chernobyl accident led to the development of a safety culture in the former Soviet union, which has been encouraged by increased collaboration between East and West, and substantial investment in improving reactors. Over 1 000 nuclear engineers from the former Soviet Union have visited Western nuclear power plants since 1989 and over 50 twinning arrangements are now in place between East and Western nuclear plants, largely under the auspices of WANO. The UIC notes a number of other international developments aimed at improving nuclear safety in former Eastern bloc countries.[197]

6.198 Dr Rod Hill of the CSIRO argued that assessments must be made of the balance between the risk of an accident occurring and the consequences of the accident:

> We will always be grappling with that difference in relation to nuclear energy, I believe. The fear is that, although terribly unlikely, the consequence in the public's view is significant. My understanding is that the new generation of nuclear reactors significantly reduces the likelihood of a high-consequence incident … but one must balance that consequence of a potential accident, whatever form that may take, against the continuing, ongoing damage we are doing to our environment by the burning of carbon based fuels, unless we find a solution to that.[198]

6.199 In contrast, the UIC argues that the assertion that nuclear reactor accidents are 'the epitome of low-probability but high-consequence' risks is not accurate, as the consequences of an accident are likely to be much less

195 *ibid*.
196 UIC, *Safety of Nuclear Power Reactors, loc. cit*.
197 See: UIC, *Chernobyl Accident, loc. cit*.
198 Dr Rod Hill (CSIRO), *Transcript of Evidence*, 19 August 2005, p. 8.

severe than those from other industrial and energy sources, as evidenced by data in the following section.[199]

6.200 BHP Billiton also submitted that the response to the TMI accident shows that nuclear accidents can be successfully contained:

> I think even Three Mile Island can be taken as an example of how well things can be done rather than how badly things can be done, because that accident was contained and managed. I think you could use that to make a case that, even when things go … wrong, this can still be a viable and safe way of generating energy.[200]

Nuclear power compared to other energy sources

6.201 The UIC argued that, in comparison to other energy sources, nuclear power has a superior safety record, as indicated by the data for immediate fatalities and injuries from energy accidents for the period 1969 to 1996 in tables 6.7 and 6.8 below.

Table 6.7 Severe energy accidents with the five highest number of immediate fatalities (1969–1996)

Energy source	**Date**	**Country**	**Phase**	**Fatalities**
Oil	Dec 1987	Philippines	Transport	3 000
Oil	Nov 1982	Afghanistan	Distribution	2 700
Hydro	Aug 1979	India	Power plant	2 500
Hydro	Aug 1993	China	Power plant	1 250
Hydro	Sept 1980	India	Power plant	1 000
Chernobyl				
Nuclear	April 1986	Ukraine	Power plant	31

Source Uranium Information Centre, *Submission no. 12*, p. 11.

199 UIC, *Safety of Nuclear Power Reactors, loc. cit*.

200 Dr Roger Higgins (BHP Billiton Ltd), *Transcript of Evidence*, 2 November 2005, p. 23.

Table 6.8 Severe energy accidents with the five highest number of injured (1969–1996)

Energy source	Date	Country	Phase	Injuries
Natural gas	Nov 1984	Mexico	Distribution	7 231
Oil	Jan 1980	Nigeria	Extraction	3 000
Oil	April 1982	Mexico	Distribution	1 400
Oil	Oct 1988	Russia	Distribution	1 020
Oil	Dec 1982	Venezuela	Power plant	1 000
Chernobyl				
Nuclear	April 1986	Ukraine	Power plant	370

Source Uranium Information Centre, *Submission no. 12*, p. 11.

6.202 These claims are supported by the findings of a substantial and widely cited study, *Comprehensive Assessment of Energy Systems: Severe Accidents in the Energy Sector*, undertaken by the Paul Scherrer Institut (PSI) in Switzerland for the Swiss Federal Office of Energy, published in 1998. The study derived severe accident damage indictors, which were calculated for all stages of the energy production chains for coal, oil, natural gas, LPG, hydro and nuclear. The data, which is provided per terawatt-year (TWa) of electricity generated, is listed in table 6.9. The Chernobyl accident resulted in some 31 immediate fatalities (in 1986) and is shown in the table as having caused 8 fatalities per TWa of electricity generated.

Table 6.9 Severe accident damage indicators based on worldwide records (1969–1996)

Energy source	Immediate fatalities per TWa*	Injuries per TWa	Evacuees per TWa	Monetary damage (1996 US$ million)
LPG	3 280	13 900	522 000	1 740
Hydro	883	195	34 200	620
Oil	418	441	7 220	637
Coal	342	70	0	20.4
Natural gas	85	213	5 900	86.8
Nuclear	8	100	75 700	93 500

Source Adapted from Paul Scherrer Institut, *Severe Accidents in the Energy Sector*, p. 291.
* Figures converted from gigawatt years in the PSI study to TWa by the Canadian Nuclear Association to provide a table composed of whole numbers.

6.203 The data indicates that, in terms of immediate loss of life in severe accidents per unit of electricity generated, nuclear power is by far the safest of all forms of energy generation. The next safest, natural gas, has a fatality rate 10 times that of nuclear, coal is some 43 times that of nuclear and hydro has a fatality rate more than 100 times greater than nuclear.

