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Australia's uranium

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Executive summary

- Australia has the world’s largest resources of low-cost uranium.
- Australia currently exports about 10 000 tonnes of uranium oxide per year from three operating uranium mines.
- World demand for uranium exceeds current world production and will ultimately lead to more uranium exports from Australia and greater world prices.
- The future of Australia’s uranium industry will depend on the balance achieved between the environmental concerns surrounding nuclear power, proliferation issues and the possible greenhouse gas emission benefits of using uranium as a fuel.

Contents

Introduction

The past few years since the release of the Switkowski report on uranium mining, processing and nuclear energy and the House of Representatives Standing Committee on Industry and Resources report on Australia's uranium has seen less emphasis given to the use of nuclear power in Australia.[1] Nonetheless the need to reduce Australian greenhouse gas emissions and the approval of a fifth uranium mine for Australia means that the question of nuclear power for Australia and Australia's large uranium resources have been an ongoing theme in policy debate.[2]

In this context, Australia's large resources of uranium—the feedstock of nuclear power—will become more important. In addition, the growing gap between supply and demand of uranium has the potential to drive world prices higher, ultimately to the advantage of Australia's uranium miners.

This paper examines the issues of Australia's uranium in the context of world supply and demand, shows the factors affecting world prices, and looks to the future of the uranium industry in the environmental debate over greenhouse gas emissions.

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1. Department of Prime Minister and Cabinet, Review of uranium mining, processing and nuclear energy in Australia, *Uranium mining, processing and nuclear energy—opportunities for Australia?*, Department of Prime Minister and Cabinet, Canberra, 2006, http://pandora.nla.gov.au/pan/66043/20070301-0000/www.pmc.gov.au/umpner/docs/nuclear_report.pdf; and House of Representatives Standing Committee on Industry and Resources, *Australia's uranium—greenhouse friendly fuel for an energy hungry world*, Canberra, November 2006, http://www.aph.gov.au/house/committee/isr/uranium/report/fullreport.pdf. Both viewed 24 August 2009.

2. Australia's fifth uranium mine will be Four Mile in northern South Australia. See the Hon. Peter Garrett MP, 'World's best environmental practice for new mine', *Media release*, 14 July 2009, viewed 24 August 2009, http://www.environment.gov.au/minister/garrett/2009/pubs/mr20090714b.pdf. Also see, for example, Alexander Symonds, 'Joyce prefers nuclear to ETS', *Australian Financial Review*, 24 August 2009, p. 7, http://parlinfo.aph.gov.au/parlInfo/search/display/display.w3p;query=Id%3A%22media%2Fpressclp%2FX1HU6%22, viewed 9 September 2009 and Paul Howes, 'Nuclear the jewel in clean energy crown', *Australian Financial Review*, 19 August 2009, p. 63, viewed 9 September 2009, http://parlinfo.aph.gov.au/parlInfo/search/display/display.w3p;query=Id%3A%22media%2Fpressclp%2F7MFU6%22.

Uranium

Uranium is a naturally occurring radioactive element which is a mixture of several forms, or 'isotopes', of uranium.[3] Of these isotopes, uranium-235—referred to symbolically as ^{235}U—is capable of sustaining a nuclear chain reaction. A chain reaction can be controlled to release large amounts of energy which can be used to generate heat.[4] The heat energy released is used to generate steam which drives turbines which in turn generate electricity. Although other elements are also capable of sustaining chain reactions, uranium is the cheapest and most abundant.[5] Hence ^{235}U is of importance as a fuel in the nuclear reactors used to produce electricity in a number of countries worldwide.

Uranium—containing ^{235}U—is extracted from naturally occurring uranium ores. These ores are processed using acid or alkaline leach technologies to recover uranium concentrates which are bright yellow in colour and referred to as 'yellowcake'.[6] Yellowcake is then heated

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3. In simple terms, an element is a substance which cannot be changed into another substance by ordinary chemical processes. Iron, for example, is an element. A radioactive element is an element that has an unstable atomic nucleus—this sort of element spontaneously and randomly alters the state of its atomic nucleus emitting sub-atomic particles in the process. This process is called radioactivity. Isotopes are atoms of the same element but with different atomic nuclei.

