REPORT SUMMARY
May 2007

Clearing the Air About Nuclear Power

Pembina Institute's Life Cycle Study of Nuclear Power

This summary report highlights the findings of the Pembina Institute's groundbreaking life cycle study of nuclear power and will be followed by a series of factsheets on specific issues, including mining impacts, climate impacts and waste.

Recently, Canadians have been hearing a lot about the supposed advantages of nuclear power, including government ministers touting it as a zero emission solution to climate change and nuclear industry television ads claiming that nuclear power is clean, reliable and affordable.

The Pembina Institute thinks it's time to get clear about the real facts on nuclear power. The Institute has taken a comprehensive look at the full spectrum of waste and pollution issues associated with all four major stages of nuclear energy production in Canada: uranium mining and milling; uranium refining, conversion and fuel fabrication; nuclear power plant operation; and waste fuel management.

Any cradle-to-grave analysis of an energy source is likely to find environmental and health impacts. However, the range and scale of impacts and risks associated with nuclear power production make it unique among energy sources.

Simply put, no other energy source combines the generation of a range of conventional pollutants and waste streams — including heavy metals, smog and acid rain contributors, and water contaminants — with the generation of extremely large volumes of radioactive wastes. Add to this accident, security and weapons proliferation risks that are not associated with any other energy source and this supposedly clean energy option looks a great deal dirtier and riskier.

Is nuclear power clean?

The nuclear power process leads to the release of hazardous and/or radioactive pollutants to air, land and water and is also — despite claims to the contrary — a source of greenhouse gases. Nuclear power production in Canada produces approximately 85,000 highly radioactive waste fuel bundles each year along with 500,000 tonnes or more of toxic and radioactive mine tailings (wastes left after uranium extraction).

In fact, each stage of the nuclear energy production process generates large volumes of uniquely hard-to-manage wastes — wastes that in many cases

Environmental impacts were examined for CANDU nuclear technology, the only reactor type currently in use in Canada. The study findings likely underestimate the overall impacts of the use of nuclear energy due to significant gaps in the publicly available information on releases of pollutants and contaminants, as well as on the fate of certain nuclear industry waste streams.

the PEMBINA institute
Sustainable Energy Solutions

For more information and references, please see the full report *Nuclear Power in Canada: An Examination of Risks, Impacts and Sustainability* at www.pembina.org

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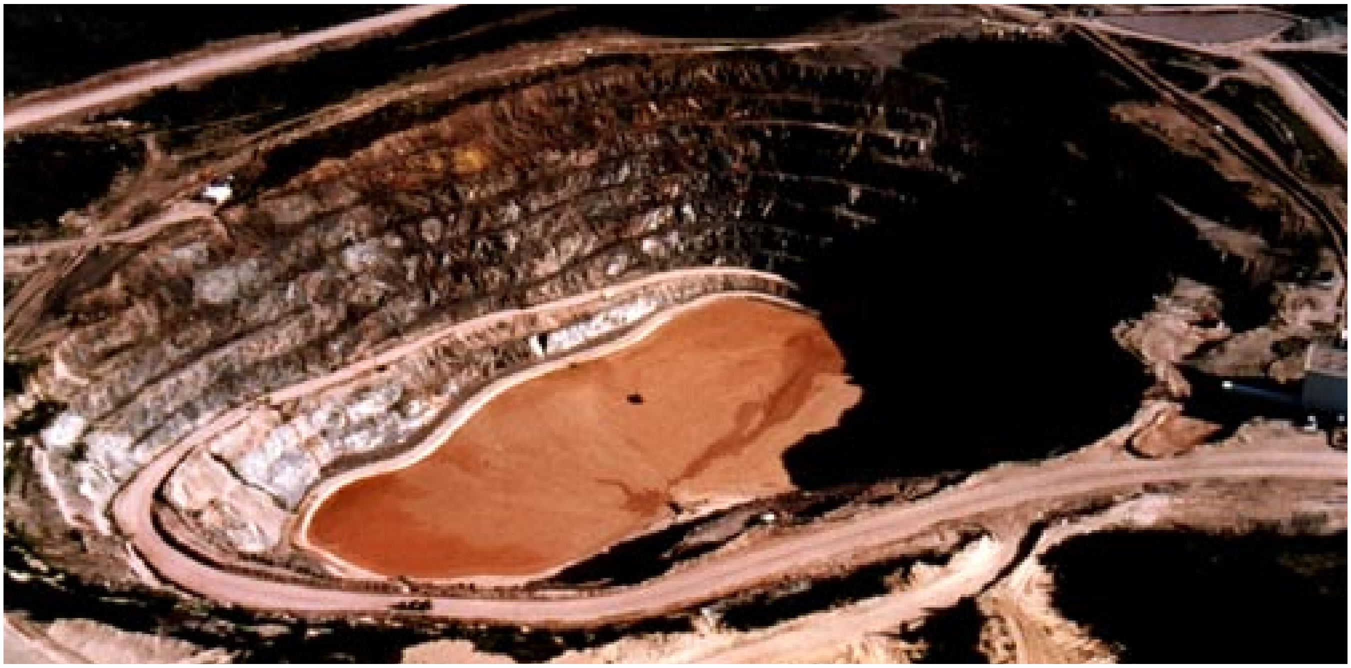


