INQUIRY AND PUBLIC HEARING REPORT

Dry Storage of Irradiated Nuclear Fuel from the Gentilly 2 Power Station

BUREAU D'AUDIENCES PUBLIQUES SUR L'ENVIRONNEMENT

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This document is an English translation of the report of the Bureau d'audiences publiques sur l'environnement on the proposal for dry storage of irradiated nuclear fuel from the Gentilly 2 power station.

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Gouvernement du Québec
Bureau d'audience publique sur l'environnement

BAPE 15 ANS

Quebec City, December 15, 1994

Mr. Jacques Brassard
Minister of the Environment and Wildlife
3900 de Marly Street, 6th Floor
Sainte-Foy, Quebec
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Dear Mr. Brassard,

I am pleased to submit the report of the Bureau d'audiences publiques sur l'environnement on the inquiry and public hearings conducted regarding the proposal for dry storage of irradiated nuclear fuel from the Gentilly 2 power station.

The inquiry and public hearings took place between August 15 and December 15, 1994, under the supervision of Mr. Alain Cloutier, a member of the Bureau, and of panel members, Dr. Wladimir Paskievici and Dr. André Arsenault.

Pursuant to an agreement between your predecessor and your federal counterpart, the public examination was conducted in accordance with Quebec procedure, with the participation of a panel member proposed by the federal government.

Following examination of the proposal, the panel has approved temporary dry storage and recommended the use of silo technology. It cannot, however, support the use of modules at this time, in view of the continuing uncertainties surrounding this option. In addition, the panel has noted the public perception of the risks associated with radiation and with the operation of the power station.

Sincerely,

BERTRAND TÉTREAULT
Chairman

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BAPE 15 ANS

Quebec City, December 12, 1994

Mr. Bertrand Tétreault, Chairman
Bureau d'audiences publiques
sur l'environnement
625 Saint-Amable Street, 2nd Floor
Quebec City, Quebec
G1R 2G5

Dear Mr. Tétreault,

I am pleased to submit to you the report of the panel that conducted the inquiry and public hearings regarding the proposal for dry storage of irradiated nuclear fuel from the Gentilly 2 power station.

The panel considers temporary dry storage of the irradiated fuel essential. However, while Hydro-Québec's proposal involves two types of dry storage technology, the silo and the module, the panel recommends the silo. A number of uncertainties remain with respect to the module and must be resolved before the government can approve this option.

The panel has also made a number of observations relating to the problem of disposal, the risks of radiation and the public perception of these risks in the context of the operation of the power station. It has done so in an effort, first, to improve the current approach of the management of the power station and, secondly, to resolve some of the uncertainties relating to long-term management of the irradiated fuel.

Sincerely,

Alain Cloutier
Chairman of the panel

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Table of Contents

List of Figures and Tables

List of Abbreviations and Acronyms

ACNS	Advisory Committee on Nuclear Safety
AECB	Atomic Energy Control Board
AECL	Atomic Energy of Canada Limited
ALARA	As Low As Reasonably Achievable
BAPE	Bureau d'audiences publiques sur l'environnement
CANDU	CANada Deuterium Uranium
CANSTOR	CANDU Storage
CIC	Concrete Integrated Canister
CLSC	Centre local de services communautaires (Local Community Services Centre)
CROP	Centre de recherche sur l'opinion publique inc.
DOL	Derived Operational Limit
EARP	Environmental Assessment and Review Process
FEARO	Federal Environmental Assessment Review Office
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
IRP	Integrated Resource Planning
MAD	Maximum Allowable Dose
MAPAQ	Ministère de l'Agriculture, des Pêcheries et de l'Alimentation (Ministry of Agriculture, Fisheries and Food)
MEF	Ministère de l'Environnement et de la Faune (Ministry of the Environment and Wildlife)
MRN	Ministère des Ressources naturelles (Ministry of Natural Resources)
RWSA	Radioactive Waste Storage Area

Glossary of Nuclear Terms

Actinides
Series of natural and artificial radioactive elements having atomic numbers greater than 89.

AECL silo
Reinforced concrete structure containing 1 airtight cylinder filled with 9 sealed baskets, or the equivalent of 540 irradiated nuclear fuel bundles.

Airtight cylinder
Leak-proof steel structure inside an AECL silo or CANSTOR module containing baskets of fuel.

Alpha ray
High-energy helium nuclei emitted by some radioactive nuclei. Alpha rays have little penetrating power. They can travel a few centimetres through the air and can be stopped by a sheet of paper (Figure 8).

Atom
The smallest unit of a chemical element. The atom consists of a nucleus made up of protons and neutrons, and surrounded by electrons.