6.204 The study also provides data for severe accidents in OECD and non-OECD records. In terms of the numbers of immediate fatalities per unit of electricity generated, nuclear is again by far the safest form of energy generation in both groups of countries. In the OECD countries, the study records that nuclear power has caused no fatalities or injuries, and is also the safest when delayed fatalities are included (i.e. the latent fatalities due to Chernobyl).[201]

6.205 The report states that while the fatality numbers are highly reliable, the numbers injured and monetary damage are less certain and must be interpreted with caution. Furthermore, while the economic loss associated with the Chernobyl accident is highly dominant, the report notes that estimates for the monetary damage due to the accident vary by an order of magnitude, from US$20 billion to $320 billion.[202]

6.206 The number of delayed fatalities associated with the Chernobyl accident, which was discussed in the preceding section, may rise to some 9 000 over the lifetime of the most exposed populations. In terms of the delayed fatality rates for nuclear, the PSI study states that:

> … in view of the drastic differences in design, operation and emergency procedures, the Chernobyl-specific results are considered not relevant for the 'Western World.'[203]

6.207 Probabilistic safety assessments of plant-specific health risks of representative western nuclear plants (two in the US and one in Switzerland) found a difference of several orders of magnitude between Chernobyl-based estimates of the frequency of delayed fatalities and probabilistic plant-specific estimates for the representative Swiss and US plants.[204]

6.208 FOE claimed that the burning of fossil fuels leads to a large number of fatalities due to the emission of toxic gases and particulates. However, it was claimed that, in addition to delayed fatalities due to Chernobyl, the data in table 6.9 fails to include an estimate of the fatalities arising from the routine radioactive emissions from nuclear fuel cycle facilities. As noted in the discussion of exposures to the public from the fuel cycle above, FOE and others claimed that about 80 000 fatal cancers are caused by routine operations of fuel cycle facilities. These submitters concluded that:

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201 PSI, *Comprehensive Assessment of Energy Systems: Severe Accidents in the Energy Sector*, PSI, Villigen, Switzerland, 1998, pp. 298, 292, viewed 26 September 2006, <http://gabe.web.psi.ch/pdfs/PSI_Report/ENSAD98.pdf>.

202 *ibid.*, pp. xix, 277.

203 *ibid.*, p. 298.

204 *ibid.*, p. 278.

> Compared to the overall fatalities from fossil fuel electricity or nuclear power, renewable energy sources—including hydroelectricity—are much safer.[205]

6.209 In addition to the catastrophic events listed in the tables above, the UIC noted that 6 027 workers died in 3 639 separate accidents in Chinese coal mines in 2004 alone. On average, there are 4.2 fatalities per million tonnes (Mt) of coal mined in China. This compares with 7 fatalities/Mt in Ukraine, 0.034/Mt in the US, and 0.009/Mt in Australia.[206]

6.210 The UIC noted that China plans to more than quadruple its nuclear power capacity to 40 gigawatts electric (GWe) (to 4 per cent of total projected electricity demand) by 2020, which will obviate the need to mine an additional 17 Mt per year of coal for power generation—thus avoiding some 71 additional coal-related deaths per year, based on the average fatality rate mentioned above.

6.211 However, ANSTO observed that even in Australia, with the safest coal mining record in the world, there have been 112 coal mining deaths in NSW alone since 1979 and 281 deaths Australia-wide in 18 major disasters since 1902. In comparison, there have been three deaths from accidents at uranium mines in Australia since 1979.[207]

6.212 Jindalee Resources and others argued that:

> Uranium mining is one of the safest industries operating in Australia. Whilst the special nature of uranium mining is recognised, and appropriate mine management systems are essential for the health and safety of all involved, uranium has been mined successfully in Australia for over 30 years without any serious loss of life or health associated issues. In contrast, coal mining world wide causes the deaths of 12,000 to 15,000 miners a year with China alone reporting 6,027 … deaths in 2004 and 6,200 in 2003.[208]

6.213 However, in comparing the numbers of fatalities in the coal industry with those in the nuclear industry, Dr Caldicott argued that for nuclear power:

> … workers are not followed up epidemiologically and it takes them up to 50 or 60 years to get their cancers, whereas when people are killed in coal mines you know because they are killed

205 FOE et. al., *Exhibit no. 71, op. cit.*, section 5.2.

206 UIC, *Submission no. 12*, p. 12.

207 ANSTO, *Submission no. 29.1*, p. 1; Dr Ron Cameron (ANSTO), *Transcript of Evidence*, 13 October 2005, p. 10. There has been one death at Ranger (in 1996) and two deaths at Olympic Dam (1992 and 2005).

208 Jindalee Resources Ltd, *Submission no. 31*, p. 3. See also: Mr Andrew Crooks, *Submission no. 84*, pp. 11, 17.

> that day … we are talking about something that is going to affect people and other species for the rest of time … when a cancer arises it does not denote its origin. This material is highly carcinogenic.[209]

6.214 Nonetheless, Jindalee Resources observed that while much is made of radiation risks associated with uranium mining, there is no public awareness that coal-fired power stations generate large quantities of fly-ash that is highly radioactive:

> I find it fascinating that if you go to a coal-fired power station and you look at the fly-ash that is around the power station, it is as radioactive as hell. The point that the public does not realise is that all coal is radioactive. At one stage I was in a plane and we had a big sodium iodide crystal to do some uranium exploration in South Australia. We flew over the Sir Thomas Playford power station at Port Augusta and we got the biggest uranium anomaly you have ever seen—from the fly-ash around the base of the coal-fired power station. One thing that people do not realise is that all fossil fuels are radioactive to some degree. In its concentrated form, with all the residue, coal is fiercely radioactive …[210]

6.215 Similarly, Summit Resources observed that:

> … it should also be noted that coal also contains uranium and generates radiation. Crustal uranium is readily dissolved by oxygen in rainwater and then by way of the water table flows downstream and when these ground waters come into contact with coal, mostly carbon and a natural reducing agent, the uranium is precipitated onto the coal which contains orders of magnitude more uranium than the average crustal material. Unlike nuclear plants, coal fired power stations do not 'burn' the uranium or manage their contaminated waste. The uranium is either sent up the smoke stack or left as contaminated fly ash waste at the plant.[211]

6.216 While conceding that nuclear power's safety record is 'encouraging', AMP CISFT also argued that this doesn't necessarily provide evidence that nuclear power is 'safe':

> For example, if nuclear reactors are designed to have an offsite fatality frequency of less than 1 every 10 million years, the calculated probability that there has been any accident leading to

209 Dr Helen Caldicott, *Transcript of Evidence*, 16 September 2005, p. 15.

210 Mr Donald Kennedy (Jindalee Resources Ltd), *Transcript of Evidence*, 23 September 2005, p. 58.

211 Summit Resources Ltd, *Submission no. 15*, p. 33.

> an offsite fatality from any of the commercial reactors, with a total of 11 000 reactor operating years, is approximately 0.11%.[212]