The Rabbit Lake Uranium Mine in northern Saskatchewan. Seventy-five percent of the uranium mined in Canada comes from open-pit mines, which produce up to 40 tonnes of waste rock for each tonne of ore that is extracted. Up to 85% of the radiological elements contained in the original uranium ore end up in the tailings after milling.

will require care not for hundreds, but for hundreds of thousands of years.

Currently, no approved long-term plans for the management of these wastes exist in Canada. Meanwhile, the history of failures in storage facilities for uranium mine tailings in Canada and elsewhere demonstrates the problems these waste streams can lead to, including severe contamination of surface water and groundwater with radioactive and conventionally toxic pollutants.

Is nuclear power sustainable?

Nuclear energy is no more a renewable energy source than oil or gas. It relies on a non-renewable and now declining fuel supply — uranium. World uranium prices have increased more than tenfold since 2001, reflecting a worldwide uranium shortage. It is estimated that current Canadian reserves of high-grade uranium will last 40 years at current levels of consumption (compared to estimated natural gas reserves of approximately 70 years).

If we are forced to turn to lower-grade uranium deposits in the future, the already substantial emissions (including greenhouse gas emissions) from uranium mining and milling operations will increase, as will the amounts of waste rock and tailings generated by uranium mines and mills.

Nuclear proponents suggest that that reprocessing waste fuel could be a way of dealing with both shrinking quantities of high-grade ores and the question of what to do with growing stockpiles of highly radioactive waste fuel. Reprocessing, however, has major waste and security risks of its own and would require the construction of extensive and expensive reprocessing facilities.

Fast breeder reactors that would create a near perpetual uranium-plutonium fuel cycle pose similar challenges and are thought to be decades away from even a prototype stage of development. Ideas like extracting uranium from seawater or using thorium as fuel in reactors are even less developed.

Is nuclear power greenhouse-gas emissions free?

Greenhouse gases (GHG) are released at each stage of the nuclear power production process. Power plant

A world wide shift to using nuclear power as a response to climate change would place pressure on high grade uranium ore reserves. The greenhouse gas emissions associated with nuclear would rise substantially if greater use is made of lower grade ores.