Atomic Energy Control Board
Federal government agency responsible for ensuring that the use of nuclear energy in Canada poses no undue risk to health, general or physical security, and the environment.

Atomic Energy of Canada Limited
Crown corporation created to develop nuclear technology for peaceful purposes. AECL has designed the CANDU reactors and developed the *Temporary dry storage* process which Hydro-Québec proposes to adopt.

Becquerel
Système International unit used to measure the activity of radioactive substances (symbol: Bq). This unit has replaced the curie.

Beta ray
Electrons emitted by some radioactive nuclei. They can travel a few metres through the air and can be stopped by a sheet of plywood (Figure 8).

CANDU	For CANada Deuterium Uranium. Canadian-designed nuclear reactors using natural uranium as fuel and heavy water as the moderator.
CANSTOR module	Reinforced concrete structure containing 20 airtight cylinders holding 10 sealed baskets, or the equivalent of 12,000 irradiated nuclear fuel bundles.
CIC silo	*Concrete Integrated Canister.* Concrete and steel structure developed by Ontario Hydro to store 384 irradiated fuel bundles.
Cladding tube	Zirconium alloy tube containing uranium dioxide pellets. The cladding prevents the release of fission products into the coolant fluid. See also *Fuel rod.*
Collective dose	Total dose of ionizing radiation received by a group of individuals. The collective dose is calculated by multiplying the estimated individual dose by the number of individuals exposed.
Condenser	Device used to change steam from the secondary cooling loop to the liquid state following its passage through the turbine (Figure 2).
Conduction	Transfer of heat through a solid. Differs from *Convection.*
Containment	Retention of radioactive materials within an airtight structure. See *Reactor building* and *Containment system.*
Containment system	System designed to prevent any radioactivity from escaping the reactor building. The Gentilly 2 containment system includes the concrete reactor building, an isolation mechanism, a sprinkler system which is activated as required, and a set of air coolers.
Convection	Transfer of heat by contact with and displacement of a fluid (gas, liquid). For example, air heated on contact with a heating element.

Coolant system	Primary cooling loop used to absorb heat in the nuclear reactor (Figure 2). Gentilly 2 uses heavy water as its coolant.
Decay	Transformation of a radioactive element into another element. This transformation is generally accompanied by the emission of *alpha, beta* or *gamma* radiation.
Decommissioning	Action taken to terminate all, or part of, the operations of a nuclear facility.
Decontamination	Action taken to eliminate radioactive or chemical substances from a surface.
Dismantling	Action taken to dismantle or demolish nuclear facilities as the final stage in decommissioning.
Dose	Amount of radiation absorbed, weighted by modifying factors. The Système International recommends that equivalent doses be expressed numerically in sieverts (Sv).
Dry storage	Non-underwater storage of irradiated nuclear fuel.
Electron	Elementary particle having an electrical charge and revolving around the nucleus of an atom.
Element	Substance believed to be indecomposable except through radioactive decay or nuclear reaction. Matter is made up of elements. An element is characterized by the number of protons present in its nucleus.
Equivalent dose	Equivalent doses, expressed in Sv, are obtained by multiplying absorbed doses, expressed in grays, by factors proportional to the biological effects of the different types of radiation, the distribution of the doses in the human body, and any other correction factors required.
Fission	Splitting of the nucleus of an atom (of uranium, for example) into two parts that are more or less equal.

Fission products	Elements produced by splitting the nuclei of uranium atoms in a nuclear reactor. Fission products are radioactive.
Fuel basket	Sealed stainless steel cylinder containing 60 irradiated fuel bundles (Figure 5).
Fuel bundle	Group of rods, or fuel elements, containing uranium dioxide pellets.
Fuel rod	Zirconium alloy tube containing 31 uranium dioxide pellets (Figure 3). See also *Cladding tube*.
Gamma ray	Form of energy similar to the X-rays emitted by some radioactive nuclei. Gamma rays are highly penetrating and can only be stopped by substantial shielding, such as a one-metre concrete wall (Figure 8).
Gantry crane	Device used to lift the shipping flask.
Gray	Système International unit used to measure the dose of radioactivity absorbed by a substance (symbol: Gy). This unit has replaced the rad.
Half-life	Time required for half the atoms in a given radionuclide to decay. The half-life may vary from a millionth of a second to billions of years.
Heavy water	Water resembling ordinary water but consisting of one atom of oxygen and two atoms of heavy hydrogen, or deuterium (D_2O). Ordinary water contains one part heavy water per 7000. Heavy water is used as the moderator and coolant in a CANDU reactor.
International Atomic Energy Agency	International agency established by the UN to oversee the safe, peaceful use of atomic energy in countries which are parties to the Treaty on the Non-Proliferation of Nuclear Weapons.