6.217 Summit Resources stated emphatically that 'the nuclear power industry is the safest form of power generation that man has used to date.'[213] In addition to the statistics for deaths of coal miners cited earlier, Mr Eggers noted that, in terms of deaths at power stations:

> … coal-fired power stations since 1997 have killed 6,500 people; natural gas, 1,200 people; hydro, 4,000 and maybe more, but this is usually to do with dam failures; and the nuclear industry has killed 31 people.[214]

6.218 Summit Resources also compared the risks associated with the transport of LNG:

> Here in Australia LNG is a very hazardous product. It is also a terrorist target. One of these tankers leaving the North West Shelf has the equivalent of 55 Hiroshima bombs sitting in it. This is mitigated, but, as we all know, it could cause up to hundreds of thousands of deaths in a major city where they deliver this fuel. Since 1989, Australia has shipped 1,600 shipments of these cargoes out of Australia without incident, due to a stringent safety regime.[215]

6.219 Nova Energy argued that risks in the mining of uranium are well understood and managed successfully:

> Continued developments in operational health and safety in the mining industry mean that the risks in the mining and handling of uranium are well understood and standard operating procedures are well used. Similarly, advances in the nuclear energy generating technologies clearly demonstrate a growing maturity in that industry.[216]

6.220 In relation to the routine operations of the nuclear power industry, the Committee also notes that the Fox Inquiry report concluded that:

> … while the operations of the nuclear power industry need close regulation and close surveillance, they probably do *not* entail risks greater in sum than those inherent in alternative energy industries. Certainly those risks provide *no proper basis* for a refusal on our

212 AMP CISFT, *op. cit.*, p. 6.

213 Mr Alan Eggers (Summit Resources Ltd), *Transcript of Evidence*, 3 November 2005, p. 2.

214 *ibid.*, p. 3.

215 *ibid*.

216 Mr Richard Pearce (Nova Energy Ltd), *Transcript of Evidence*, 23 September 2005, p. 69.

> part to supply the advanced industrial countries which are likely to be our customers.[217]

Terrorism and the safety of nuclear facilities

6.221 A principal concern of some submitters was the alleged vulnerability of nuclear power plants (NPPs) and other nuclear facilities to acts of terrorism. The IAEA has likewise identified the possible radiological hazards caused by an attack on, or sabotage of, a nuclear facility or a transport vehicle as one of four potential nuclear security risks.[218]

6.222 The MAPW (Victorian Branch) argued that:

> Nuclear reactors and associated facilities, particularly spent fuel storage facilities, which contain large quantities of long-lived radioactive substances, potentially pose a highly attractive target for terrorist attack. Indeed considering feasibility, visibility, large number of potential targets, potential for severe consequences, with persistent environmental contamination over large areas and need for costly clean-up, major social disruption following widespread fear and panic and need for evacuation of populations in the fallout path, economic damage and political effect, it is hard to envisage many more attractive potential targets for terrorists.[219]

6.223 MAPW (Victorian Branch) made a number of other claims, including that all current containment structures surrounding reactors could be breached by attacks such as those that occurred at the World Trade Centre (WTC) in New York in 2001. Attacks could also target more peripheral but important components of a plant's operations, such as cooling water conduits or plant safety systems. Simulated attacks on Russian and US reactors are said to have revealed significant vulnerabilities.[220]

6.224 MAPW and Dr Helen Caldicott also argued that spent fuel storage tanks are even more vulnerable than reactors, because these are allegedly often housed in simpler buildings with less robust containment structures. It was also argued that an attack on a reprocessing plant or spent fuel pools could result in greater and longer-lived radioactivity release than

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217 Mr R W Fox, *op. cit.*, p. 177. Emphasis added.

218 See: Dr Mohamed ElBaradei, *Nuclear Terrorism: Identifying and Combating the Risks*, Statement of the Director General, IAEA, Vienna, 16 March 2005, viewed 14 July 2006, <http://www.iaea.org/NewsCenter/Statements/2005/ebsp2005n003.html>.

219 MAPW (Victorian Branch), *Submission no. 30*, p. 13.

220 *ibid.*, p. 14.

following an attack on a reactor, because spent fuel pools contain larger concentrations of radioactivity than a reactor core.[221] It was submitted that:

> Thus even without the use of nuclear weapons, targeting of operating nuclear reactors and/or associated fuel storage or reprocessing facilities would essentially convert a war to a nuclear war, and a conventional terrorist attack into a nuclear attack.[222]

6.225 While it was conceded that preventative security measures are being implemented to reduce the likelihood of a successful attack, 'in the long-term only the complete dismantling of nuclear power plants will fully prevent such a devastating eventuality.'[223]

6.226 The UIC states that, since the events of 11 September 2001, various studies have examined similar attacks on nuclear power plants and, contrary to the MAPW's claims, these have concluded that reactor structures would protect reactor fuel from impacts of large commercial aircraft. One study, funded by the US Department of Energy, used a fully-fuelled Boeing 767-400 weighing over 200 tonnes flying at 560 km/hr. This study found that no part of the aircraft or its fuel would penetrate the containment structure. The analyses also showed no breach of spent fuel storage pools and that transport casks retained their integrity.[224]

6.227 In another test, conducted in 1988 by the Sandia National Laboratories (SNL) in the US, a rocket-propelled F4 Phantom jet was flown into concrete at 765 km/hr (to test whether a proposed Japanese nuclear power plant could withstand the impact of a heavy aircraft). The maximum penetration of the concrete in this experiment was six centimetres.[225]

6.228 Mr Stephen Mann, representing Areva, submitted that:

> I do not think the general population understand or realise the safeguards that exist now following the September 11 incidents. People were talking about aeroplanes flying into nuclear reactors. Aeroplanes can fly into any of the modern nuclear reactors and it would automatically shut down. There would not be any contamination. I do not think people really understand that.[226]

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221 MAPW (Victorian Branch), *Exhibit no. 52, Vulnerability of Us nuclear power plants to terrorists*, p. 2; Dr Helen Caldicott, *Exhibit no. 24, op. cit.*, p. 2.