4. A uranium atom when struck by a sub-atomic particle called a neutron, splits yielding two smaller atoms and several more neutrons giving off heat in the process. If the neutrons so released strike other uranium atoms and they in turn produce neutrons striking yet more uranium atoms, a chain reaction can result. This process is able to be controlled and the heat harnessed to produce the steam needed to drive steam turbines. See Ian Clark and Barry Cook, 'Uranium', Introduction to Australia's Minerals, vol. 5, Uranium Information Centre, 2000, p. 2. Note that the Uranium Information Centre is now defunct; some of its material is on the Australian Uranium Association web site at http://aua.org.au, accessed 24 August 2009.

5. The use of the element thorium as a nuclear fuel is also considered to have long-term potential. Uranium Information Centre, 'Thorium', *Briefing paper*, no. 67, November 2006, viewed 9 September 2009, http://parlinfo.aph.gov.au/parlInfo/search/display/display.w3p;query=Id%3A%22library%2Fjrnart%2FYP9U6%22 and World Nuclear Association, 'Thorium', viewed 24 August 2009, http://world-nuclear.org/info/default.aspx?id=448&terms=Thorium. See also Greg Baker, 'Thorium in Australia', *Research paper*, no. 11, 2007–08, Parliamentary Library, Canberra, 2007, viewed 9 september 2009, http://www.aph.gov.au/library/pubs/rp/2007-08/08rp11.pdf.

6. A description of these leach technologies can be found in Paul Kay, 'Beyond the three mines—in situ uranium leaching proposals in South Australia', *Research paper*, no. 12, 1997–98, Parliamentary Library, Canberra, 1998, viewed 9 September 2009, http://www.aph.gov.au/library/pubs/RP/1997-98/98rp12.htm; and Uranium Information Centre, 'In situ leach (ISL) mining of uranium', *Briefing paper*, no. 40, UIC, November 2006, viewed 9 September 2009, http://parlinfo.aph.gov.au/parlInfo/search/display/display.w3p;query=Id%3A%22library%2Fjrnart%2F0Q9U6%22.

to about 700°C to produce a dark powder containing more than 98 per cent uranium oxide—U_3O_8—which is placed in 200-litre steel drums for export.[7]

^{235}U does not form a high enough proportion of uranium in its natural state for the uranium to be useful as a fuel. The natural occurrence of about 0.7 per cent ^{235}U needs to be increased—'enriched'—to around three per cent ^{235}U.[8] Uranium producers in Australia do not attempt this process which needs highly specialised and expensive equipment. This enrichment process is carried out overseas using Australian-exported uranium. Eventually the ^{235}U-enriched uranium is used to manufacture fuel rods for nuclear power reactors in countries prepared to sign Australian nuclear safeguards agreements.

Australia's uranium resources

Australia has the world's largest resources of low-cost uranium (recoverable at costs of less than US$40 per kilogram of uranium), with approximately 40 per cent of known world resources in this category. It has 27 per cent of the world's resources recoverable at less than US$80 per kilogram of uranium and 22 per cent of the world's resources recoverable at less than US$130 per kilogram of uranium.[9]

In tonnage terms, Australia has 709 000 tonnes of uranium resources recoverable at costs of less than US$40 per kilogram of uranium; 714 000 tonnes of resources recoverable at costs of less than US$80 per kilogram of uranium; and 725 000 tonnes of resources recoverable at costs of less than US$130 per kilogram of uranium.[10] In effect this means that Australian uranium resources are mostly able to be extracted at low cost—as the above figures show it

7. Ian Clark and Barry Cook, op. cit., p. 11. Also see footnote 17 for the amount of uranium in U3O8.

8. ibid., p. 12.