International Commission on Radiological Protection	Autonomous international body of medical and scientific experts which publishes recommendations for protection against ionizing radiation. These recommendations serve as the basis for the Canadian standards.
Irradiated fuel	Spent nuclear fuel removed from the CANDU reactor.
Irradiation	Exposure to ionizing radiation.
Isotope	Atom of an element with the same number of protons in the nucleus but a different number of neutrons. Isotopes have the same chemical properties but different physical properties. Some isotopes are radioactive; they are known as *radioisotopes*.
Maximum allowable dose (MAD)	Total dose of ionizing radiation to which a person can be exposed in one year without exceeding the standards and regulations of the ***Atomic Energy Control Board***.
Moderator	Canadian-designed nuclear reactors use heavy water as the moderator. The moderator promotes the chain reaction in the reactor core.
Natural radioactivity	Radioactivity naturally present in soil, air, water, and the human body.
Neutron	Elementary particle of an atomic nucleus with no electrical charge.
Nuclear Liability Act	Federal legislation on accident insurance for nuclear power stations.
Pressure tube	Tubes piercing the pressure vessel of the CANDU reactor in which the fuel bundles are placed and the heavy water coolant is circulated under pressure.

Primary cooling loop	Loop containing the *coolant fluid* under pressure. This loop allows the heavy water to circulate through the reactor, absorbing the thermal energy produced by the nuclear reaction in the form of heat. This heat is then transported to the steam generators (Figure 2). See also *Secondary cooling loop* and *Steam generator*.
Protected area	Fenced area located within the exclusion area, access to which is strictly controlled by Hydro-Québec's security staff. Electronic systems, visual inspections and individual control guarantee the integrity of the perimeter.
Radioactive waste storage area	Concrete trench containing solid low- and moderate-level radioactive wastes.
Radioactivity	Property of certain elements to emit energy spontaneously in the form of particles or rays. This radiation may take the form of alpha, beta or gamma radiation.
Radioisotope or radionuclide	Radioactive atom.
Radiological dose	Term used in radiological protection to measure the possible biological consequences of the exposure of a person to ionizing radiation.
Radiological protection	Scientific discipline which studies the dangers of ionizing radiation and means of reducing them. By extension, all measures designed to study the effects of ionizing radiation on the human body, and to ensure the protection of workers and the public by compliance with prescribed standards.
Rare gases	The rare gases are helium, neon, argon, krypton, xenon and radon. The operation of a nuclear reactor creates radioisotopes of some of these gases.

Reactor building	Closed concrete building with 1-metre walls, forming an air-tight enclosure around the nuclear reactor to prevent any release of radioactive materials.
Reactor core	Central portion of the nuclear reactor containing the *fuel* and the *moderator*. It is in the reactor core that the fission of uranium nuclei occurs by chain reaction.
Reprocessing	Chemical process involving the extraction of uranium and plutonium from irradiated fuel for reuse.
Safety	Measures designed to protect workers, the public and the environment against the risk of radiation.
Secondary cooling loop	Loop used to produce and transport the steam required for operation of the turbine generator. The demineralized water used in the secondary cooling loop circulates through the steam generators, where it is transformed into steam by the heat transmitted by the coolant fluid. The steam operates the turbine generator and is then condensed before returning to the steam generators (Figure 2).
Security	Measures designed to prevent subversive activity and to ensure that all fissile materials are controlled and subject to constant surveillance to prevent unauthorized removal.
Shielded work station	Shielded enclosure used for automated drying and welding operations on baskets of irradiated fuel.
Shielding	Device used to isolate a radioactive source. In a storage pool, radiological shielding is provided by approximately 4 metres of water, and in an AECL-type silo or CANSTOR module, by a one-meter thick concrete covering.
Shipping flask	Shielded structure consisting of a cylindrical section on an attached base. The shipping flask provides shielding during the transfer of irradiated fuel from the storage pool to the dry storage site.

Sievert, millisievert and microsievert	The sievert (symbol: Sv) is the Système International unit used to measure the dose received by the body and to assess its biological effects. The millisievert (symbol: mSv) is one thousandth of a sievert. The microsievert (symbol: µSv) is one billionth of a sievert. See also *Dose and Equivalent Dose*.
Steam generator	Large tank in which steam is produced. The generators consist of a set of tubes carrying the coolant (heavy water) heated by the reactor. These tubes are in contact with the ordinary demineralized water in the secondary loop, which is changed into steam by the heat (Figure 2).
Storage pool	Tank filled with water and used to store irradiated fuel following its removal from the reactor until its radioactivity declines. The water serves both as a coolant for the fuel and as protection against radiation.
Temporary storage	Storage of irradiated nuclear fuel with provision for subsequent retrieval.
Tritium	Isotope of hydrogen formed during the operation of a CANDU reactor and accumulated in heavy water.
Zirconium	Metal used in alloy form for parts of the reactor because of its corrosion resistance.