222 MAPW (Victorian Branch), *Submission no. 30*, p. 14.

223 Cited in MAPW (Victorian Branch), *Exhibit no. 54, Nuclear Power and the Terrorist Threat*, p. 1. See also: FOE et. al., Exhibit no. 71, *Nuclear Power: No solution to climate change*, section 3.8.

224 See: NEI, *Deterring Terrorism: Aircraft Crash Impact Analyses Demonstrate Nuclear Power Plant's Structural Strength*, December 2002, viewed 29 September 2006, <http://www.nei.org/documents/EPRINuclearPlantStructuralStudy200212.pdf>.

225 UIC, *Safety of Nuclear Power Reactors, loc. cit*.

226 Mr Stephen Mann (Areva), *Transcript of Evidence*, 23 September 2005, p. 10.

6.229 Among its other responses to the WTC attacks, the NRC began an accelerated security and engineering review. The review looked at what could possibly happen if terrorists used an aircraft to attack a nuclear power plant. The potential consequences of other types of terrorist attacks were also assessed. The NRC analysed what might happen as a result of such attacks and what other factors might affect the possibility or magnitude of a radiation release.[227]

6.230 The NRC states that as part of the security review it has conducted detailed engineering studies of a number of nuclear power plants. The studies at the specific facilities confirmed that the plants are robust. It was also found that even in the unlikely event of a radiological release due to a terrorist attack, there would be time to implement the required offsite planning strategies already in place to protect public health and safety.

6.231 In relation to the security of spent fuel storage, the NRC considers spent fuel storage facilities to be robust so that in the event of a terrorist attack similar to those of 2001, no negative effect on the storage of radioactive materials would result. The NRC states that spent fuel pools and dry storage casks do not have flammable material to fuel long-duration fires, unlike the structures that were destroyed in the events of September 2001. However, the NRC states that it is conducting an evaluation that includes consideration of potential consequences of terrorist attacks using various explosives or other techniques on spent fuel pools and dry storage casks.[228]

6.232 Since September 2001 NPP security has been significantly strengthened and the NRC has issued new security requirements for plant sites. All US plants have met these requirements. NPPs must meet the highest security standards of any industry in the US. Since 2001, the US nuclear power industry has spent an additional US$1.2 billion on security-related improvements.[229]

6.233 More generally, the NEI states that the defence-in-depth philosophy used in the construction and operation of NPPs provides high levels of protection for public health and safety.[230] In addition to the reactor containment and reactor vessel construction, which are designed to be

227 NRC, *Frequently Asked Questions About Security Assessments at Nuclear Power Plants*, viewed 29 September 2006, <http://www.nrc.gov/what-we-do/safeguards/faq-security-assess-nuc-pwr-plants.html#1>.

228 NRC, *Frequently Asked Questions About NRC's Response to the 9/11/01 Events*, viewed 29 September 2006, <http://www.nrc.gov/what-we-do/safeguards/faq-911.html#17>.

229 NEI, *Post-Sept. 11 Security Enhancements: More Personnel, Patrols, Equipment, Barriers*, viewed 29 September 2006, <http://www.nei.org/index.asp?catnum=2&catid=275>.

230 NEI, *Nuclear Power Plant Security*, March 2005, viewed 29 September 2006, <http://www.nei.org/doc.asp?catnum=3&catid=290>.

impervious to catastrophes and to airborne objects up to a certain force, NPPs have:

- fortified physical barriers to resist penetration;
- armed security forces and advanced surveillance equipment;
- use of mock drills that ensure industry can protect against a threat by a well-trained paramilitary force intent on forcing its way into a plant to commit sabotage, armed with automatic weapons and explosives, with the assistance of an 'insider' who could pass along information and help to the attackers; and
- personnel procedures to protect from internal threats.[231]

6.234 Among a range of international initiatives to enhance nuclear security, in 2005 the UN General Assembly adopted the *International Convention for the Suppression of Acts of Nuclear Terrorism*. The Convention details offences relating to unlawful and intentional possession and use of radioactive material or a radioactive device, and use or damage of nuclear facilities. The Convention requires States Parties to make every effort to adopt appropriate measures to ensure the protection of radioactive material.[232]

6.235 The Committee addresses other security risks, including the risk of terrorist groups acquiring nuclear materials for the construction of nuclear weapons and the potential for Australian Obligated Nuclear Material (AONM) and other radioactive material to be diverted for use in 'dirty bombs', in chapter eight. Other Australian and international efforts to prevent, detect and respond to such attacks are discussed further in chapter eight.

6.236 While written in a different historical and strategic context, the Fox Inquiry report concluded that the risk of nuclear terrorism did not constitute a sufficient reason for Australia declining to supply uranium, but that the matter should be kept under constant scrutiny and control by Government.[233]

Depleted uranium

6.237 Some submitters expressed concerns about alleged health and environmental impacts of the use of depleted uranium, particularly depleted uranium used in munitions. It was also argued that an expansion of uranium mining would automatically lead to an increase in the amount of this material available for weapons production.

231 UIC, *Safety of Nuclear Power Reactors, loc. cit*.

232 IAEA, *IAEA Annual Report for 2005*, 'The year in Review', IAEA, Vienna, 2006, p. 7, viewed 29 September 2006, <http://www.iaea.org/Publications/Reports/Anrep2005/yearreview.pdf>.

