Uranium Enrichment

fact sheet
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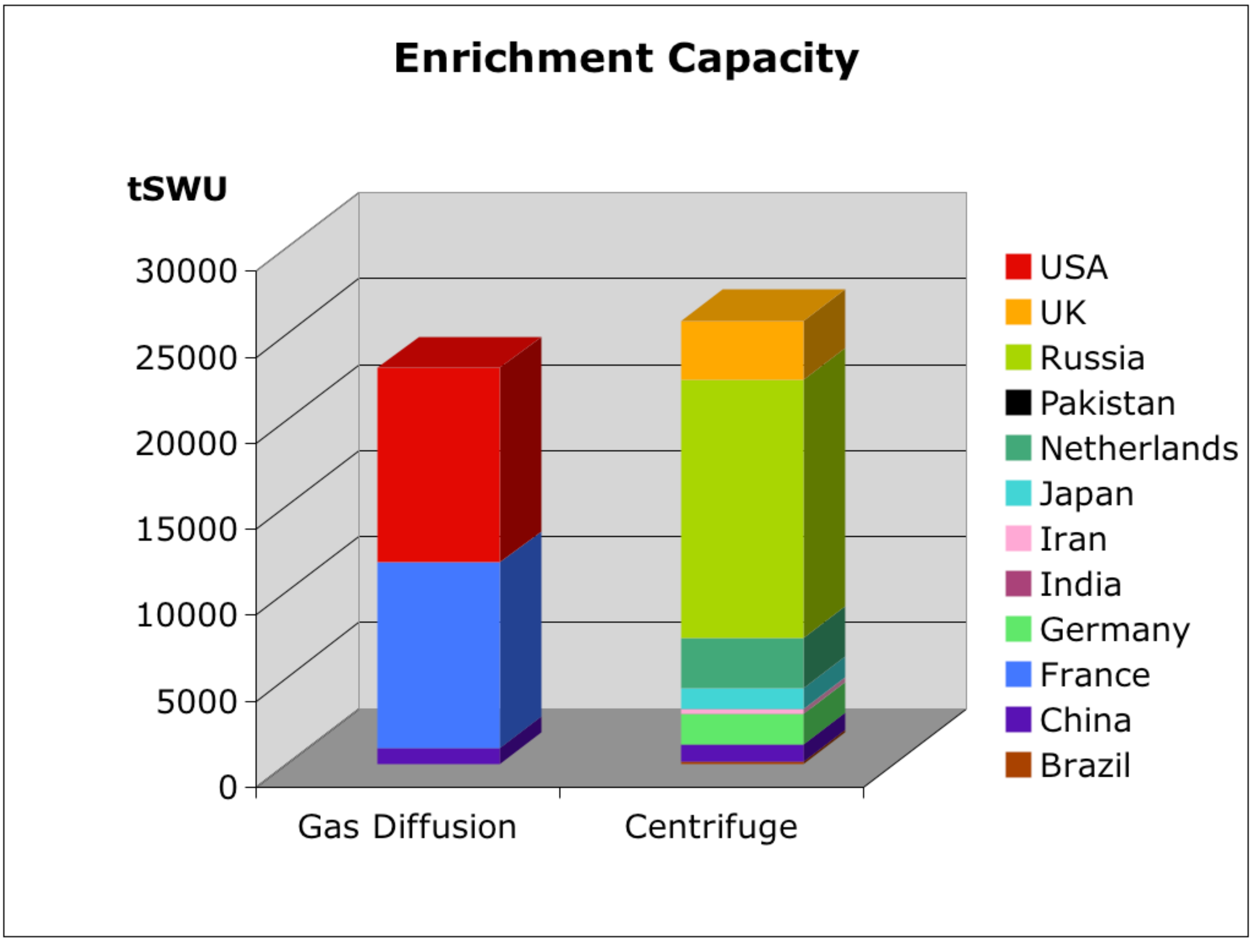

Civil enrichment plants can and have been have been misused in nuclear weapons programs.

The world's existing and planned enrichment capacity is able to meet present and foreseeable nuclear fuel supplies.

Over the last six months there has been a great deal of public attention paid to the possibility of Australia developing its own uranium enrichment industry. The Prime Minister has stressed the benefits of 'value adding' by processing uranium prior to it being exported. This fact sheet provides essential information to enable an interested citizen to assess this proposition.

Key Questions:

- What is uranium enrichment?
- How is uranium enriched?
- What safety issues are involved?
- Does uranium enrichment produce nuclear waste?
- What is the current or likely demand for more enrichment capacity?
- What about nuclear weapons proliferation?
- What other implications would there be for Australia?

What is uranium enrichment?

Enrichment is a process that increases the capacity of uranium to fuel a nuclear chain reaction, either for use in nuclear power plants or for nuclear weapons.