9. OECD Nuclear Energy Agency and International Atomic Energy Agency, *Uranium 2007: resources, production and demand*, NEA and IAEA, Paris and Vienna, 2008, p. 17, viewed 9 September 2009, http://dpl/Ejournals/OECD_Uranium/2007.pdf. The figures given do not include inferred resources, which are resources which are believed to occur based on geological evidence. Note that the amount given for less than US$80 per kilogram includes the amount for less than US$40 per kilogram, and the amount for less than US$130 per kilogram includes the amounts for less than US$80 per kilogram and less than US$40 per kilogram.

10. ibid. Although these amounts appear small, it should be noted that one kilogram of enriched uranium ultimately yields about 360 gigawatt hours of electricity. Total annual electricity generation in Australia would need less than one tonne of enriched uranium which is less than five tonnes of uranium from the mine. Uranium Information Centre, 'The nuclear fuel cycle, 2006, viewed 3 August 2009, http://parlinfo.aph.gov.au/parlInfo/search/display/display.w3p;query=Id%3A%22library%2Fjrnart%2FLHHU6%22 and Electricity Supply Association of Australia, *Electricity Gas Australia 2008*, ESAA, 2008, Table 2.5, pp. 16–17.

has a mere 5000 tonnes recoverable at between US$40 and US$80 per kilogram and 11 000 tonnes recoverable at between US$80 and US$130 per kilogram.[11]

This resource base, and the potential to develop new mines and increase uranium production, makes Australia significant in the world uranium market.

Demand for uranium

Demand for Australia's uranium is ultimately a function of installed nuclear electricity capacity in countries prepared to sign up to an Australian nuclear safeguards agreement.

Worldwide there are currently 436 nuclear power plants in operation. Their total installed capacity is around 370 gigawatts electrical which is equivalent to about eight times the total installed capacity of all conventional electricity generation plants in Australia.[12] By the year 2030, it is expected that nuclear power reactors operating worldwide will have an installed electricity generating capacity of between 473 and 748 gigawatts electrical.[13] Factors which influence this growth in nuclear generating capacity include economic and population growth, energy security, environmental considerations, and the relative cost of nuclear power generation.

For some time now, world requirements for uranium have exceeded world production, with a proportion of requirements being met from the conversion of highly enriched uranium from obsolete military warheads. Additional supplies also come from uranium produced in the new states formed after the break up of the Soviet Union; these had not previously been provided to the world market.[14]

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11. House of Representatives Standing Committee on Industry and Resources, *Australia's uranium—greenhouse friendly fuel for an energy hungry world*, Canberra, November 2006, p. 81, http://www.aph.gov.au/house/committee/isr/uranium/report/fullreport.pdf, accessed on 24 August 2009.