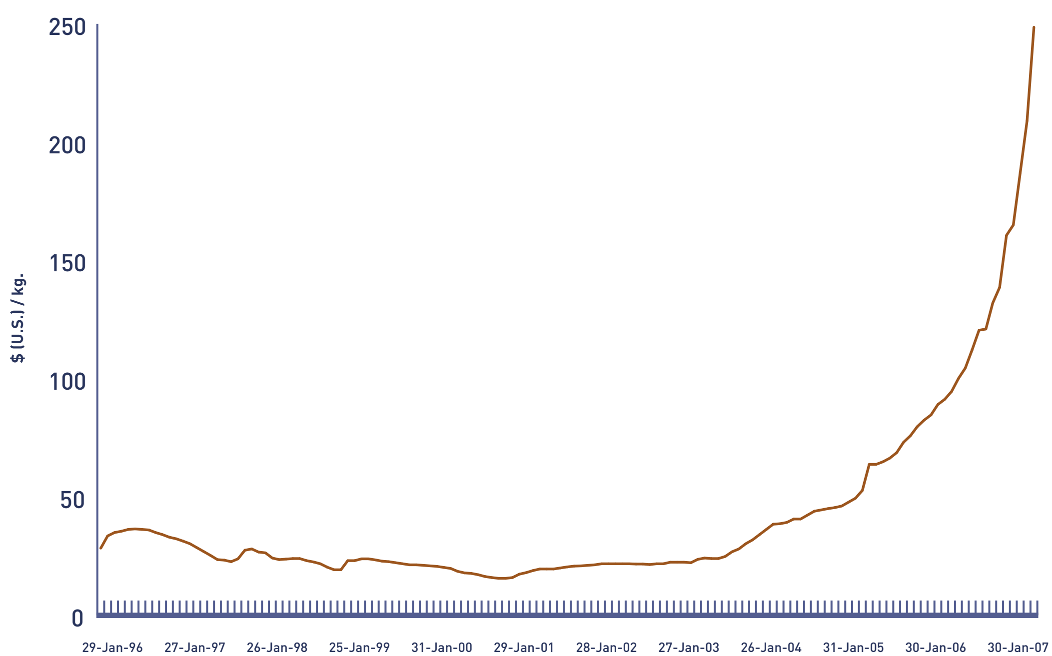
The report examined GHG emissions associated with using CANDU-type reactors. Producing enriched uranium fuel for other types of reactors can result in higher emissions of greenhouse gases, particularly where gas diffusion-based enrichment processes are employed. CANDU reactors, on the other hand, produce greater volumes of waste fuel.

construction is generally accepted as the most significant source of direct releases. Further releases of GHGs occur through the operation of equipment in the uranium mining process, the milling of uranium ore, mill tailings management activities, and refining and conversion operations. Significant releases of GHGs may also occur in the processes of plant refurbishment and decommissioning, the management of waste fuel and other radioactive wastes, and the decommissioning and remediation of uranium mine sites.

Overall, while the GHG emission profile of nuclear power looks attractive when compared with conventional fossil fuel sources, it is also clear that it is far from zero. At the same time nuclear power's GHG emission profile is generally higher than that of low-impact renewable energy sources like wind and run of the river hydro. A world wide shift to using nuclear power as a response to climate change would place pressure on high grade uranium ore reserves. The greenhouse gas emissions associated with nuclear would rise if greater use is made of lower grade ores, due to the need to extract and process more ore to produce the same amount of uranium for use as fuel in nuclear reactors.

It is not simply the direct GHG emissions from nuclear plants, however, that we have to consider when examining the usefulness of nuclear power as

URANIUM PRICE TRENDS — JANUARY 1996-APRIL 2007



Uranium prices have soared as a surplus of uranium from the decommissioning of Soviet-era nuclear weapons has been consumed and high-grade ore bodies have been depleted.

Some Ontario nuclear plants have had average operating capacities below 40% rather than the expected 85–90% range. Reactors expected to last approximately 40 years have required major repairs and rebuilding after 25 years or less.

a climate change solution. In Ontario, the poor performance of nuclear units (see next section) has led to a dramatic increase in reliance on carbon-intensive coal power. The need to replace the power from the eight reactors shut down for repairs in 1997 meant that emissions of GHGs and sulphur dioxide from the province's coal-fired power plants more than doubled, while nitrogen oxide emissions increased by 170%. In fact there was a 120 megatonne increase in GHG emissions from the province's electricity generators due to of the reactor failures in the 1996-2006 period.

Is nuclear power reliable?