233 Mr R W Fox, *op. cit.*, p. 178.

6.238 As described in the overview of the fuel cycle in chapter two, depleted uranium is a product (known as 'tails') of the uranium enrichment process. The UIC explained that every tonne of natural uranium produced and enriched for use in a nuclear reactor gives about 130 kg of enriched fuel (3.5 per cent or more U-235). The balance is depleted uranium (some 99.8 per cent U-238, with some 0.2 percent U-235). This major portion has been depleted in its fissile U-235 isotope by the enrichment process and is commonly known as DU. Consequently, DU is weakly radioactive and a radiation dose from it would be about 60 per cent that from natural uranium with the same mass.[234]

6.239 DU is stored either as UF_6 or it is de-converted back to U_3O_8 which is more benign chemically and thus more suited for long-term storage. It is also less toxic. Every year over 50 000 tonnes of DU is added to already substantial stockpiles in the US, Europe and Russia. World stocks of DU are about 1.2 million tonnes. [235]

6.240 Some DU is drawn from these stockpiles to dilute high-enriched (>90 per cent) uranium (HEU) released from weapons programs, particularly in Russia, and destined for use in civil reactors. This weapons-grade material is diluted about 25:1 with DU, or 29:1 with DU that has been enriched slightly (to 1.5 per cent U-235) to minimise levels of (natural) U-234 in the product.

6.241 Other than for diluting HEU for use as reactor fuel, DU also has applications where its very high density (1.7 times that of lead) is beneficial. DU is used in aircraft control surfaces, helicopter counterweights and yacht keels. The military uses of DU include defensive armour plate and in armour penetrating military ordnance. DU can ignite on impact if the temperature exceeds 600ºC. DU was widely used in the 1991 Gulf War (300 tonnes) and less so in Kosovo (11 tonnes).[236]

6.242 Ms Ilona Renwick submitted that:

> As well as causing severe injuries and death, depleted uranium remains in the soil or the air and has a half life for millions of years. Its potency remains during this time to cause radiation sickness, cancers, and birth defects.
>
> Death is likely from any one who comes in contact with it – contamination may occur just by working near it - breathing it in. This has been evidenced by the health effects on people who went

234 UIC, *Submission no. 12*, p. 33.

235 See: UIC, *Uranium and Depleted Uranium*, Nuclear Issues Briefing Paper No. 53, October 2005, viewed 29 September 2006, < http://www.uic.com.au/nip53.htm>.

236 *ibid*.

> into Iraq after the first Gulf War in 1991. Many of them have become sick and died.
>
> We have Australians who have been in those locations where the effects have been passed onto their children.[237]

6.243 The Darwin NO-WAR Committee submitted that:

> DU consists of approximately 99% uranium-238 which, while it has a relatively low level of radioactivity, is very dangerous if inhaled or ingested. It is not only radioactive but toxic, with a proven negative effect on DNA, nerve tissues and kidneys. In areas where DU weapons have been used (for example Basra in Iraq) large increases in cancers and birth defects are being observed. Troops stationed in areas where DU weapons have been used, or those who were in DU armoured tanks when they were hit, have been diagnosed with a range of symptoms consistent with radiation poisoning.[238]

6.244 It was argued that the effects of DU weapons reach beyond their immediate target, continue after the war and have an unduly negative impact on the environment: 'They also constitute an unduly inhumane risk for both civilians and combatants.'[239]

6.245 The PHAA also argued that concerns about the use of DU in munitions arose because of health problems suffered by people in Iraq following the 1991 Gulf War. PHAA pointed to UN cancer statistics for southern Iraq which were said to indicate a seven-fold increase in cancer during the period 1989-1994. It was also argued that the incidence of congenital malformations in Iraq has risen sharply since the Gulf War. In addition, many US Gulf War veterans are disabled by a range of symptoms, called Gulf War Syndrome, for which there was said to be no generally accepted explanation.[240]

6.246 Mrs Judy Forsyth also alleged that the :

> US and the UK have used depleted uranium shells in Bosnia and Iraq , causing cancers and leukaemia to thousands of soldiers and civilians. Thousands of Iraqi children have been affected with birth deformities which have been genetically inherited from parents who inhaled or ingested depleted uranium during and after the Gulf War. It is possible that these illnesses will be observed in Australian and other Coalition troops returning from Iraq in the

237 Ms Ilona Renwick, *Submission no. 76.1*, p. 1.

238 Darwin No-WAR Committee, *Submission no. 13*, p. 2.

239 *ibid.*, p. 3.

240 PHAA, *op. cit.*, p. 2

same way as US Gulf War veterans and their children were affected.[241]

6.247 Furthermore, Mrs Forsyth argued that there can be no guarantee that Australia uranium, exported to the US and UK, is not being used in the weapons.[242]

6.248 The PHAA urged the Australian Government to seek an immediate international moratorium on the use of DU munitions and an independent study on health and environmental effects of DU, including studies of both the civilian and the military populations that have been exposed.

6.249 The PHAA further urged the Australian Government to ensure that no DU munitions are used on Australian soil (e.g. in joint military exercises) and that no Australian troops join any military coalition in which DU munitions might be used. However, the PHAA acknowledged that the Australian Defence Forces no longer use munitions that contain DU.[243]

6.250 In contrast, the UIC submitted that depleted uranium is not classified as a dangerous substance radiologically. Its emissions are very low, since the half life of U-238 is the same as the age of the earth (4.5 billion years). There were said to be no reputable reports of cancer or other negative health effects from radiation exposure to ingested or inhaled natural or depleted uranium.[244]

6.251 Some military personnel involved in the 1991 Gulf War later complained of continuing stress-like symptoms for which no obvious cause could be found. These symptoms have at times been attributed to the use of depleted uranium in shells and other missiles, which are said to have caused toxic effects. Similar complaints arose from later fighting in the Balkans, particularly the Kosovo conflict.

6.252 Depleted uranium is a heavy metal and, in common with other heavy metals, is chemically toxic. Because it is also slightly radioactive, there is therefore said to be a hypothetical possibility that it could give rise to a radiological hazard under some circumstances such as dispersal in a finely divided form so that it is inhaled. However, because of the latency period for the induction of cancer for radiation, it is not credible that any cases of radiation induced cancer could yet be attributed to the Gulf and Kosovo conflicts. Furthermore, extensive studies have concluded that no radiological health hazard should be expected from exposure to depleted uranium.