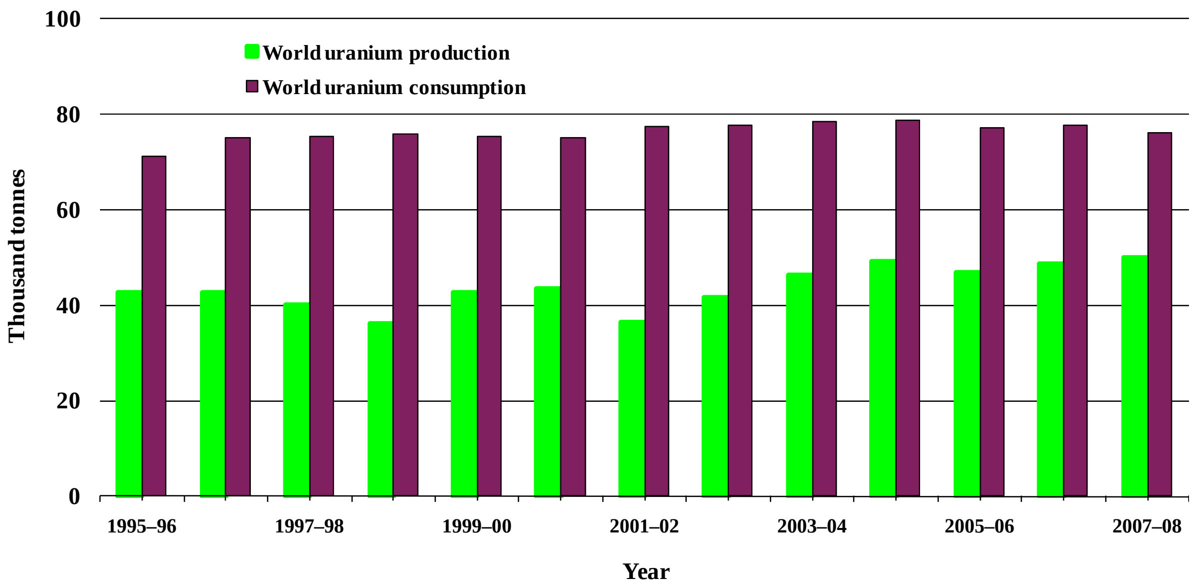
12. International Atomic Energy Agency, *Power Reactor Information System* at http://www.iaea.org/programmes/a2/index.html, accessed on 24 August 2009. In 2006–07, Australia's grid-connected installed generation capacity was 47 gigawatts. Energy Supply Association of Australia, *Electricity Gas Australia 2008*, ESAA, Melbourne, 2008, p. 14. Note that a megawatt is one million watts and a gigawatt is one thousand megawatts. One thousand watts (one kilowatt) is the amount needed to power a standard one-bar radiator.

13. International Atomic Energy Agency, *Energy, electricity and nuclear power estimates for the period up to 2030*, 2008 edition, IAEA, Vienna, 2008, p. 17.

14. Uranium is now supplied to the world market from Kazakhstan, the Russian Federation, and Uzbekistan. OECD Nuclear Energy Agency and International Atomic Energy Agency, *Uranium 2007: resources, production and demand*, NEA and IAEA, Paris and Vienna, 2008, p. 37, viewed 9 September 2009, http://dpl/Ejournals/OECD_Uranium/2007.pdf.

Graph 1 shows world production and consumption of uranium since 1995–96.[15]

Graph 1. World uranium production and consumption 1995–96 to 2007–08



Despite the obvious long-term imbalance and the consequent reduction in stockpiles, world uranium prices have not risen until the last few years. Low prices were due to the presence of a large world uranium stockpile, the use of uranium from the states of the former Soviet Union and the uncertainty of the outcome of political decisions concerning the use of military stockpiles and the de-commissioning of old warheads. Other factors included a low growth rate in world nuclear generating capacity and an expansion in global mine production. The peak in prices in 2007–08 was due to strong demand coinciding with concerns about the availability of future supply.[16]

Graph 2 shows monthly average world uranium spot prices since January 2000. Because of the dominance of the USA in the world uranium market, these prices are quoted as $US per pound of U_3O_8.[17] Although Australia's uranium is sold under long-term contract rather than onto the spot market, these spot prices do give an indication of the state of the world uranium market in which future contracts will be written. It is clear from these data that there has been a large increase in uranium spot prices in the past few years. Although prices have come back

