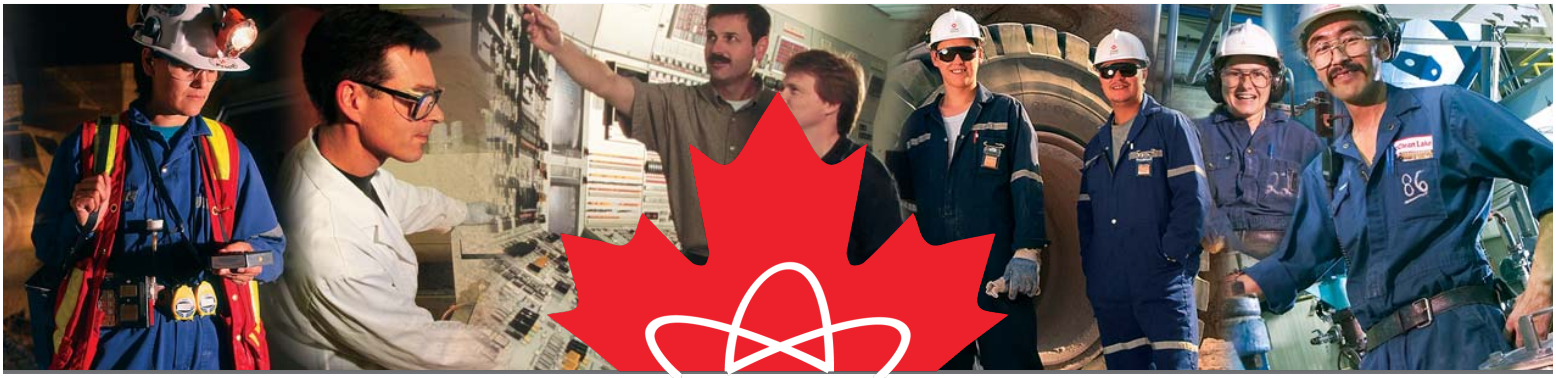

CANADIAN NUCLEAR WORKERS' COUNCIL

Nuclear Waste Management:
International Best Practises

Deep Geological Repository

Most countries with commercial nuclear power production have plans in place to isolate the wastes from their nuclear fuel cycle in a deep geological repository (DGR). For example, Belgium, China, Finland, France, Germany, Hungary, Japan, the Netherlands, Russia, Sweden, Switzerland, the United Kingdom and the United States. Sources for the following information include: Nuclear Waste Management Organization, World Nuclear Association and the National Energy Institute.

Belgium:

- Belgium's first commercial nuclear reactor began operating in 1974. It now has seven operating reactors representing about 5,700 MW (54% of its electricity).
- The National Agency for Radioactive Waste and Enriched Materials is responsible for the management of all radioactive materials, including transport, treatment, conditioning, storage and disposal. The Agency's main facility is at Mol-Dessel, located in a small municipality in the Flemish part of Belgium. The producers of radioactive waste pay its costs. Each utility pays a levy on each kWh of electricity sold, which goes into a decommissioning and waste management fund.
- Used fuel processing was suspended in 1993 and used fuel is now stored at the nuclear power plants.
- In 2006, the government decided to dispose of low and intermediate wastes in a surface repository at Dessel.
- Research is underway on a DGR for high level wastes at Mol. The focus is on the clays at this location. An experimental underground research laboratory was constructed 225 m deep in 1980. The goal is to demonstrate the feasibility of disposing of radioactive waste in deep clay layers.

China:

- There are 30 operating nuclear plants in Mainland China, with 24 under construction. China's policy is for a closed fuel cycle.
- China has two surface low and intermediate level waste facilities, and plans are in place for three more.
- China's DGR siting process began in 1985. The preliminary concept is focused on a repository in granite with bentonite proposed as the buffer and backfill material.
- China's Atomic Energy Authority is responsible for developing plans and projects for high-level waste disposal and the China National Nuclear Corporation will develop transportation and repository technology for CANDU fuel and high-level waste from the reprocessing of used light water reactor fuel.
- Site characterization has occurred in five different regions of China. Work is currently focused on a possible location in the Beishan region of northwest China. Construction of a repository is not expected to began until about 2050.