241 Mrs Judy Forsyth, *op. cit.*, p. 4.

242 *ibid.*, p. 1.

243 PHAA, *loc. cit.*

244 UIC, *Submission no. 12*, p. 33.

6.253 Moreover, the UIC argued that the risk from external exposure is essentially zero, even when pure metal is handled. No detectable increase of cancer, leukaemia, birth defects or other negative health effects have ever been observed from radiation exposure to inhaled or ingested natural uranium concentrates, at levels far exceeding those likely in areas where depleted uranium munitions are said to have been used. This is mainly because the low radioactivity per unit mass of uranium means that the mass needed for significant internal exposure would be virtually impossible to accumulate in the body, and depleted uranium is less than half as radioactive as natural uranium.[245]

6.254 Information published by the WHO states that a recent UN Environment Program report, giving field measurements taken around selected impact sites in Kosovo, indicates that contamination by DU in the environment was localised to a few tens of metres around impact sites. Contamination by DU dusts of local vegetation and water supplies was found to be extremely low. Thus, the probability of significant exposure to local populations was considered to be very low.[246]

6.255 A two-year study by SNL reported in 2005 that, consistent with earlier studies, reports of serious health risks from DU exposure during the 1991 Gulf War, both for military personnel and Iraqi civilians, are not supported by medical statistics or by analysis.[247]

6.256 The WHO also noted that because DU is only weakly radioactive, very large amounts of dust (in the order of grams) would have to be inhaled for the additional risk of lung cancer to be detectable in an exposed group. Risks for other radiation-induced cancers, including leukaemia, are considered to be very much lower than for lung cancer. Further, the WHO states that no reproductive or developmental effects have been reported in humans.[248]

6.257 The conditions for the use of AONM set out in Australia's bilateral safeguards agreements, which are discussed at greater length in chapter eight, include the requirement that AONM will be used only for peaceful purposes and will not be diverted to military or explosive purposes. In this context, 'military purpose' includes depleted uranium munitions.

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245 *ibid*.

246 WHO, *Depleted Uranium*, Fact Sheet No. 257, January 2003, viewed 29 September 2006, <http://www.who.int/mediacentre/factsheets/fs257/en/print.html>.

247 See: SNL, *An Analysis of Uranium Dispersal and Health Effects Using a Gulf War Case Study*, SNL, Albuquerque, New Mexico, July 2005, viewed 29 September 2006, <http://www.sandia.gov/news-center/news-releases/2005/def-nonprolif-sec/snl-dusand.pdf>.

248 WHO, *Depleted Uranium*, *loc. cit.*

Radiation and public perceptions

6.258 Throughout the chapter, including in the immediately preceding discussion of the health effects of depleted uranium, the Committee has cited statements of concern about radiation exposure and its effects on human health from various submitters.

6.259 Other submitters responded that these concerns often reveal misunderstandings about the nature of radiation and misperceive the actual risks associated with radiation exposure from the normal operations of fuel cycle facilities, including uranium mining and milling. For example, Nova Energy submitted that:

> Some of these concerns are legitimate and as such they are acknowledged by the international community, and authoritative bodies such as the IAEA have been formed to mitigate specific risk. Other concerns appear to be emotive rather than rational and may, deliberately or otherwise, engender community fear and distrust of uranium mining and nuclear power. This in turn influences political policy. Nova Energy believes it is very important for the Committee to address these issues in its process to provide a fact based discussion for the Australian community.[249]

6.260 As explained at the beginning of the chapter, all human beings are constantly exposed to background radiation and the contribution from nuclear power is less than one per cent. Professor Leslie Kemeny explained that:

> Fear of unseen, unsmelled and untouchable radiation should be tempered by the fact that our global community lives in a radiation field called 'background radiation' which is inescapable and which is a natural variant of human existence just like temperature or humidity. The human body can safely accept large variations of background radiation dose which is a function of altitude, geology, occupation, building materials, sunspot activity, diet and many other factors. Background radiation doses in some buildings or limestone caves or even coal mines are often greater than that in a uranium mine or a nuclear power station!
>
> Around three-quarters of our radiation dose comes from natural sources such as cosmic radiation from the sun, radon gas in the air and radioactive materials in the ground, and in waters and oceans of the world. The human body itself is a significant radiation

249 Nova Energy Ltd, *Submission no. 50*, p. 26.

> source. At close encounter, human beings irradiate each other both day and night.
>
> Approximately one quarter of our background radiation dose arises from some form of human activity, such as medical diagnostic and therapeutic sources, the burning of coal and the use of electronic appliances. Within this segment the contribution from peaceful uses of nuclear energy and from past fallout from nuclear tests is less than 1 per cent.[250]

6.261 Based on his conviction of the hormetic effects of exposure to very low doses of radiation, Professor Peter Parsons also argued that opposition to nuclear power is in part due to 'acceptance by the public of phantom risks from radiation phobia based upon the invalid linear-no-threshold assumption'.[251]

6.262 Several submitters argued that the general understanding of radiation in Australia is poor and should be addressed in schools and through publicly available information. It was emphasised that there is a need for improved public education about the risks associated with radiation:

> The general level of understanding of radiation and radioactive processes in Australia is poor. Education … on nuclear matters needs to be addressed at both the school and general public levels.[252]

6.263 Similarly, Professor Ralph Parsons submitted that:

> Accurate information about the risks associated with ionising radiation must be more widely understood and disseminated before the concerns of the public about further uranium developments can be adequately addressed.[253]

6.264 Likewise, Arafura Resources argued that there is a need for public eduction around the nature and risks associated with radiation exposure:

> The public have to have a basic understanding of the nature of radiation and a point of reference, which might be that the radiation emitted by the sun or an X-ray you get at the surgery—which is beneficial to your health in diagnosing conditions that you may have in your body—can be managed by the dosage level. You might equate it to the same degree that you would allocate a conventional medicine, a Panadol tablet or something like that. You should only have so many Panadol per hour. The same