Introduction

An agreement between the ministers of the Environment for Canada and Quebec has led to a joint public review into the proposal for dry storage of irradiated nuclear fuel from the Gentilly 2 power station. A joint public review has been conducted by the government authorities in accordance with Quebec's public hearings procedure under the supervision of the Bureau d'audiences publiques sur l'environnement (BAPE). Under the terms of this agreement, the chairman of BAPE appointed a panel member proposed by the federal government. The panel's report is to be submitted by the Quebec Minister of the Environment and Wildlife to his federal counterpart and to the Minister of Natural Resources Canada.

The panel wishes to point out that it is a separate entity from the panel responsible for the public review of the proposed concept for disposal of nuclear fuel wastes in the Canadian Shield. This federal panel conducted a public hearing in 1990 and expects to resume its activities in late 1995 or in 1996.

After completing its review on the technological aspects of the proposal, the panel examined the radiological risks in conjunction with those associated with the operation of the power station. Next, it examined the public perception of these risks. The panel did not, however, undertake a comprehensive environmental review of the Gentilly 2 power station.

Chapter 1 Description of the Proposal

This chapter describes the proposal for *dry storage** of irradiated nuclear fuel from the Gentilly 2 power station on the basis of the impact study, the related documents and the information provided by Hydro-Québec in part one of the public hearings. The issues covered in this chapter are: nuclear power in Quebec, characteristics of nuclear fuel, selection of storage technology, choice of a site, assessment of environmental impact, environmental surveillance and monitoring, and the economic impact of the proposal.