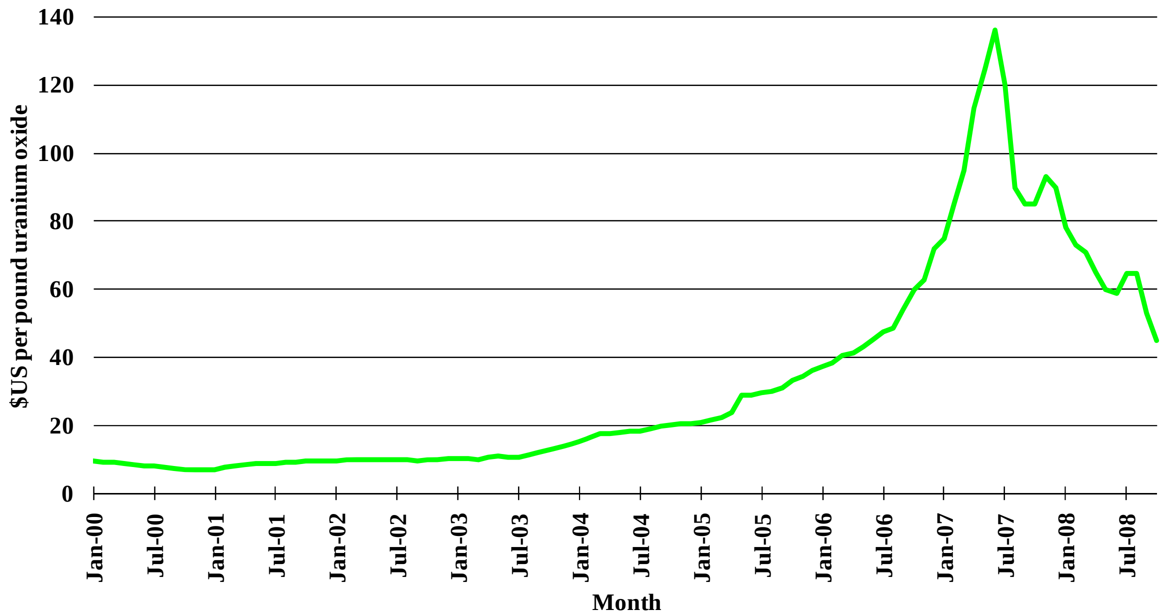
15. Graph data from Australian Bureau of Agricultural and Resource Economics (ABARE), *Australian commodities*, various issues, viewed 9 September 2009, http://www.abare.gov.au.

16. ABARE, *Australian commodities*, vol. 16, no. 1, March quarter 2009, p. 158, viewed 9 September 2009, http://www.abare.gov.au/publications_html/ac/ac_09/ac09_March_b.pdf.

17. One pound (0.45 kilograms) of U3O8 contain 0.85 pounds (0.39 kilograms) of uranium.

from their highs, Australian Bureau of Agricultural and Resource Economics (ABARE) predicts that an increasing demand coupled with declining secondary supplies will lead to a future increase in uranium spot prices.[18]

Graph 2. Uranium prices January 2000 to October 2008



Australian production and exports

Production of uranium in Australia makes up about one-fifth of world production. Production is from three mines—Ranger in the Northern Territory, and Olympic Dam and Beverley in South Australia.[19]