Uranium primarily occurs naturally as two isotopes: 99.3% is Uranium-238 and 0.7% is Uranium-235. Their atoms are identical except for the number of neutrons in the nucleus: Uranium-238 has three more and this makes it less able to fission. Uranium enrichment is used to increase the percentage of the fissile U-235.

Nuclear reactors typically require uranium fuel enriched to about 3% to 5% U-235. Nuclear bombs typically use 'Highly Enriched Uranium', enriched to 90% U-235, although lower levels of enrichment can be used.

How is uranium enriched?

There are a wide range of techniques for enriching uranium, all of which are based on using the slight differences between the heavier U-238 and U-235 to separate them. As a first step the uranium metal is turned into a gas (uranium hexafluoride, UF_6).

Methods which have been used include pumping the gas through membranes or nozzles, spinning it in centrifuges at speeds approaching the speed of sound, using slightly different chemical properties of the isotopes (caused by slight differences in the size of the atoms), and with lasers using different optical properties to create charged atoms or molecules by energizing some of their electrons. The most widely used is the centrifuge process, for producing both reactor grade and highly enriched uranium.

In the 1960s and 70s Australia maintained a research program at Lucas Heights into centrifuge enrichment. Australia currently has a research and development program, whose details are classified, for laser enrichment called SILEX (Separation of Isotopes by Laser Excitation). It has recently been licensed to General Electric Energy where the company hopes to develop a demonstration pilot separation plant.

What safety issues are involved?

Safety issues involved with enrichment include:

- Storage of depleted uranium in the form of uranium hexafluoride, UF_6. This is a highly corrosive and toxic chemical. Storage containers are subject to corrosion and consequently leakage and environmental damage. Storage yards have to be monitored and maintained, often for many years, until the material is dealt with. The scale of the amounts involved has created an almost intractable problem.
- Transport of the UF_6. Potential handling problems and dangers that may arise in the event of an accident.
- Protection against radiation. Workers have to be suitably protected and exposed as little as possible to the ionizing radiation that uranium emits, the danger of which increases with higher levels of enrichment.

Does uranium enrichment produce nuclear waste?

Since only a small proportion of the original uranium contains Uranium-235, large amounts of waste result from the enrichment process. This is depleted uranium (DU), a name that derives from the fact that much (but not all) of the Uranium-235 has been extracted from it. Despite this, it remains toxic and around 60% as radioactive as naturally occurring uranium. It is estimated that the global stockpile of DU is 1.3 to 1.5 million tonnes, much of which is stored as uranium hexafluoride, UF_6.

World demand for enrichment

At the current level of demand, the existing enrichment facilities exceed that needed for low enriched uranium used in commercial nuclear power stations.

The capacity of an enrichment facility to increase the percentage of U-235 is measured in 'Separative Work Units (SWU)'. Uranium enrichment plants typically have a capacity from a few hundred to several thousand tonnes SWU. The SWU required to enrich uranium depends on the enrichment level of the input and the required enrichment level of the output product. Typically the input stream will be natural uranium with only 0.7% U-235.

About 100-120,000 SWU is required to enrich the annual fuel loading for a typical 1000 MW light water reactor. Current worldwide production facilities can produce about 47,000 tSWU (Refer Table 1 and notes). This equates roughly to a capacity to supply 430 GW of electricity production, compared to the currently installed generation capacity of about 370 GWe.

Hence, unless the number of nuclear power stations increases significantly, there is sufficient enrichment capacity for the time being and probably at least for the next decade. Whether more will be required after that will depend on whether the dreams of the nuclear industry for a 'nuclear renaissance' are in fact realised in practice. At the moment the number of reactors under construction is less than the number of reactors likely to be retired because they are reaching the end of their lifetime.

Table 1 – Commercial Uranium Enrichment Capacity – tSWU per year

	Gaseous Diffusion	Centrifuge Plants
Brazil		120
China	900	1,000
France	10,800	
Germany		1,800
India		5
Iran		250
Japan		1,250
Netherlands		2,900
Pakistan		5
Russia		15,000
UK		3,400
USA	11,300	
	23,000	22,730
Estimated Total		**48,730**

tSWU is 1,000 kg SWU
Source: http://www.wise-uranium.org/efac.html, modified slightly using estimates for Brazil and Iran based on Makhijani.[1] Other sources differ, and there are uncertainties due to secrecy and the division between civil and military uses. Israel and North Korea's capacities are not publicly known. India's capacity has been estimated as 4,500 SWU and Pakistan at 9,000-15,000, some of which is for military applications.[2] Some additional capacity exists in laboratory and research facilities. New centrifuge plants are planned in France and the USA, although these may be to replace some older facilities. Argentina's plans are unclear.

Enrichment is a complex high technology process whose development has usually been heavily subsidised by nuclear aspirant governments. Developing a plant in Australia is unlikely to be feasible without using the expertise of the small number of existing consortia that specialize in it. Further, transport of uranium is not a large part of the cost of the nuclear fuel cycle, so there is little advantage to locating an enrichment facility near uranium mining.