250 Professor Leslie Kemeny, *Exhibit no. 43, Pseudo-Science and Lost Opportunities*, pp. 4–5.

251 Professor Peter Parsons, *Exhibit no. 23, op. cit.*, p. 2.

252 Name withheld, *Submission no. 25*, p. 2.

253 Professor Ralph Parsons, *op. cit.*, p. 1.

> relative scale would be attributed to radiation. There are standards at the moment—there are ways of measuring and limiting exposure to it. The other issue is that the public think that radiation is being introduced into their lives. They need to know the background radiation level that exists around their lives—around their houses, beaches, rocks … That would be a better point of reference for them. It is about the magnitude. People see radiation as dangerous. They do not appreciate that there are different degrees and scales of radiation.[254]

6.265 Similarly, the Australian Nuclear Forum (ANF) argued that:

> … if decisions are made to move forward with our uranium industry, we submit that governments must prepare the population by giving them clear and simple information on matters of uranium and radiation safety. For too long—for a generation at least—the nuclear industry has suffered from myth and misinformation in the media and the schools, leading to fear in the public mind. There always will be some controversy, but governments have a duty to inform and to lead.[255]

6.266 Professor Kemeny emphasised that commonly held fears about radiation are often created and manipulated by the opponents of nuclear power. Accordingly, Professor Kemeny emphasised the importance of improved public education about nuclear matters and radiation in particular:

> For more than three decades, the Australian community has been assailed with false perceptions of danger or high risk emotively linked with such words as *radiation*, *research reactor* and *uranium*. In the absence of sound education and informed realism, some will react to this with fear and anger …
>
> The false assessment of nuclear risk is a favoured strategy of Australia's radical anti-nuclear activists, self-promoting eco-politicians with hidden agendas. It does not matter whether the infrastructure project is a uranium mine, a new research reactor, a nuclear waste repository or a nuclear plant …The radical activist will construct a threatening scenario to suit an eco-political objective. In this, informed realism, nuclear physics and the laws of probability play no part …
>
> The ultimate weapon of the anti-nuclear activist is it try to establish some causal link between low-level radiation and cancer. This false hypothesis forms the centrepiece of most 'anti-nuclear'

254 Mr Alistair Stephen (Arafura Resources NL), *Transcript of Evidence*, 23 September 2005, p. 51.
255 Mr Jim Brough (ANF), *Transcript of Evidence*, 16 September 2005, p. 43.

> campaigns. It is a powerful way of frightening people and controlling community attitudes …
>
> Many anti-nuclear activists are willing to perpetrate scientific fraud and exercise emotional blackmail in order to create radiation phobia in the minds of their audiences.[256]

6.267 Finally, Professor Kemeny argued that the benefits of nuclear science and technology, in the fields of medicine, industry and environmental science, outweigh any risks:

> In the new millennium there will be increasing use of nuclear science and technology in every field of human endeavour. The immense benefits far outweigh the risks. And the risks of radiation must be assessed on a scientific basis and with informed realism … The manipulative assessment of nuclear risk must not deprive humanity of these immense benefits.[257]

Conclusions

6.268 The Committee concludes that nuclear power, like all other major energy industries, is not and nor could it ever be entirely risk free. However, notwithstanding the tragedy of the Chernobyl accident, the nuclear power industry's safety record surpasses all others.

6.269 In the 50 year history of civil nuclear power generation, which spans more than 12 000 cumulative reactor years of commercial operation in 32 countries, there have been only two significant accidents to nuclear power plants—at Three Mile Island in 1979 and Chernobyl in 1986. Only the Chernobyl accident resulted in fatalities.

6.270 There have been some 60 deaths directly attributed to the Chernobyl accident to date. However, not all these deaths were due to radiation exposure. While there have been more than 4 000 thyroid cancer cases, particularly among children and adolescents at the time of the accident, fortunately there have only been nine deaths documented by 2002. The survival rate has been almost 99 per cent.

6.271 While the precise number of eventual deaths likely to be attributable to the Chernobyl accident is uncertain, the multi UN agency Chernobyl Forum report estimates that excess cancer deaths could rise to 3 960 over the lifetime of the most affected populations (Chernobyl liquidators, evacuees and residents of the strict control zones).

256 Professor Leslie Kemeny, *op. cit.*, pp. 4, 6. Emphasis in original.

257 Professor Leslie Kemeny, *Exhibit no. 9, op. cit.*, p. 3.

6.272 Projections for cancer deaths among some six million residents of contaminated areas in Belarus, the Russian Federation and Ukraine are much less certain because they were generally exposed to doses not much higher than natural background radiation levels. Projections are based on statistical estimates using information from the studies of atomic bomb survivors, who were exposed to much higher radiation dose rates (high doses in a short time period), and employ the conservative linear no-threshold assumption that risk continues in a linear fashion at lower doses. Estimates suggest that up to 4 970 additional cancer deaths may occur in this population from radiation exposure, or about 0.6 per cent of the cancer deaths expected in this population due to other causes.

6.273 That is, while emphasising that predictions should be treated with great caution, the Chernobyl Forum estimates that a total of up to 8 930 excess deaths from solid cancers and leukaemia might be expected over the course of a lifetime in the most exposed populations in Belarus, the Russian Federation and Ukraine. This is a population of more than 7 million people, comprised of Chernobyl liquidators, evacuees, residents of strict control zones and persons living in 'contaminated' areas.

6.274 Other Chernobyl-related radiation induced cancer deaths could occur elsewhere in Europe, although the dose to these populations is much lower again and the relative increase in cancer deaths is expected to be much smaller. Estimates for these populations are very uncertain and are not likely to be detected by monitoring national cancer statistics.

6.275 In any case, the Committee notes the Chernobyl Forum's findings that the most pressing health problems for areas most affected by the accident is *not* radiation exposure but poor life style factors associated with alcohol and tobacco use, as well as poverty. The largest public health problem has been the mental health impact. Persistent 'misconceptions and myths' about the threat of radiation have promoted a 'paralysing fatalism' among residents.