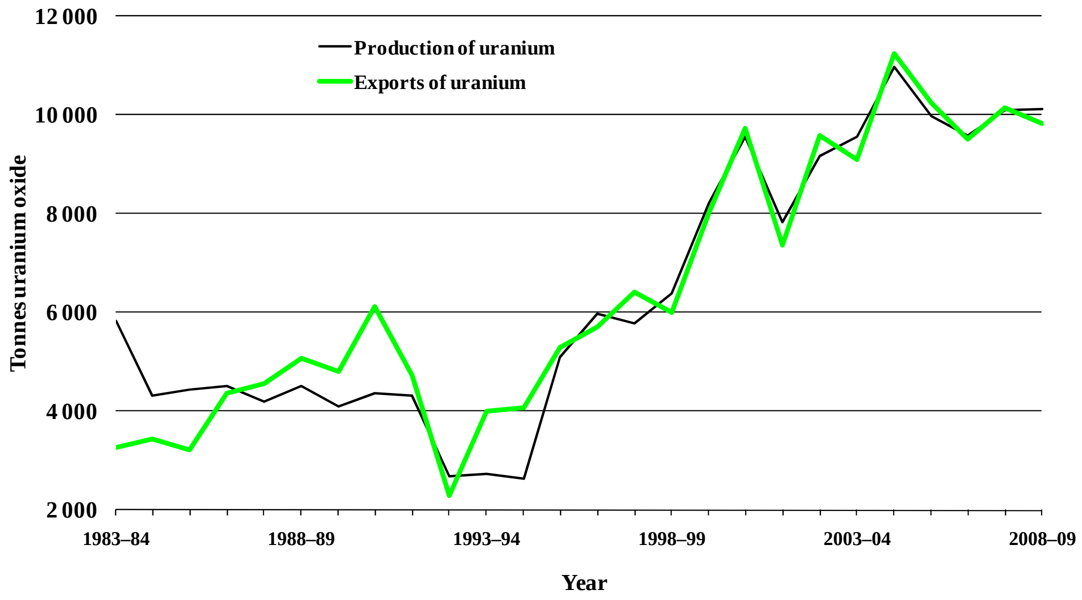
18. Graph data from ABARE, *Australian commodity statistics 2008*, p. 339, viewed 9 September 2009, http://www.abare.gov.au/publications_html/acs/acs_08/acs_08.html. For a discussion of future trends in the uranium spot price see ABARE, *Australian commodities*, vol. 16, no. 1, March quarter 2009, p. 158, viewed 9 September 2009, http://www.abare.gov.au/publications_html/ac/ac_09/ac09_March_b.pdf and *Uranium mining, processing and nuclear energy—opportunities for Australia?*, op. cit., p. 23, viewed 9 September 2009, http://pandora.nla.gov.au/pan/66043/20070301-0000/www.pmc.gov.au/umpner/docs/nuclear_report.pdf.

19. A fourth mine, Honeymoon in South Australia has been approved with production expected to begin in 2010. ‘Approval to mine’, *Canberra Times*, 30 September 2006, p. 4, viewed 9 September 2009, http://parlinfo.aph.gov.au/parlInfo/search/display/display.w3p;query=Id%3A%22media%2Fpre

Australian production and exports of uranium closely parallel one another—all Australian production is exported because there is no significant domestic demand.

Graph 3 shows that current production and exports are about 10 000 tonnes of uranium oxide per year.[20] Figures for 2008–09 included in the graph are ABARE forecasts.[21]

