Know Nukes!

A Fact Sheet by Dr. Jeremy Whitlock
***The Canadian Nuclear FAQ*: www.nuclearfaq.ca**

How safe are CANDU reactors?

The record of nuclear power plant operation is one of the safest of any industry – in terms of both worker and public injury (there has never been a radiation-related death in Canada due to nuclear power). Emissions from operations are very low and all radioactive waste products are retained and isolated on site. Reactor cooling water is also isolated from the outside world.

CANDU technology is a world leader in safety performance. Safety is ensured through multiple back-up control and shutdown systems, rigorous training of personnel, strict oversight from the federal regulator (the Canadian Nuclear Safety Commission, *www.nuclearsafety.gc.ca*), and a "defense-in-depth" approach that protects the public using multiple barriers. These barriers start with the robust fuel itself, designed to operate for over a year in the reactor at high temperatures and pressures, and contain all toxic by-products. The barriers continue through layers of containment and shielding, monitored by safety systems that are constantly tested. One of the final barriers is the massive containment building around the reactor and all of its support equipment. These structures, among the strongest on the planet, are designed to isolate all credible accidents from the outside world.

What about "meltdowns"?

"Meltdown" describes a postulated accident where reactor cooling is lost and uranium fuel heats up to the point of melting (this occurs at over 2000°C). Multiple protection and backup systems, including "passive systems" that operate without external intervention, exist to prevent this from happening. In a CANDU reactor the risk of fuel melting is considered to be negligibly small under all credible accident scenarios, since the fuel is surrounded by two massive low-pressure, low-temperature water reservoirs (the moderator and the reactor vault) that act as emergency long-term heat sinks.

Can *Chernobyl* happen here?

No. The 1986 accident at the Unit 4 Chernobyl reactor in the Ukraine was the result of poor reactor design (including lack of containment) that would not have been licensable outside of the former USSR, as well as poor training and working conditions that would also be unacceptable in the West. (For more discussion on this, see *www.nuclearfaq.ca*).

Why bother with nuclear energy in the first place?

There are good reasons to look at a wide range of new energy-generating technologies, given the increasing demand for electricity and the environmental and resource-depletion issues associated with fossil fuels. Nuclear energy offers almost emission-free operation, a stable and domestic fuel source, a relatively small and easily managed waste product, and made-in-Canada technology. As a reliable baseload energy source, nuclear power plants enable the use of wind farms and other emerging renewable technologies by providing the necessary grid support. Nuclear energy is not in competition with other technologies; it is part of a diverse approach that ensures reliability and stability of our electricity supply.

Are CANDU reactors cost competitive?

Electricity generated by CANDU reactors in Ontario, Quebec, and New Brunswick is among the lowest-cost in those provinces. Moreover, unlike other conventional sources, the price of nuclear electricity incorporates much of the environmental "cost" of the technology since emissions and waste products are contained, and decommissioning funds are included in the rate base (by law). Some of the large stations in Ontario saw major cost increases during construction or refurbishment (e.g. the final construction cost of Darlington doubled), which was largely due to political interference during construction. When the supplier and project manager have full control of scope and schedule, the record shows that CANDU plants can be built within budget and on time. If Canada can do this on the other side of the planet (as we recently did in China with the Qinshan twin-CANDU project), we can do it at home.

As an investment by the Canadian public, the CANDU program has paid its shareholders back many times over. Since the 1950s Canadians have invested about $6 billion in nuclear R&D (unadjusted for inflation). On average each year, mainly through electricity production and uranium exports, the nuclear sector accounts for roughly this same level of economic activity – $6 billion. (Note: Often the $6 billion historical investment is reported in current, or inflation-adjusted, dollars, bringing it to something like $17 billion. The same can be done with the benefits accrued over the years as well, but even without doing this the pay-back to Canadians is on the positive side.)

What happens to the waste?

All waste from a CANDU plant is retained on site and isolated from the environment. The most toxic component of this waste is the used fuel itself. Fortunately the fuel is also the smallest waste component in terms of volume, and dealing with it is relatively simple. Used fuel is in the same robust form as when it went into the reactor, except now it produces heat and radiation. Initially it is stored in water-filled pools used for cooling and shielding. After 7-10 years the fuel has decreased significantly in heat output and can be moved to air-cooled concrete storage containers on site. All of the used nuclear fuel generated to date in Canada is stored using either of these two methods at each of the reactor sites. The federal government has recently approved a long-term plan to move the used fuel to deep underground disposal vaults, but this process won't take place for decades, allowing for comprehensive public review at every step along the way. There is no rush since interim storage is economical and expandable. The volume is also relatively small: all of the used fuel generated to date by all of Canada's CANDU reactors over 45 years of operation, if stacked like cordwood, would fill a soccer field to the height of a player. By way of comparison, this volume is about half that of the municipal

garbage generated by the City of Toronto in one day. Low volume, robust nature, ease of management, decreasing toxicity with time, and total retention of toxic products make the waste stream of nuclear energy one of the positive aspects of the technology.

