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# Can nuclear energy reduce $CO_2$ emissions?

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In his Dame Pattie Menzies Oration on 18 April, science minister Brendan Nelson promoted nuclear energy as a means of reducing Australia's $CO_2$ emissions. He also implied that opponents of nuclear energy are hysterical, while proponents are rational. Therefore, it is timely to make a rational examination of the potential for nuclear energy to reduce $CO_2$ emissions.

Nuclear power stations themselves do not emit $CO_2$. But most of the energy inputs to the full life cycle of nuclear fuel come from fossil fuels and so are responsible for $CO_2$ emissions. The nuclear fuel cycle is a complex process with the following steps, some of which are large energy users:

- mining and milling to produce an oxide of uranium known as 'yellow-cake', $U_3O_8$;
- conversion into the gas, uranium hexafluoride, $UF_6$;
- enrichment to increase the concentration of the isotope U-235;
- fuel fabrication, where enriched $UF_6$ is converted into uranium oxide ($UO_2$) powder and pressed into small pellets which are inserted into fuel rods;
- power station construction;
- operation and maintenance of power station;
- interim storage of spent fuel;
- optional reprocessing of spent fuel;
- long-term waste management (which only exists in theory); and
- power station decommissioning (which has never been done for a large nuclear power station).

The energy inputs of several of these steps of the nuclear fuel 'cycle' have been investigated by authors who are independent of the nuclear industry: e.g. in 1991 by Nigel Mortimer, now Head of the Resources Research Unit at Sheffield Hallam University, UK; and independently in 2003 by Jan Willem Storm Van Leeuwin, a senior consultant in energy systems, together with Philip Smith, a nuclear physicist, both of whom are based in Holland.

They find that, especially for mining and milling and enrichment, the results depend sensitively on the grade of uranium used. For ***high-grade ores*** (i.e. those with at least 0.2% uranium oxide, $U_3O_8$) the energy inputs are indeed much less than the electricity generated. But the nuclear power station must operate for 7-10 years to generate its energy inputs. (For comparison, wind power requires only 3-6 months.) For a power station with lifetime 30-35 years, this is acceptable, although it introduces a limitation on the rate of growth of the nuclear industry, as discussed below.

For ***low-grade ores*** (less than about 0.01-0.02% $U_3O_8$, i.e. 10-20 times less concentrated than the high-grade ores), Van Leeuwin and Smith find that the fossil energy consumption in mining, milling and enrichment becomes so large that nuclear power emits more $CO_2$ than an equivalent gas-fired power station. Furthermore, the quantity of known uranium reserves with ore grades richer than this critical level is very limited. If 16% of the world's electricity production came from nuclear energy (i.e. the current situation), these high-grade reserves would only last about 19 years. This is hardly sufficient for a sustainable substitute for coal.

The World Nuclear Association (WNA) has written a reply of sorts to Van Leeuwin and Smith, see http://www.world-nuclear.org/, as an appendix to its 'Information and Issue Brief' entitled 'Energy Analysis of Power Systems'. The main body of the brief only considers high-grade uranium ore and focuses on the mechanism of enrichment. The appendix does not engage with the main issues that Van Leeuwin and Smith raise, but rather obscures them, e.g. by citing a report by the Swedish electricity utility, Vattenfall, that does not address the issues either. Van Leeuwin and Smith have rebutted WNA's 'reply' in detail -- see their website http://www.oprit.rug.nl/deenen/.

So, are there alternative future pathways for nuclear energy? Although there are vast quantities of uranium oxide in the Earth's crust, they exist mostly at very low concentrations, typically $4 \times 10^{-4}$ %, and so the energy inputs to extract them would be much greater than the energy outputs of the nuclear power station. Sea-water contains uranium at a concentration of about $2 \times 10^{-7}$ %, so the energy inputs to extract this uranium are likely to be very large, but an evaluation has never been published.

A possible solution would be to switch to fast breeder reactors, which produce so much plutonium that in theory they can multiply the original uranium fuel by 60. Large-scale chemical reprocessing of spent fuel would be necessary to extract the plutonium and unused uranium, and this has its own hazards and costs, since spent fuel is highly radioactive. In the USA three reprocessing plants were built at various times, but none was commercially viable and all have been shut down. However, non-military reprocessing is carried out in France and, until recently, the UK. In April 2005 the reprocessing plant at Sellafield in the UK was shut down, possibly permanently, because it was discovered that 83,000 litres of highly radioactive liquid leaked unnoticed from it for up 9 months. In practice only a little of the world's plutonium is being 'recycled' and vast quantities of high-level nuclear wastes, containing plutonium and highly radioactive fission products such as strontium-90 and cesium-137, are in temporary storages.

Fast breeders use liquid sodium as a coolant and so are more dangerous than ordinary nuclear reactors. So far, fast breeders have all been technical and economic failures. The largest was the French 1200 MW Superphénix, which commenced operation in 1985 as a commercial industrial prototype. It operated only intermittently and very rarely at full power, experiencing leaks from its cooling system and several accidents. It was shut down at the end of 1998 after costing an estimated total of about A$15 billion. This does not appear to be a fruitful pathway for nuclear energy.

Following the disaster at Chernobyl, many energy policy professionals have also questioned the continued use of the ordinary 'burner' reactor. They propose that any future development of nuclear energy should be based on new types of reactors that are 'fail-safe' and proliferation-proof. Since the nuclear industry appears unwilling to make large, risky investments in the development of new technology, this would require huge quantities of government funding. This is all the more reason for scrutinising rigorously the claims that nuclear energy can safely, sustainably and economically reduce $CO_2$ emissions in the long term.

A recent pro-nuclear study by the MIT in USA estimates that a new nuclear power station would generate electricity at US 6.7 cents/kWh (about 9 c/kWh Australian), although it found that there are opportunities for reducing this. For comparison, wind power at very good sites in the USA is currently priced in the range US 4-5 c/kWh and declining. In the deregulated electricity market of the UK, nuclear power was until recently subsidised to the tune of 1.2 billion pounds sterling per year, obtained from a levy on all electricity users. This amounted to 3 p/kWh or about A 6 c/kWh, far exceeding the current subsidy to renewable energy from the Australian Mandatory Renewable Energy Target.

Finally, the long period required by nuclear power to generate its energy inputs, even using relatively high-grade ore, entails that, during a period of rapid expansion of the nuclear power industry over several decades, more $CO_2$ emissions could be emitted than are saved. This was demonstrated as early as 1975 by Amory B. Lovins, CEO of the Rocky Mountain Institute, USA, and John Price, an Australian physicist. Eventually, possibly decades after the growth in nuclear power reached a plateau, there would be net $CO_2$ reductions. But by then there may be no more high-grade uranium ores.

So, on the basis of present technology and the small existing high-grade uranium reserves, the potential contribution of nuclear power to the reduction of $CO_2$ emissions is quite limited in quantity and could only be further implemented slowly, if it is to decrease $CO_2$ emissions.

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