Finland:

- Four operating nuclear reactors provide about 30 percent of Finland's electricity. They started commercial operation in 1983. A fifth reactor is currently under construction and another is planned.
- Initially Finland intended to export its used nuclear fuel and/or reprocess it.
- In the 1980s, Finland's policy shifted to a deep geological repository. As a condition of licence renewal, Finland's power companies are responsible for nuclear waste management until its final disposal.
- In 1987, Finland's *Nuclear Energy Act* included final disposal as an option and the Ministry of Trade and Industry established a fund. An amendment to the act in 1994 stipulates that wastes should be handled wholly in Finland.
- Posiva Oy was set up by the two nuclear operators to management the process going forward. Funds accumulate in a State Nuclear Waste Management Fund from charges on generated electricity. This represents about 10% of nuclear electricity production costs. These funds are intended to cover the costs of disposing of nuclear waste and used fuel as well as the decommissioning of the operating reactors.
- Used fuel is currently stored in surface pools at existing operating plants.
- Underground repositories for low and intermediate wastes have been in operation at Olkiluoto (1992) and Loviisa (1997). The Olkiluoto site will accommodate decommissioning wastes in the future as well.
- The siting process for a deep geological repository began in the 1980s. Between 1986 and 1992, preliminary site characterization and feasibility studies were undertaken at five potential sites.
- Olkiluoto Island was selected in 2000 as the site for final disposal. The local community is supportive. Encapsulated used fuel will be deposited about 400-450 metres below the surface in 2 billion year old igneous rock.
- The construction licence for the DGR and fuel encapsulation was granted in 2015. Construction is expected to begin late in 2016. An operating licence application is expected in 2020 with facility operation expected to commence in 2023.
- The repository could be sealed in 2120 pending the outcome of current discussion in Finland related to the need for a second DGR.

France:

- Nuclear energy provides about 75% of this country's electricity (will be 50% by 2025) and it is the world's largest net exporter of electricity due to this low cost generation.
- France has 59 operational nuclear power plants.
- Thirteen experimental and power reactors are being decommissioned in France. Decommissioning plans await the progress on availability of sites for disposing of intermediate level wastes.
- France is also a major exporter of reactor and fuel products and services.
- Approximately 17% of its electricity is generated from recycled nuclear fuel.
- France's 1991 *Waste Management Act* was updated in 2006 and included the establishment of the ANDRA-Agence Nationale pour la gestion des Dechats Radioactifs to be responsible for the long-term management of used nuclear fuel. Deep geological repository was selected as the reference solution. Wastes are to be retrievable. The principle of reprocessing used fuel and using recycled plutonium and uranium was also endorsed.
- ANDRA set the direction for R&D: underground rock laboratory in eastern France situated in clays established in 1999; another investigating granites; and work on partitioning, transmutation and long-term surface storage following conditioning.
- ANDRA is responsible for the following low and intermediate level disposal facilities:
  - Centre de la Manche next to La Hague opened in 1969. It is now capped with a multi-layer grassed cover.
  - Centre de l'Aube near Soulaines.
  - Morvilliers facility in the Aube district around Troyes east of Paris.
  - Sites are being considered for two more facilities to manage the disposal of low and intermediate waste in a repository likely to be in clay about 15 metres below the surface. ANDRA is looking for willing host communities.
- DGR construction licence was submitted in 2015 and is expected in 2017 with construction starting in 2020. The pilot phase of disposal would begin in 2025.
- Funds for waste management and decommissioning are segregated and are with the producers. Electricite de France sets aside € 0.14 cents/k/Wh for waste management costs. The reference cost is estimated to be €25 billion (2011 Euro).

Germany:

- Until March 2011, Germany's nuclear fleet provided about a quarter of the country's electricity. Following a 2011 government decision to phase out Germany's nuclear fleet, today, eight reactors provide about 16%.
- Almost half of Germany's electricity is produced by coal generation.
- While Germany has some of the lowest wholesale electricity prices in Europe, its retail prices are among the highest. More than half of the domestic electricity price is due to taxes and surcharges related to its energy policies.
- Utilities are responsible for the interim storage of spent fuel and have formed joint companies to build and operate off-site surface facilities at Ahaus (northeast Germany near the border with the Netherlands) and Gorleben (state of Lower Saxony). Today the current policy calls for interim storage at reactor sites.
- Germany's government issued a recommendation in 1963 to use geological salt formations for waste disposal. Planning for a national repository began in 1973 with a site at the Gorleben salt dome being approved in 1977. A year earlier, amendments to Germany's *Atomic Energy Act* gave the government's Federal Office for Radiation Protection (BfS) the responsibility for such a repository. BfS is also responsible for radiation from medical diagnostics, mobile communications and nuclear technology.
- Gesellschaft fur Nucklear-Service (GNS) is responsible for all operations related to the transport and disposal of waste in Germany at nine sites. GNS and Betrieb von Endlagern fur Abfallstoffe was established in 1979. It is 75% owned by GNS with the remaining ownership being held by four German utilities — E.On, RWE, EnBW and Vattenfall.
- BfS stopped site investigations at Gorleben in 2000 with new siting recommendations being issued in 2002. Two sites were required for investigation. The Gorleben site has not been ruled out for further consideration and a repository in clay is being considered at a number of sites in Germany.
- New repository criteria were enacted in 2009 that require scientific demonstration that the waste will be stable in the repository for a million years and that the waste must be retrievable. A 33-member commission was created to develop "basic principles" for site selection and selection criteria for rock formations. Membership includes representatives from parliament, academia, civil society organizations, industry, the environment and trade unions.
- Germany's cabinet adopted the Commission's recommendations in August 2015 and the plan will be submitted to the European Commission. Two locations are being considered for waste disposal—one for low and intermediated wastes in a former iron mine and an undetermined site for high-level wastes.
- Separated high-level wastes previously reprocessed in France and the UK will be returned to Germany between 2017 and 2022 and be stored at four interim sites.
- Up to 2012, Germany has been shutting down and decommissioning 19 experimental and commercial reactors. Full demolition and site clearance will occur at eleven of the 19 sites.
- Eight operating reactors were prematurely shut down in 2012 by government direction but are operating today.

India:

- India has a largely indigenous nuclear power programme, aided in a significant way by CANDU technology exports several decades ago.
- India is outside the Nuclear Non-Proliferation Treaty given its weapons program. Until 2009, India was largely excluded for 34 years from trade in nuclear plant or materials.
- Fourteen point six GWe of nuclear capacity is expected to be on line by 2024 and 63 GWe by 2032.
- By 2050, India plans to have nuclear power supply 25% of its electricity.
- It has focused on developing a nuclear fuel cycle based on India's reserves of thorium. India plans to become a world leader in nuclear technology given its expertise in the thorium fuel cycle and fast reactors.
- Radioactive wastes from India's nuclear reactors and reprocessing plants are treated and stored at each site. India has three waste immobilization plants. Borosilicate glass is used for this purpose as in Europe.
- India's Atomic Energy Commission (AEC) is responsible for research on repository development and siting. This research is undertaken at the Bhabha Atomic Research Centre in Trombay, Mumbai.
- Reprocessing of used nuclear fuel was first undertaken in 1964. A new plant was built in 2011. An engineering scale Power Reactor Thorium Reprocessing Facility became operational in 2015.

Japan:

- Japan imports about 84% of its energy requirements.
- Japan's 50 plus reactors have historically provided about 30% of the country's electricity. Post Fukushima, following a major regulatory overhaul, Japan's nuclear reactors will meet about 25% of its electricity.
- Japan has a full fuel cycle set-up, including enrichment and reprocessing and is a leader in fast reactor R&D.
- The country's first commercial reactor commenced operation in mid-1966.
- Forty-three of Japan's reactors are operable and capable of restart. Two restarted in 2015 and 24 have applied for restart approval.
- Japan Nuclear Energy Limited (JFNL) operates a large low-level waste storage facility near Rokkasho. The Japanese government and JNFL are seeking approval for another low-level storage facility in the Aomori prefecture.
- Japan's first high-level interim waste storage facility—the Vitrified Waste Storage Centre—opened in 1995. The first shipment of vitrified high-level waste from the reprocessing of Japanese fuel arrived that same year. Reprocessing is done in France and the United Kingdom.
- Another Recyclable Fuel Storage Centre was established in 2005 to provide an additional 50 years of interim storage before the fuel is reprocessed.
- R&D for high-level waste began in 1976. The Japanese government passed a Law on Final Disposal of Specified Radioactive Waste in 2000 mandating deep geological disposal.
- The Nuclear Waste Management Organization (NUMO) was established in October of 2000 by the private sector to implement a DGR. Japan's Atomic Energy Agency has been contributing to the process as it operates off-site underground research laboratories in both crystalline and sedimentary rock.
- Host municipalities were solicited from across Japan as part of the siting process.
- Following the Great Tohoku earthquake and Fukushima Daiichi accident, the *Designated Radioactive Waste Final Disposal Act* was amended in 2015. This gave the Government of Japan a role nominating "scientifically favourable areas" for the DGR. Once possible locations are short-listed the federal government will seek local government consent.
- Site selection is expected to commence in 2025 with DGR operation expected in 2035.
- Funds for the DGR are accumulated based on a yen/kWh charge from the electricity utilities charge that is paid to and managed by the Radioactive Management Funding and Research Centre. This fund does not include financial compensation from the government to local communities.