Can nuclear waste be recycled?

One reason to avoid rushing to commit used CANDU fuel to permanent disposal is that it has a potential for recycling in the future. Currently we use less than 5% of the potential energy in the uranium fuel. The bulk of the uranium is in a form that most current-generation reactors largely don't use. However, it is possible to convert this material, in special reactors called "Breeder Reactors", into usable fuel. Doing so would turn our current used fuel storage sites into "mines" of nuclear fuel for future generations, and potentially extend uranium resources for thousands of years. This process would also destroy most of the long-lived waste products in the fuel, significantly reducing the long-term storage challenge. The potential to turn waste into fuel is another of the positive stories of nuclear power. New processes for reprocessing used fuel with greater efficiency and proliferation-resistance are now under development, although fuel recycling is not currently planned in Canada.

In addition, one of the unique features of CANDU reactors is that they can use as fuel the used fuel from other reactor types – in effect turning their garbage into energy, again in a proliferation resistant process.

How long will uranium last?

Canada is currently the world's largest supplier of uranium (about one-third of global supply). In terms of current "known" and "reasonably known" reserves, there are several centuries' worth of accessible uranium on the planet. Moreover, fluctuations in uranium supply are not strongly coupled to the cost of nuclear electricity, since fuel supply is only a minor contributor to the total cost of operation. If fuel recycling were to be implemented on a broad scale however (see above), these reserves could be extended to the thousands of years. In addition, CANDU reactors offer other unique fuelling options such as using another common mineral called "thorium" as fuel, which is even more abundant than uranium in the earth's crust.

What about proliferation?

"Proliferation" refers to the spread of nuclear weapons to countries that don't already have them. Since the beginning of Canada's nuclear program, minimizing the proliferation risks of the technology has been a priority. Used nuclear fuel from all commercial reactor types contains a small amount of plutonium which theoretically can be used in a nuclear weapon, and therefore must be protected from potential diversion. The risk is quite small for power reactor fuel like in a CANDU, due to many factors including the low concentration of the plutonium (even lower than in other reactor types), the poor quality of the plutonium for weapons purposes, and the fact that several more convenient routes to nuclear weapons proliferation exist (no nuclear state has used a power reactor to manufacture its weapons). Nevertheless, Canada is a founding member of the International Atomic Energy Agency (IAEA, the global proliferation "watchdog"), and a signatory to a number of non-proliferation agreements and treaties. All CANDU reactors are rigorously safeguarded against fuel diversion, and the international community accepts the high proliferation resistance of CANDU technology. If recycling of used fuel were to become a reality in Canada, it would incorporate new proliferation-resistant technology.

What is the risk of terrorism?

Nuclear power plants, like other major industries and infrastructures, are potential targets for terrorism; this risk is taken seriously in the design and physical protection of each facility. Accordingly, nuclear plants are among the most secure and robust installations on the planet, even against new and emerging challenges that were unanticipated when the plants were being designed. Several studies conducted since the attacks of September 11, 2001 conclude that the likely consequences of an aircraft impact on a nuclear facility would not include significant damage to the reactor itself. New reactor designs, such as ACR, explicitly include this scenario in the design basis of their protection systems.

Are nuclear plants insurable?

Yes, the insurance industry does insure power reactors for their replacement value in cases where the owner corporation is not large enough to self-insure its assets, as is the case with some major utilities. The insurance industry also provides coverage for reactor owners against public claims in the unlikely event of off-site (i.e. public) consequences, but this liability is limited under federal law (the Nuclear Liability Act) to $75 million, soon to be increased to $650 million. Off-site consequences exceeding this limit would be covered by special intervention of Parliament, similarly to how major disasters in general are handled. The purpose of the owner's liability cap is reasonable control of the litigation risk (particularly since no accidents have occurred upon which actuarial assessments might be based), and also to expedite payment of claims to the public by removing the requirement to prove negligence (in effect, "no fault" insurance coverage).

Do CANDU stations emit radiation?