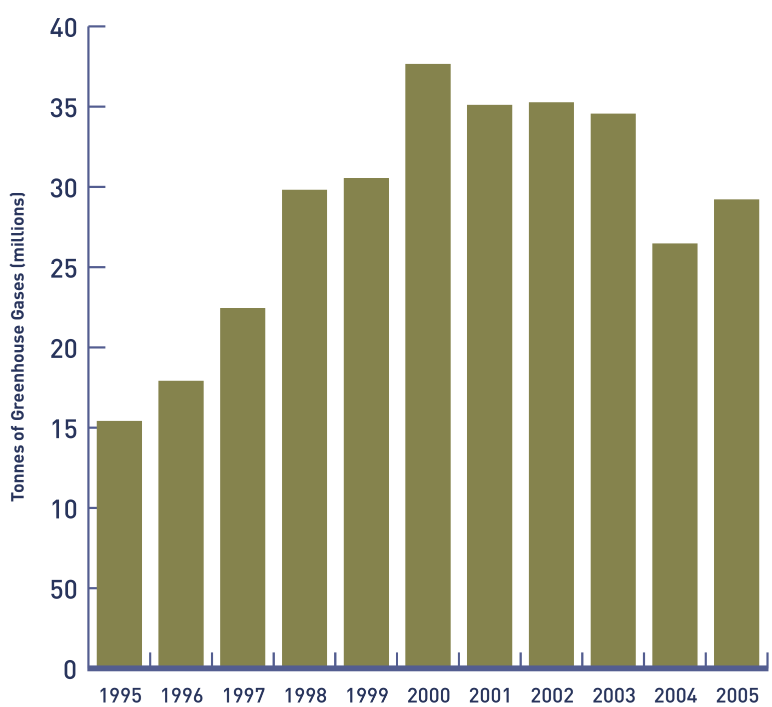
The Ontario CANDU reactor fleet has a record of severe performance and maintenance problems. Over the past decade, some Ontario facilities have had average operating capacities below 40% rather than the expected 85–90% range. Reactors expected to last approximately 40 years have required major repairs and rebuilding after 25 years or less of service. Refurbishment projects themselves have run hundreds of millions of dollars over budget and years behind schedule.

Is nuclear power a cost-effective solution?

Nuclear power generating facilities have very high capital costs and long construction times compared to other electricity supply options. In Ontario, the history of serious delays and cost overruns on nuclear generating facility projects is responsible for $15 billion of the nearly $20 billion "stranded debt" left by the former Ontario Hydro. Ontario electricity consumers now pay down that debt through charges on their electricity bills.

Nuclear energy also brings with it a unique set of financial risks, including the very high costs and uncertainty involved in handling, storing and managing waste fuel and other radioactive materials. The Nuclear Waste Management Organization estimates, for example, that implementing its proposed strategy for managing waste fuel from existing reactors would cost in the range of $24 billion and would take more than 300 years. This would be in addition to the costs for developing and managing facilities for low and intermediate level radioactive waste and

TOTAL GREENHOUSE GAS EMISSIONS FROM ONTARIO COAL-FIRED GENERATING STATIONS 1995-2005



As premature aging led to the shutdown of Ontario nuclear units in the 1990s, use of coal soared — as did GHG emissions. Now the Ontario Power Authority is recommending keeping coal plants operating until 2014 to provide "insurance" power, against future nuclear failures.

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for managing waste rock and tailings at uranium mine sites. Meanwhile, the costs of decommissioning Ontario's existing aging reactors have been estimated at $7.474 billion.

In light of these costs and risks, the only circumstances under which private investment in nuclear energy ever occurs is when governments (i.e., taxpayers and ratepayers) guarantee profits and markets and assume the major risks and liabilities for cost overruns, fuel and waste disposal costs, decommissioning and accidents. Even under these kinds of "sweetheart deal" conditions, private investors have been reluctant to invest in nuclear power. In fact, when Bruce Power Inc. signed a $4.5 billion agreement with the Government of Ontario to refurbish two reactors — a deal that included all of these kinds of guarantees and more — one of its partners, Cameco Corp., a company in the business of uranium mining and nuclear fuel production, bowed out citing insufficient returns.

Is nuclear power safe?

Our understanding of radiation risks has changed a lot since the construction of Canada's first commercial power reactors in the early 1970s. For example, recent research on the effects of even very low levels of ionizing radiation suggests that no level is safe to health. The International Agency for Research on Cancer (IARC) lists a number of radionuclides as carcinogenic, including isotopes produced in uranium mining and milling, fuel production and nuclear power plant operations.

Despite our better understanding of these risks, Canadian standards and practices have not kept pace. For example, the existing drinking water standard in Ontario for tritium (discharges from nuclear power plants are the primary source) of 7,000 Bq/L is significantly weaker than the standards in the United States of 740 Bq/L and in the European Union of 100 Bq/L. Workers in the mining and refining, conversion and fuel fabrication facilities are also routinely exposed to levels of radiation that would be considered unacceptable for members of the general public.