Sweden:

- Sweden's nine operating nuclear power reactors provide 40% of its electricity.
- A 1980 government decision was made to phase out nuclear power but was repealed in 2010.
- In 2015, Sweden made the decision to close four older reactors by 2020.
- The country has a tax against nuclear power (0.67 Euro cents/kWh), which represents about a third of the operating cost of nuclear power. Wind and biomass are subsidized by about 3 times that.
- Some low-level waste disposed of at reactor sites and some is incinerated at the Studsvik RadWaste incineration facility.
- A dedicated ship moves the used fuel and wastes from the power plants to storage or repositories.
- The Swedish Nuclear Fuel and Waste Management Company (SKB), established in 1977, is responsible for the management of nuclear and radioactive waste. SKB is owned by four-power companies — Vattenfall, Forsmark, OKG and E.ON Sweden.
- Nuclear power plant operators are responsible for the costs of managing and disposing of spent fuel. A fee (averaged 021 Euro cents/kWh) set by the government is paid to a fund managed by the Swedish Radiation Safety Authority to cover waste management and decommissioning. A new fee level was set for 2015-2017 by the government in 2014 (0.46 Euro cents).

Sweden: *(continued)*

- The CLAB interim repository has been operating at Oskarshamn since 1985. The facility was expanded in 2000. SKB applied for a licence to further expand the facility in 2015. Used fuel is stored under water in an underground cavern for 40-50 years. It will then be encapsulated in copper canisters for final placement packed with bentonite clay in a 500-metre repository in granite.
- An underground repository for operational radioactive waste and medical and industrial radioactive wastes (up to intermediate level) has been operating near Forsmark (Osthammar) since 1988.
- The siting process for a DGR began in the early 1990s. Eight municipalities were studied initially and between 2002 and 2008 detailed underground evaluations were undertaken at two potential sites.
- In 2011, SKB applied for a repository construction licence at one of the sites at Osthammar, in Stockholm County. High-level waste would be stored 50 meters below the Baltic Sea. A decision is expected in 2017 with construction to start in the early 2020s.

Switzerland:

- Switzerland's five nuclear reactors provide 40% of the country's electricity.
- In 2011, Switzerland's parliament decided not to replace any reactors and phase out nuclear power in 2034 (in spite of strong public support for nuclear power).
- Zwilag, a company owned by Switzerland's four nuclear utilities, manages most of the country's radioactive waste. Commercial operation of a central interim dry cask storage facility ZZL for high level wastes, started in 2001. The site also has incinerates, conditions and stores low and intermediate-level wastes.
- Until 2006, Swiss utilities have been sending used fuel for reprocessing in France and the UK, but Switzerland remains responsible for managing the high-level wastes generated by the process. Most of the used fuel was shipped by rail and/or by ship to the UK. Changes to Switzerland's *Nuclear Energy Act* in 2005 mean used fuel is now at reactor sited or sent to the ZZL facility for interim above ground storage.
- A national co-operative for the disposal of radioactive wastes (NAGRA) was established in 1972 to safely manage Switzerland's used nuclear fuel. The co-operative includes power plant operators and the federal government. NAGRA has operated an underground research lab at Grimsel since 1983.
- A potential site was identified by NAGRA, however in 2005 the government asked NAGRA to look at other sites. As part of a strategic plan, approved by the Swiss Federal Council, other potential sites were investigated in six possible regions. NAGARA short-listed two sites (Jura Ost and Zurich Nordost) in January 2015 that could accommodate repositories for low and intermediate and high level wastes.
- Four of the original six sites remain in reserve. NAGRA expects a decision by the Swiss Federal Council in 2017 with a final decision by the government anticipated by 2027.
- A Decommissioning Fund was established in 1984, into which power plant operators make annual contributions. A national waste disposal fund was created in 2002. Similarly, nuclear plant owners pay a levy to this fund that is set by Switzerland's *Nuclear Energy Act*.