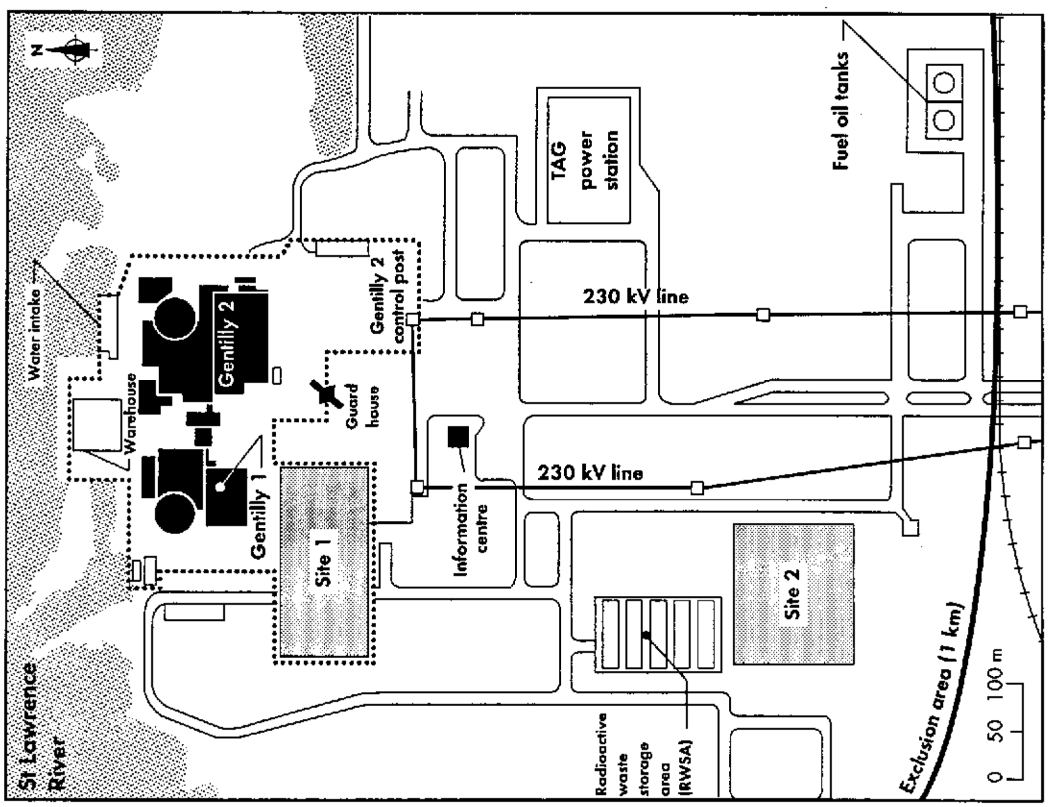
Nuclear Power in Quebec

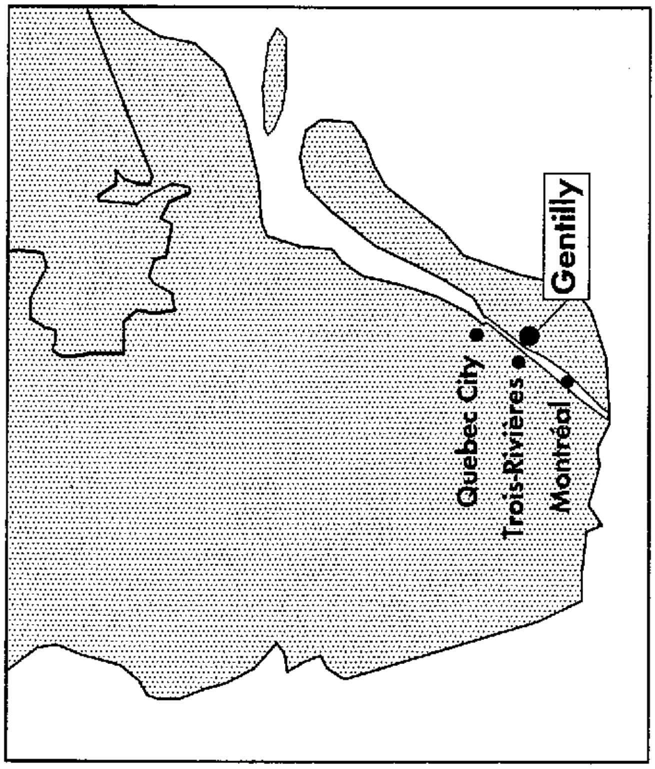
Gentilly 2, the only nuclear power station in operation in Quebec, is located on the south shore of the St Lawrence River approximately 15 kilometres (km) east of Trois-Rivières in the municipality of Bécancour (Figure 1). This *CANDU**-type (CANada Deuterium Uranium) nuclear power station has been operating commercially as a base-load power station since October 1983, with a rated power output of 685 megawatts (MW).

A nuclear power station is actually a thermal power station which uses uranium as fuel to produce heat from the *fission** of *atoms** (Figure 2). To produce this reaction, atoms of uranium are bombarded with *neutrons**. The atoms react by splitting, releasing large quantities of energy and more neutrons, which continue the reaction.

* Indicates a term defined in the glossary.

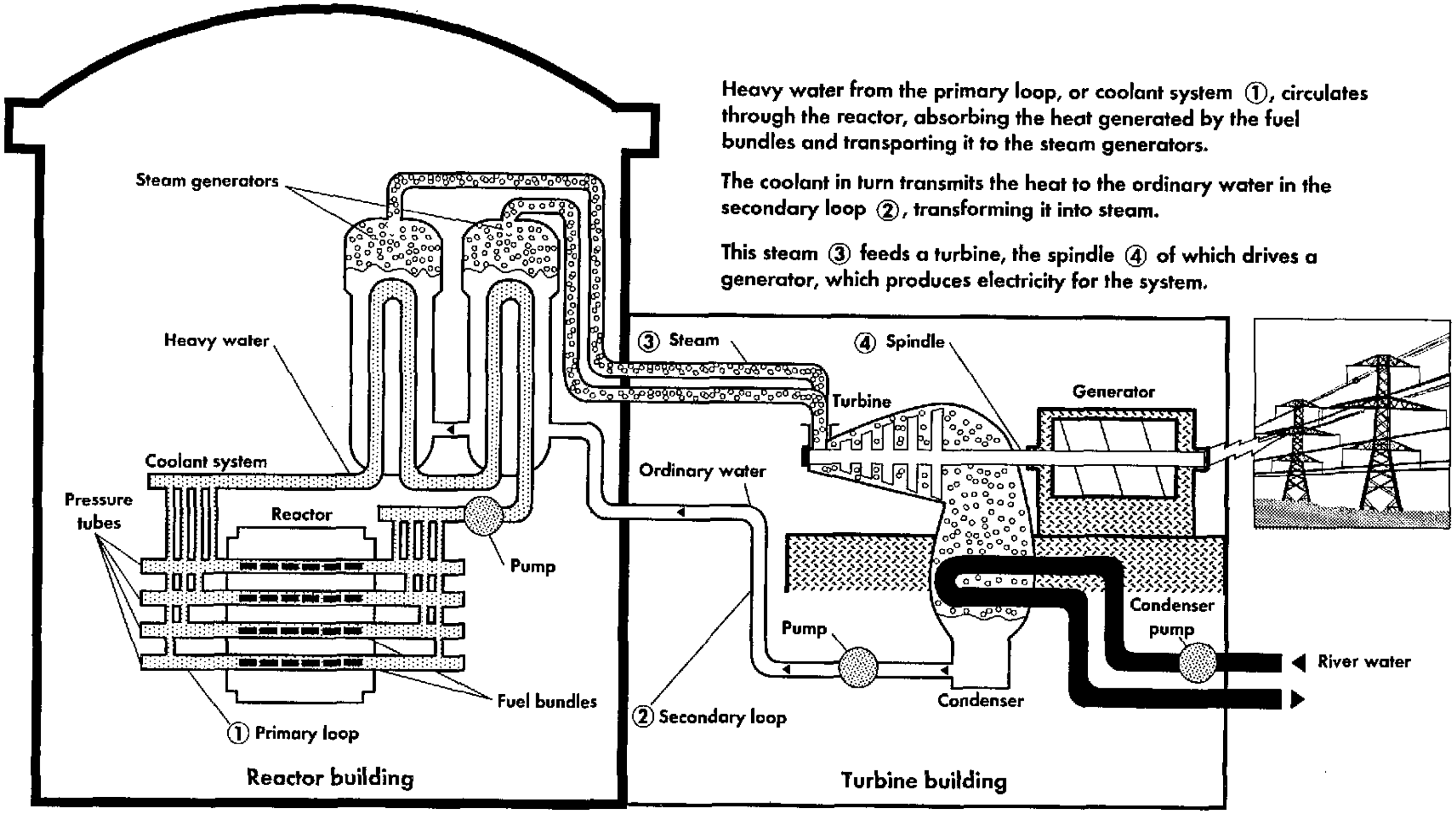
Figure 1 Location and Overview of Facilities in the Gentilly 2 Area