Graph 3. Australian production and exports of uranium 1983–84 to 2008–09



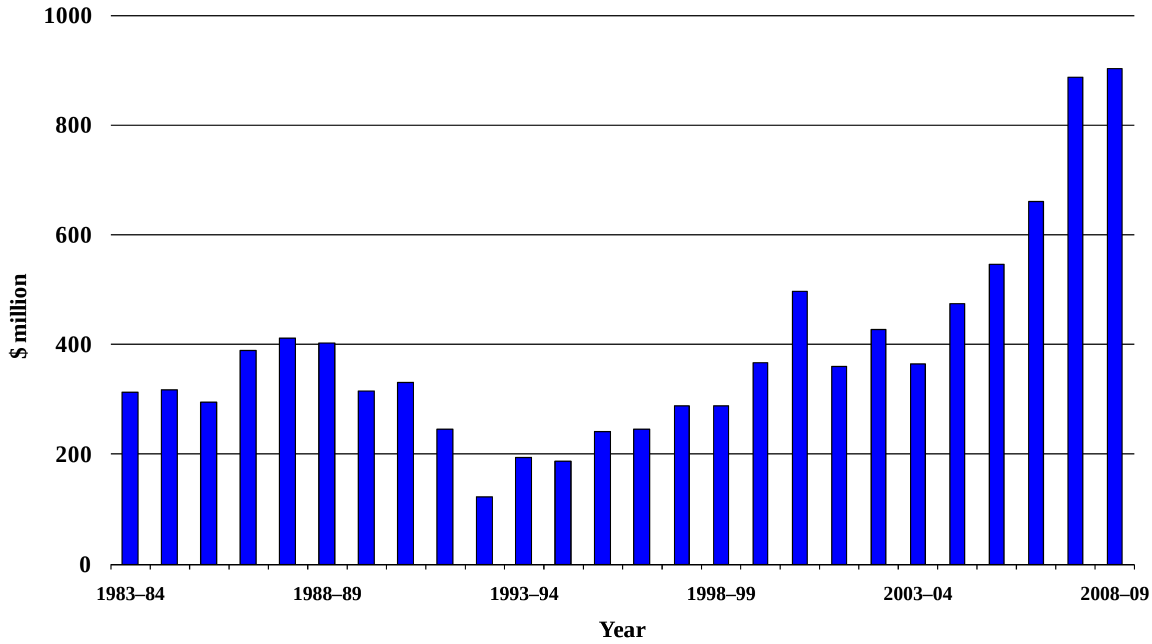
ssclp%2FKM0L6%22. Also see 'A uranium mine is good news for jobs—Australia has the resources to become a major energy player', *The Age*, 17 July 2009, p. 15, viewed 9 September 2009, http://parlinfo.aph.gov.au/parlInfo/search/display/display.w3p;query=Id%3A%22media%2Fpressclp%2FF25U6%22. Australia's fifth mine, Four Mile, in South Australia was approved in July 2009 [*The Age*, op. cit.]. Honeymoon is expected to produce about 400 tonnes of uranium oxide per year; see Uranium 1, 'Honeymoon project', viewed 4 September 2009, http://www.uranium1.com/indexu.php?section=uranium%20projects&page=5. Four Mile is expected to produce about 2000 tonnes per year; see Sally-Jane Tasker, 'Uranium makes a comeback', *The Australian*, 16 July 2009, p. 18, viewed 9 September 2009, http://parlinfo.aph.gov.au/parlInfo/search/display/display.w3p;query=Id%3A%22media%2Fpressclp%2F3V4U6%22.

20. Graph data from ABARE, *Australian commodities*, several issues, and ABARE, *Australian commodity statistics 2008*, p. 336, viewed 9 September 2009, http://www.abare.gov.au/publications_html/acs/acs_08/acs_08.html.

21. Australian Bureau of Agricultural and Resource Economics, *Australian commodities*, June quarter 2009, pp. 408 and 411, viewed 9 September 2009, http://www.abare.gov.au/publications_html/ac/ac_09/ac09_June.pdf.

Uranium is an important export earner for Australia. In 2007–08, for example, Australia exported $887 million worth of uranium. Graph 4 shows the value of Australian exports of uranium since 1983–84. In that period, exports have averaged about $400 million per year but, from a low of $123 million in 1992–93, exports have progressed to a forecast $903 million for 2008–09.[22]

Graph 4: Value of Australian uranium exports 1983–84 to 2008–09



Nuclear safeguards agreements

Australia applies nuclear safeguard conditions to the export of uranium. These safeguards, which began in 1977 and have been in place through several governments, are intended to ensure that Australian uranium is not used for, or diverted to, nuclear weapons programs.[23] In

22. Data sourced from Australian Bureau of Agricultural and Resource Economics, *Australian commodity statistics 2008*, p. 336, viewed 9 September 2009, http://www.abare.gov.au/publications_html/acs/acs_08/acs_08.pdf and ABARE, *Australian commodities*, vol. 16, no. 2, June quarter 2009, p. 401 and p. 408, viewed 9 September 2009, http://www.abare.gov.au/publications_html/ac/ac_09/ac09_June.pdf.