The Darlington nuclear power plant, east of Toronto, is the last nuclear power plant built in Canada. Completed in 1993, the plant was originally budgeted to cost $4 billion. The final cost was over $14 billion.

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As well, researchers have pointed to substantial health risks related to the eating of certain types of "country" food — particularly caribou — found in the vicinity of uranium mine and mill operations as a result of contamination of these animals' food sources, particularly lichens, by radionuclides.

Of course, what makes nuclear plants unique is what happens if something does go wrong. A serious accident or incident could result in the release of large amounts of radioactive material to the atmosphere, which could then spread over a large area. By comparison, the impacts of major incidents or accidents at more conventional power facilities would be short term and largely limited to the facilities themselves.

Finally, nuclear energy's shared beginnings with nuclear weapons programs has led to strong links between the technologies and materials used for energy production and for nuclear weapons development. Concerns about these connections have grown in the past few years due to of nuclear programs in North Korea, Iran, India and Pakistan. Any large-scale expansion of reliance on nuclear energy would carry the significant risk of the spread of materials and technologies that could be used for weapons development. India's 1974 nuclear bomb test, a project developed in part using Canadian-supplied technology and uranium, demonstrated this problem all too clearly. These risks would become even greater with fuel reprocessing or the development of fast breeder reactor technology.

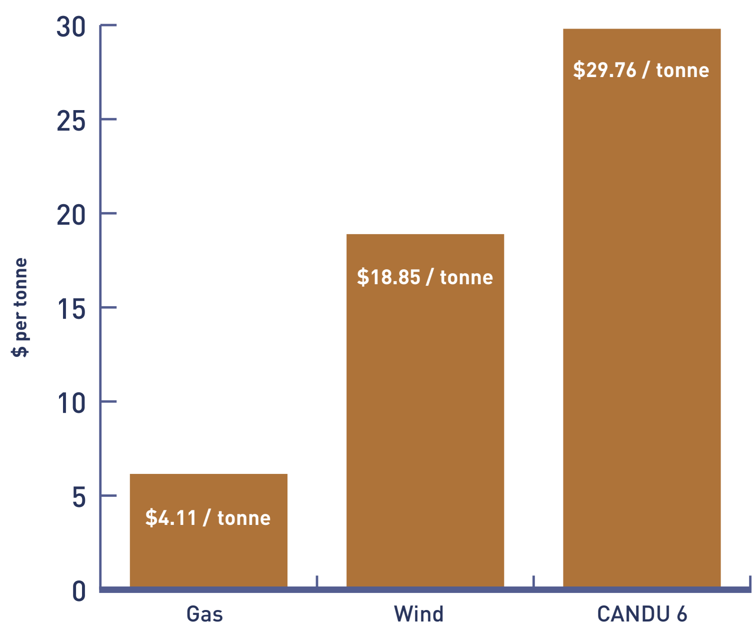
The big picture

Turning to nuclear power to address climate change would mean trading the problem of greenhouse gas emissions, for which a wide range of other solutions exist, for several complex and difficult problems for which solutions are generally much more costly and difficult — if they exist at all.

Added to that, the history of poor performance, high costs and declining reliability that has been the real history of the CANDU nuclear program in Canada makes the idea of re-investing billions of dollars in nuclear energy look much less attractive than a simple comparison of GHG emissions from various conventional energy sources might first suggest.

Proponents of nuclear energy often present the situation as a choice between expanding the role of

COMPARATIVE COST FOR GREENHOUSE GAS REDUCTIONS



The Ontario Clean Air Alliance used data from CIBC World Markets and the Ontario Power Authority to calculate the cost per tonne for greenhouse gas (GHG) emissions for three energy sources: natural gas (combined cycle), wind and nuclear. Nuclear power-driven GHG emission reductions were by far the costliest.

The reality is we have a wide range of options for keeping the lights on while significantly reducing GHG emissions, without having to resort to the high-risk and high-cost nuclear option.

nuclear power or risking blackouts and continuing on a business as usual path towards increasing GHG emissions and global climate change. The reality is that we have a wide range of options for keeping the lights on while significantly reducing GHG emissions without having to resort to the high cost and high-risk nuclear path. A combination of energy efficiency improvements, fuel switching, low impact renewable energy sources, and high efficiency uses of natural gas can provide the foundation for a low GHG emission energy system. Those kinds of options should be the focus GHG reduction strategies and future energy policies.