Source : adapted from Di6, Figure 3.7.

Figure 2 Operation of the Gentilly 2 Nuclear Power Station



Source : adapted from Hydro-Québec, 1993.

Most of the energy produced by the fission of uranium nuclei is released in the form of heat and recovered by the water circulating around the fuel: this is known as the *coolant system**. This water transmits the heat to a secondary loop via a *steam generator**; the steam produced in the generator drives a turbine connected to a generator. The rotation of this generator produces electricity.

Nuclear energy accounts for 4% of all electricity produced in Quebec, compared to 48% in Ontario and 30% in New Brunswick. The comparable figure for Canada as a whole is 17% (Di6[1], p. 1-1).

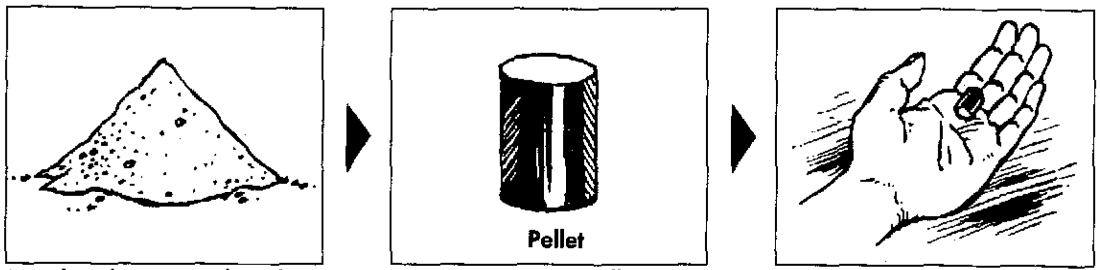
CANDU nuclear power stations use natural uranium as fuel and *heavy water** (D_2O) as coolant and *moderator**. The wastes produced by the Gentilly 2 power station include liquid effluents which are discharged into the St Lawrence River and atmospheric emissions. Operation of the power station also produces low-level radioactive wastes and highly radioactive *irradiated fuel**. The low-level radioactive wastes are stored on site in the *radioactive waste storage area** (RWSA), while the irradiated fuel must first be cooled in the enclosed storage pool adjacent to the reactor until the most appropriate method of temporary storage is determined.