23. The Australian Safeguards and Non-Proliferation Office, *Annual Report 2007–08*, 2008, p. 18, viewed 9 September 2009, http://www.asno.dfat.gov.au/annual_report_0708/ASNO_2007_08_ar.pdf has the following:

    A fundamental tenet of the Australian Government's uranium policy is that Australia exports uranium only to countries which are a party to the nuclear Non-Proliferation Treaty (NPT), and practical terms, this is based primarily on the buyer being a signatory to the Nuclear Non-Proliferation Treaty.[24] In addition, Australia requires buying countries to enter into a bilateral agreement, thereby further ensuring among other things that the uranium is covered by International Atomic Energy Agency safeguards throughout its life; that Australian uranium is only transferred to third parties with Australian consent; and that the uranium is kept physically secure. Australia currently has 22 nuclear safeguards agreements which cover 39 countries plus Taiwan.[25] Compliance with Australia's nuclear safeguards policy is monitored by the Australian Safeguards and Non-Proliferation Office.[26]

The future

The future of Australia's uranium industry will depend largely on global growth in nuclear generating capacity. Concerns about the environmental effects of greenhouse gas emissions from coal-fired electricity generation and the uncertain price of oil will likely increase the importance of nuclear-powered electricity in the future mix of global energy sources. However, Australian and worldwide concerns about the environmental health dangers of mining and using uranium, the need to store nuclear fission products for very long periods of time, and the issues concerned with the de-commissioning of nuclear electricity reactors at the end of their useful life, may act to limit growth in nuclear generating capacity.[27]

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are within Australia's network of bilateral safeguards agreements. These agreements place obligations on the bilateral partner relating to nuclear material, which is subject to the provisions of the particular bilateral agreement, known as Australian Obligated Nuclear Material (AONM). Moreover, these obligations apply to uranium as it moves through the different stages of the nuclear fuel cycle as well as to material generated through the use of that uranium.

24. The full text of the Nuclear Non-Proliferation Treaty is at http://www.iaea.org/Publications/Documents/Infcircs/Others/infcirc140.pdf, accessed on 24 August 2009.

25. Australian Safeguards and Non-Proliferation Office, *Annual Report 2007–08*, 2008, p. 19, viewed 24 August 2009, http://www.asno.dfat.gov.au/annual_report_0708/ASNO_2007_08_ar.pdf.

26. The Australian Safeguards and Non-Proliferation Office is at http://www.asno.dfat.gov.au. A recent report of the Joint Standing Committee on Treaties (JSCOT) contained a range of views about the effectiveness of nuclear safeguards regarding exports of Australian uranium. See Joint Standing Committee on Treaties, 'Agreement with the Russian Federation on cooperation in the use of nuclear energy for peaceful purposes', *Review into treaties*, Report 94, Chapter 2, tabled on 14 May 2008, viewed 27 August 2009, http://www.aph.gov.au/house/committee/jsct/14may2008/report1/chapter2.pdf.

27. Environmental concerns have led to the closure of nuclear electricity reactors in several countries. Sweden's Barsebäck 1 power station was closed in 1999 following an earlier decision to close that country's nuclear industry. The decision was reversed in February 2009. See David Charter, 'Targets return Swedes to the nuclear family', *The Weekend Australian*,

7 February 2009, p. 12, viewed 9 September 2009, http://parlinfo.aph.gov.au/parlInfo/search/display/display.w3p;query=Id%3A%22media%2Fpressclp%2F52QS6%22. In Germany, many nuclear reactors were closed in the late 1980s and early 1990s and no new reactors are planned. See for example Nick Hordern, 'Red faces in Europe over greenhouse gas targets', *Australian Financial Review*, 24 February 2000, viewed 9 September 2009, http://parlinfo.aph.gov.au/parlInfo/search/display/display.w3p;query=Id%3A%22media%2Fpressclp%2F65W06%22 and the International Atomic Energy Agency's Power Reactor Information System at http://www.iaea.org/programmes/a2/index.html. For Germany, see also 'Nuclear power in Germany', World Nuclear Association at http://www.world-nuclear.org/info/inf43.html, viewed 25 August 2009.