Nuclear energy production waste streams – a synopsis

Solid and Liquid Wastes

Uranium mining and milling

- An estimated 575,000 tonnes of tailings per year. Uranium mill tailings are acidic, or potentially acid generating, and contain a range of long-lived radionuclides, heavy metals and other contaminants.
- Up to 18 million tonnes of waste rock per year, which may also contain radionuclides, heavy metals, and be acid generating.
- More than 213 million tonnes of uranium mine tailings in storage facilities in Canada and 109 million tonnes of waste rock.
- Water pollution from uranium mines and mills was found by Health Canada and Environment Canada to be toxic for the purposes of the Canadian Environmental Protection Act in 2004.

Refining and conversion operations

- It is estimated that nearly 1,000 tonnes of solid wastes and 9,000 m^3 of liquid wastes are produced each year as a result of uranium refining, conversion and fuel production for domestic energy generation purposes. Information on the precise character and what is done with these wastes could not be obtained.

Power plant operation

- Approximately 85,000 waste fuel bundles are generated by Canadian nuclear reactors each year. As of 2003, 1.7 million bundles were in storage at reactor sites. It is estimated that these wastes will have to be secured for approximately one million years for safety, environmental and security reasons.
- Approximately 6,000 cubic metres of lower level radioactive wastes are generated each year in Ontario as a result of power plant operations, maintenance and refurbishment.
- Very large amounts of low-, intermediate- and high-level radioactive wastes will be produced as a result of the eventual decommissioning of refining, conversion and fabrication facilities as well as power plants.

Water

- Severe contamination of groundwater with radionuclides, heavy metals and other contaminants has occurred at tailings management facilities and waste rock storage areas.
- Routine and accidental releases of radionuclides to surface waters occur in the course of power plant operations. Groundwater contamination with tritium has occurred at the Pickering generating facility in Ontario.

Nuclear wastes require care now — and forever.

Nuclear energy production waste streams – a synopsis *(continued)*

- Ontario's nuclear power plants are the leading source of discharges of hydrazine, an extremely hazardous pollutant, to surface waters in Canada.
- Generating facilities require large amounts of cooling water. The Darlington and Pickering facilities in Ontario are alone estimated to use approximately 8.9 trillion litres of water for cooling purposes per year — more than 19 times the annual water consumption of the City of Toronto.

Air

- Atmospheric releases of a range of radionuclides occur at all stages of nuclear power production. Releases of radon gas to the atmosphere result from mining and milling operations and from tailings management facilities. Windblown dust from mine sites and tailings management facilities (TMFs) contains a range of radionuclides. Atmospheric releases (principally uranium) also arise from refining and conversion activities.
- Routine and accidental releases of radiation and radionuclides occur from power plant operations, including tritium oxide, carbon-14, noble gases, iodine-131, radioactive particulate and elemental tritium.
- The incineration of low and intermediate-level radioactive wastes from power plant operations and maintenance in Ontario has resulted in further atmospheric releases of radionuclides, particularly tritium.
- Windblown dust from mine sites and TMFs contains a range of heavy metals. In addition, releases of a number of hazardous air pollutants, including dioxins and furans, hexachlorobenzene, heavy metals (principally lead), ammonia and hydrogen fluoride arise from uranium refining and conversion operations.
- Uranium mining and milling operations are found to be significant sources of releases of sulphur dioxide (SO_2), volatile organic compounds (VOCs) and nitrogen oxides (NOx), which contribute to smog. Releases of NOx, particulate matter (PM) and sulphuric acid arise from refining and conversion activities.

Climate

- Greenhouse gas emissions are released by nuclear power plant construction and maintenance, uranium mining, milling, refining, conversion and fuel fabication. Additional releases will occur in the course of facility decommissioning and the management of nuclear wastes.
- Estimates of the total GHG emissions associated with the use of nuclear power vary widely depending on the assumptions made about the quality of uranium ore used as the basis of fuel, waste management and decommissioning requirements, and other factors. Recent estimates in relation to the use of nuclear power in Canada suggest a minimum of 840,000 tonnes CO_2 per year.
- CO_2 emissions and other environmental impacts would increase substantially if lower grade uranium ores are used as the basis of nuclear fuel.