Characteristics of Nuclear Fuel

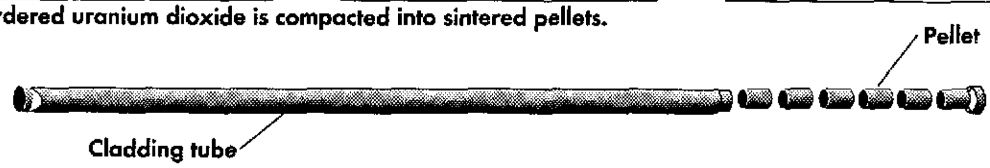
Natural uranium in the form of ceramic pellets of uranium dioxide (UO_2) is used as the fuel. These pellets are stacked end-to-end in a metal *cladding tube** made of *zirconium** alloy and sealed at both ends to form a fuel rod. A group of 37 *fuel rods** forms a *fuel bundle**. Additional information is given in Figure 3.

1. Di: initial document released during the information period (Appendix 4).

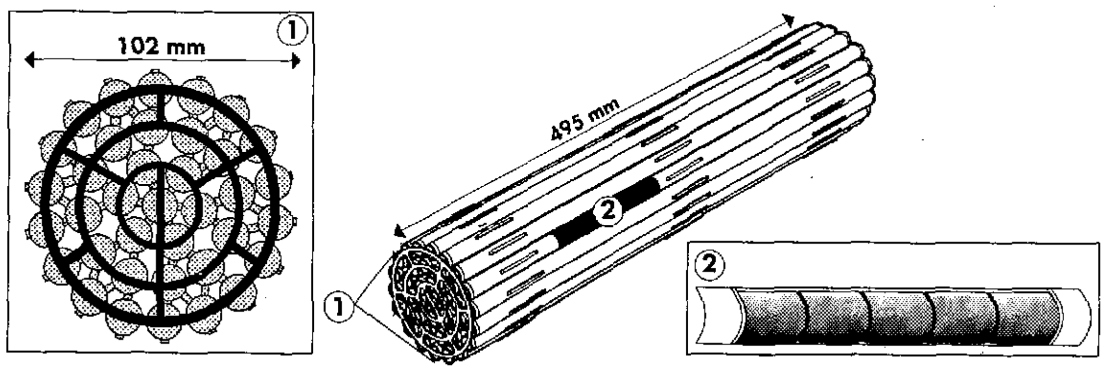
Figure 3 Preparation and Characteristics of Uranium Fuel Bundles



Powdered uranium dioxide is compacted into sintered pellets.



The pellets are stacked end-to-end in an airtight zirconium cladding tube to form a rod.



The rods are welded together to form a fuel bundle. This is the form in which the fuel is placed in the reactor.

Number of uranium pellets per rod	31
External diameter of a rod	13.08 mm
Number of rods per assembly	37
Weight of one full assembly	24 kg
Net weight of uranium per assembly	19 kg
Total number of assemblies in the reactor	4,560

Sources : adapted from Di6, Figure 3.1 and Hydro-Québec, 1992.

According to the proponent, prior to *irradiation** the fuel consists primarily of oxygen and *isotopes** of uranium 234, 235 and 238 in relative proportions of 0.01, 0.71 and 99.28% (Table 1). After approximately one year of use, the fuel bundles are removed from the reactor. The highly radioactive fuel is submerged in a specially designed storage pool to cool and to protect workers against *radiation**. After being submerged for at least six years, the irradiated fuel bundles are ready for dry storage. The energy released by the irradiated fuel is produced by *actinides** and *fission products** (Table 1). These *elements** are produced by neutron bombardment, which transforms the uranium into other unstable radioactive (radiation-emitting) elements (Appendix 1). As their *radioactivity** decreases, they change into stable, non-radioactive elements.

Table 1 Composition of Fuel Pellets Before and After Irradiation (% weight)

Elements	Before Irradiation	After Irradiation
Actinides		
Uranium-238 (initial elements)	99.28	98.42
Uranium-235 (initial elements)	0.71	0.27
Uranium-234 (initial elements)	<0.01	<0.01
Other isotopes of uranium (236, 233, 232)	—	0.08
Plutonium	—	0.40
Other actinides	—	0.01
Total	—	**99.19**
Fission Products		
Strontium, cesium, iodine, etc	—	0.81
Grand Total	**100.00**	**100.00**

Source: adapted from Di6, p. 3-3.

Figure 4 shows the decline in the residual heat of a fuel bundle over time. According to the proponent's calculations, a fuel bundle releases approximately 25,500 watts when removed from the reactor, including 23,700 watts produced by fission products. One hour after removal from the reactor, the energy produced has dropped to approximately 9000 watts. Six years later, only 6 watts are released, 92% from fission products. Between the 6th and 8th years of storage, the fuel loses 20% of its residual energy. After 50 years, energy production has decreased to just over 2 watts, with fission products accounting for only 67% of the total released energy (Di6, p. 3-4, and Di-9, p. 15).