CANDU stations release small amounts of radioactive noble (i.e. chemically inert) gases, as well as tritium (a radioactive form of hydrogen). All emissions from a CANDU station are strictly regulated by the Canadian Nuclear Safety Commission, and monitored to ensure compliance (including routine environmental sampling around each plant). The CNSC sets emission limits that are a small percentage of what might cause harm. In turn, reactor owners typically set their own operational limits at a small percentage of the CNSC limit, and in practice actual emissions are typically a small percentage of these operational limits. As a result, radiation emissions are negligible (<1%) compared to the natural levels of background radiation in the environment, and even coal stations can emit more radiation due to trace amounts of natural uranium and thorium in the coal.

Some confusion has arisen over the wide variation in international emission limits placed on tritium, which can vary from roughly 1/10 the Canadian value (U.S.A.) to roughly 10 times the Canadian value (Finland). This variation represents administrative differences only, as all limits are well below the range where actual harm might be observed, and below the international standard. This situation highlights a general challenge in regulating radioactive substances: since no health effects have been observed at the exposure levels that the public is ever likely to encounter, administrative limits have to be set where they make the most sense. The technical phrase for this is "As Low as Reasonably Achievable", or ALARA, which is a requirement to set limits as low as possible, taking economic and social considerations into effect, and without exceeding the international standard.

Are CANDU reactors reliable?

Modern CANDU reactors built by AECL are among the best performing and most reliable in the world. Some older stations in Ontario have suffered from maintenance issues, due to a combination of poor management practices and older materials and equipment. However this does not affect the record of modern CANDU 6 performance, which is the commercial AECL design built outside of Ontario and elsewhere in the world. In turn, all the best features of CANDU 6 are incorporated into ACR, and new features have been added to improve efficiency and reliability. The Ontario CANDU units, when properly managed and incorporating newer materials and equipment, have performed well. Furthermore, during the widespread 2003 blackout in Ontario and elsewhere, it was a group of CANDU units across the province, returning to service ahead of many other power plants, that played a major role in bringing the rest of the province back on line.

There must be *some* CO_2 released…

Yes, few processes can claim to be emission free, but CANDU nuclear stations are about a clean as one can get. Several international studies have examined the CO_2 releases from the entire "life cycle" of various electricity-generating technologies, assuming a similar power output, and nuclear stations typically rank among the cleanest. The largest contributor to CO_2 production in the nuclear life cycle is plant construction, uranium mining and uranium enrichment. However even this is a small fraction (1-2%) of the total CO_2 avoided by the replacement of fossil fuels. Renewable technologies such as wind power have similar CO_2 savings during operation, but compared to nuclear generally incur a greater CO_2 penalty during construction due to the size of the wind farm that must be built to equal the output of a nuclear station.

What is the environmental impact of uranium mining?

In the past, uranium mining, like most resource extraction operations, had a higher environmental impact than today. However, a modern uranium mine such as McArthur River in northern Saskatchewan is a model of environmental stewardship, with rigorous control of all effluent and airborne emissions, and a minimal footprint at the surface – all strictly regulated. While no operation, particularly a large industry, can achieve zero environmental impact, every effort is expended today to reduce this impact as much as possible. One factor in favour of nuclear power is the high energy density of its fuel, leading to several thousand times lower volume of resources that need to be extracted for the same energy generation, compared to fossil fuels.

What kind of public consultation or government inquiry has nuclear energy had?

In Canada, numerous government commissions, inquiries, and select committee hearings have been a part of the nuclear industry since its inception in the post-WWII years. These investigations, at both the provincial and federal level, have examined everything from the need for nuclear energy in the first place, to safety, cost, waste management, uranium mining, and electricity planning. Most of these processes have included public participation. Recent assessments in Ontario, Quebec, and New Brunswick continue this tradition of independent oversight, and any new plant construction today must incorporate an extensive Environmental Review process, structured around the need for thorough, independent review and public input.

Where can I find more information?

"The Canadian Nuclear FAQ" (frequently-asked questions): *www.nuclearfaq.ca*
The Canadian Nuclear Society (representing the science & technology): *www.cns-snc.ca*
The Canadian Nuclear Association (representing the industry): *www.cna.ca*
Atomic Energy of Canada Ltd. (the developer of CANDU and ACR): *www.aecl.ca*
The Canadian Nuclear Safety Commission (federal regulator): *www.nuclearsafety.gc.ca*
The Uranium Information Centre (info on uranium and the global nuclear industry): *www.uic.com.au*

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