United Kingdom:

- Fifteen reactors generate approximately 18% of the UK's electricity. About half of this capacity is to be retired by 2025.
- Approximately 19 GWe of new nuclear generation is expected by 2025. By 2030 the UK government plans to have 16 GWe operating.
- The UK has full fuel cycle facilities, including reprocessing plants.
- Much of the UK's radioactive wastes are legacy from the country's pioneering development of nuclear power. Some also are from military programs.
- Until 1982, some low and intermediate level wastes were disposed of at deep ocean sites. In 1993, the UK accepted an international ban on this practice.

United Kingdom: *(continued)*

- Since 1959, low level wastes have been disposed of at the Low Level Waste Repository at Drigg, in Cumbria. Low-level wastes were also stored at Dounreay, Scotland adjacent to a nuclear power plant complex now being decommissioned.
- Pending disposal, intermediate-level wastes are stored at Sellafield, in Cumbria and at other source sites. A new storage facility at Harwell, Oxfordshire is planned to accommodate decommissioning wastes.
- Vitrified high-level wastes resulting from reprocessing are stored at Sellafield in stainless steel canisters placed in silos. All high-level wastes will be stored for 50 years to allow for cooling before disposal.
- The Nuclear Decommissioning Authority (NDA) is responsible for implementing the UK's policy on high and low level waste. The NDA set up the Radioactive Waste Management Directorate in 2007 to develop a geological disposal solution. Communities were asked to participate in "no commitment" discussions on hosting a repository.
- Three communities have volunteered to host the DGR. Next steps in the process include a four-year geological study and ten years of surface research followed by a 15-year period for underground research, construction and commissioning. Operation is expected to commence around 2040 with closure anticipated about 2100.
- The operators of new plants will pay a fix unit price for the disposal of intermediate-level wastes and used fuel in the DGR.

United States:

- The United States is the world's largest producer of nuclear power (about 30% of the world's nuclear generation).
- One hundred reactors produced over 19% of the total U.S. electricity output in 2014.
- Today 99 units are operable and five new ones are under construction.
- The US Clean Energy Plan includes nuclear generation in its definition of "clean" energy, which could help stimulate growth in nuclear capacity.
- Nuclear waste disposal policy has been debated for several decades. Wastes include those from commercial reactor operations and legacy wastes from the military. Used fuel assemblies have been stored under water in pools, and more recently in dry casks at reactor sites. Naval used fuel is stored at the Idaho National Laboratory. Used fuel processing was prohibited in 1977.
- The US Department of Energy (DOE) is accountable for the safe disposal of radioactive waste and used fuel in a deep geological repository.
- The *Nuclear Waste Policy Ac*t of 1982 established a timetable and procedures for the building of two repositories to be funded by fees from utilities. Between 1983 and 1986, the DOE investigated nine candidate sites. In 1987, Congress directed the DOE to only study the Yucca Mountain located near a nuclear weapons site in Nevada.
- In 2002, the Yucca Mountain site was recommended to the President, who approved it. The State of Nevada strongly opposed the decision.
- In 2009, the government stated that Yucca Mountain was no longer an option and formed a Blue Ribbon Commission to provide recommendations. The Commission submitted its final report in January 2012.
- In 2013, the government issued its Strategy for the Management and Disposal of Used Nuclear Fuel and High-Level Radioactive Waste. This report and two subsequent reports by the National Research Council recommended a consent-based siting process.
- To date, utilities have paid over $17 billion into the Nuclear Waste Fund for the DOE to take over their used fuel. The fund is growing by about $750 million a year from utility contributions and interest.