Enrichment of uranium, even with the more efficient centrifuge process, is still highly energy intensive. A centrifuge plant typically requires 50 to 60 kilowatt hours of electricity per SWU produced. If a plant were to be built in Australia it would thus have to be powered, almost certainly by coal-fired electricity generating plants, thus producing significant increased greenhouse gas emissions and requiring additional generating capacity. This could be used as an argument to seek to also build a nuclear reactor. Since operating only one nuclear reactor is a very expensive proposition, this would be likely to be part of a proposal to build more reactors.

There are a number of new enrichment plants being built around the world, primarily to replace outmoded inefficient diffusion enrichment plants. This will further increase capacity. There thus does not seem to be a business case for building an enrichment plant in Australia at this time. This has been confirmed by BHP in recent testimony.[3]

Weapons Proliferation

In addition to providing the low enriched uranium for commercial nuclear power stations, enrichment facilities can also produce highly enriched uranium for use in nuclear weapons. Once uranium has been enriched to 3% for reactor fuel much of the work has been done to enrich it to weapons grade. For example, starting with natural uranium, a modern enrichment plant would take about 3.6 tonnes of uranium, and 4,000 SWU to produce the 20 kg of highly enriched uranium required for a modern Hiroshima style bomb. But starting with 3% enriched uranium reactor fuel it would take only about 520 kg of the reactor fuel and 1,500 SWU to do the same job.

Further, the same enrichment facility can be used to achieve weapons grade. Enrichment facilities, supposedly provided for peaceful purposes have been used in this way in the past, and therefore the spread of such facilities present a proliferation hazard. This may grow since the Nuclear Non-Proliferation Treaty framework is faltering in its effectiveness, and as North Korea has shown, countries may withdraw from it with only one month's notice. Please refer Fact Sheet 9 in this series for more details on nuclear proliferation.

Implications for Australia

Given that there is enough enrichment capacity in the world it is unlikely that commercial considerations would lead to the investment in an enrichment facility in Australia, particularly as there are no domestic nuclear power stations. As BHP Billiton has said "there is neither a commercial nor a non-proliferation case for it to become involved in front-end processing …".[4]

A uranium enrichment plant in Australia could also have a destabilising affect, with concerns having been expressed, for example, by a former Indonesian presidential advisor Dr. Dewi Anwar, who has said that Australia needs to reassure its neighbours that it has no desire to acquire nuclear weapons. "I think it's very important that Australia does assure the international community that it will not add another security threat to the already very unstable global situation at the moment," she said. "Indonesia and the (Association of South East Asian Nations) ASEAN countries would probably be concerned about Australia doing uranium enrichment until we get more details of it." Dr Anwar also says her country could consider the possibility of uranium enrichment. "Indonesia would also have the right to enrich uranium as long it is for peaceful purposes and within the IAEA (International Atomic Energy Agency) safeguards," she said. "Because Indonesia would not want to be totally dependent on a few nuclear suppliers." But the Foreign Affairs Minister has assured Indonesia that Australian uranium will not be used to make nuclear weapons. Alexander Downer says there is no cause for concern. "I would have that international security would have been better served by enriched uranium coming from a country as secure, as stable, as democratic and as responsible as Australia," he said.[5]

Further Reading:

BHP Billiton, Submssion to the Uranium Mining, Processing and Nuclear Power Review, 2006. http://www.dpmc.gov.au/umpner/submissions/223_sub_umpner.pdf

Institute for Energy and Environmental Research, Uranium Enrichment, 2004. http://www.ieer.org

Uranium Information Centre, "Uranium Enrichment", http://www.uic.com.au/nip33.htm

U.S. Nuclear Regulatory Commission, http://www.nrc.gov/materials/fuel-cycle-fac/ur-enrichment.html

Wikipedia, http://en.wikipedia.org./wiki/Uranium_enrichment

References:

1 Makhijani, A., et al., Institute for Energy and Environmental Research, Uranium Enrichment, 2004. http://www.ieer.org
2 Ramana, M. V., "An Estimate of India's Uranium Enrichment Capacity", Science and Global Security, 12:115-124, 2004.
3 Murphy, Katharine, "BHP says enriching uranium locally 'unviable'", The Age, 5/10/2006.
4 Murphy, op cit.
5 http://www.abc.net.au/news/newsitems/200609/s1731694.htm

About the Authors:

Professor Jim Falk has a PhD is in theoretical physics, and over the last 25 years he has specialised in the study of the nature, impact and management of science and technology in their social contexts. He is the author or co-author of over 100 scholarly papers and 5 books. He has published extensively on nuclear power and energy policy, was for a number of years a Ministerial appointee on the Alligator Rivers Region Environmental Technical Advisory Committee, and was recently appointed by the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) to assist as member of a three member expert panel to consider public submissions on the licensing of the new Opal nuclear research reactor at Lucas Heights.

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