6.276 The Chernobyl accident resulted from a flawed Soviet reactor design which would never have been certified for operation under regulatory regimes of western nations. The reactor was operated with inadequately trained personnel and without proper regard for safety. In addition, the Chernobyl plant did not have a containment structure common to most nuclear plants elsewhere in the world.

6.277 At Three Mile Island in the US, the plant design contained the radiation and there were no adverse health or environmental effects.

6.278 The Chernobyl accident has led to a significant improvement in nuclear reactor safety worldwide, especially in the former Soviet Union where remaining reactors of the Chernobyl type have now been modified and in some cases shut down. The accident also led to increased international collaboration, peer review and knowledge exchange to improve plant safety, especially through the activities of WANO.

6.279 Evidence suggests that, as for many other industries, nuclear reactor technology continues to evolve. For example, some so-called third generation reactor designs are 'passively safe'; not requiring human intervention to prevent core melt accidents. Some fourth generation reactor designs, which represent the future for nuclear energy systems, are immune from the possibility of core melt accidents altogether.

6.280 While the Chernobyl accident could lead, over the lifetime of the most exposed populations, to several thousand excess cancer deaths, other energy sources are responsible for killing thousands of workers and members of the public every year. For example, in addition to catastrophic events (e.g. 3 000 immediate fatalities in an oil transport accident in 1987 and 2 500 immediate fatalities in a hydro accident in 1979), more than 6 000 coal miners die each year in China alone. Evidence suggests that coal mining worldwide causes the deaths of 12 000 to 15 000 miners each year. On this basis, the fatality rate from coal mining worldwide exceeds, in just two days, the fatalities to date from the Chernobyl accident. Even in Australia, 112 coal miners have died in NSW mines alone since 1979.

6.281 Moreover, the numbers of fatalities cited do not include the deaths and other health impacts likely to be caused by the release of toxic gases and particulates from burning fossil fuels. Neither do these considerations consider the possible health impacts and other risks associated with climate change arising from fossil fuel use.

6.282 Naturally, the Committee regrets that fatalities have been caused by any form of energy generation. However, the Committee believes that no base-load power system is without risk of injury or fatalities and, of these, the nuclear's industry's safety performance is demonstrably superior to all others.

6.283 In terms of the health hazards from the routine operations of nuclear fuel cycle facilities, evidence suggests that occupational radiation exposures are low. In fact, the average annual effective dose to monitored nuclear industry workers is less than the exposure of air crew in civil aviation, and is also less than the radon exposure in some above-ground workplaces.

6.284 Globally, exposure by the general public to radiation from the whole fuel cycle is negligible. The average annual natural background radiation exposure is 2.4 mSv. In comparison, the average dose received by the public from nuclear power production is 0.0002 mSv and, hence, corresponds to *less than one ten thousandth* the total yearly dose received from natural background.

6.285 Radiation exposure for workers at Australian uranium mines is well below (less than half) the prescribed average annual limit for workers of 20 mSv. The radiation exposure for the public in the vicinity of the mines is also far below the prescribed level of 1 mSv for members of the public. Indeed, at Beverley in South Australia, the nearest members of the public received a dose less than one hundredth the prescribed limit in 2005.

6.286 The Committee acknowledges there have been incidents at the Ranger mine, for which ERA has been prosecuted. This is evidence of a willingness by regulators to pursue the company where necessary, contrary to the claims by the industry's opponents. The Committee notes that ERA itself acknowledges that its performance in 2004 was not adequate and has taken steps to improve. The Australian Government is satisfied that the company has met the conditions required of it. The Committee also notes that the radiation doses received by workers and the public in the two incidents did not represent a significant health risk.

6.287 The Committee is persuaded that uranium industry workers in Australia are not being exposed to unsafe doses of radiation. However, to provide greater assurance to workers and the public at large, and also to definitively answer claims—which the Committee is confident are entirely mistaken—that current radiation exposures are harming workers, the Committee recommends the establishment of:

- a national radiation dose register for selected occupationally exposed workers; and
- a system of long-term monitoring of the health outcomes for workers occupationally exposed to radiation in uranium mining, associated industries and nuclear facilities.

6.288 It was emphasised that radiation protection standards are largely based on the LNT assumption that all radiation, even very low doses, carries some risk of damage to human health. The Committee well understands that this is the international norm, established by the ICRP, and accepts that basing protection standards on cautious assumptions is prudent. However, the Committee notes that there are arguments pointing to a beneficial effect from exposures to low doses of radiation, consistent with hormesis applicable to other environmental agents.

6.289 The Committee's primary concern is to ensure that fear of health risks from very low doses of radiation not be used as a justification to oppose further uranium mining and utilisation of nuclear power—particularly given that exposures to workers and the public in other industries (e.g. air travel) exceed that for the average nuclear industry worker and that natural background radiation, to which all people are constantly exposed, is significantly greater than the average public dose from the operation of the nuclear power industry.

6.290 In the Committee's view, some critics of uranium mining and nuclear power misconceive or exaggerate the health risks from the industry's operations, for example, by wildly inaccurate assessments of the deaths attributable to the routine operations of the industry. This detracts from the credibility of these submitters—as does the dismissal of the 600-page Chernobyl Forum report as a 'whitewash'. Such views have however influenced wider public opinion and public policy in a way detrimental to the industry, and have reduced the potential community and global benefits from use of nuclear power.

6.291 The Committee agrees that, evidenced by observations made by some submitters, that there are commonly held misperceptions about: the nature of radiation; exposures to the public from the operations of the nuclear power industry, medical procedures and natural background; and the health hazards associated with the nuclear industry's operations. Incorrect and exaggerated claims point to the need for the provision of authoritative information in this highly contested area of policy, particularly for the risks associated with exposure to radiation. The Committee returns to this matter in chapter 11 where it recommends strategies to improve public understanding in an attempt to dispel irrational fears associated with radiation.

6.292 In the following two chapters the Committee addresses the third objection to the use of nuclear power—nuclear proliferation and the effectiveness of safeguards regimes.