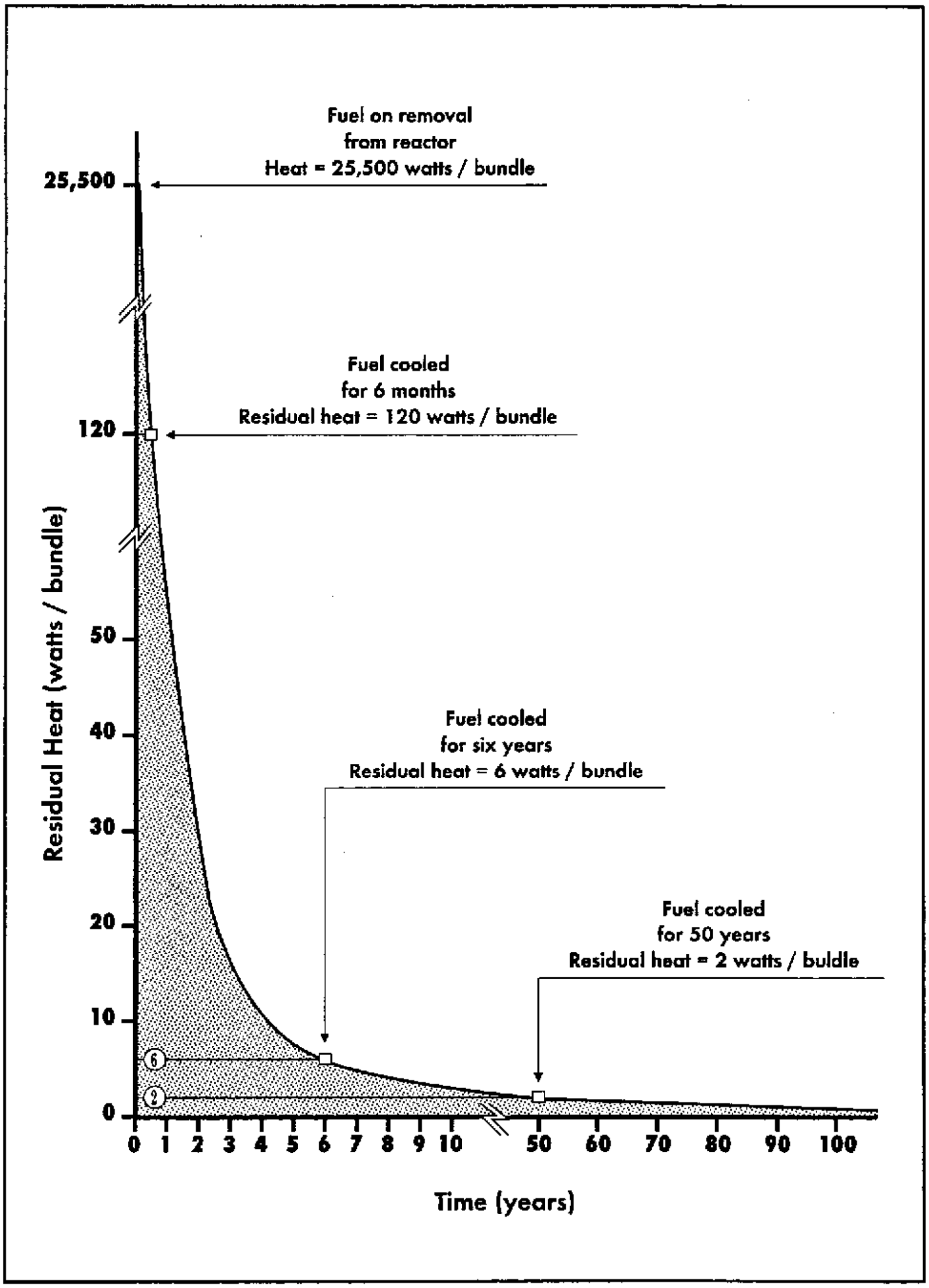
Selection of Storage Technology

Need for Temporary Storage

When the Gentilly 2 nuclear power station was built by Hydro-Québec in 1983, the *storage pool** was designed to hold 45,000 irradiated fuel bundles, the amount expected to be produced in ten years of operation. By January 1994, the pool was filled to over 90% capacity because the power station had been operating at full power since 1987. Given the fact that no permanent disposal site will be available before 2025 and fuel recycling is not planned in Canada, the proponent feels that the irradiated fuel should be stored temporarily near the power station (Di6, p. 2-2, and Hydro-Québec, 1993).

The temporary storage system proposed by the proponent is expected to be able hold all the irradiated fuel produced over the anticipated 30-year lifespan of the power station, until the permanent fuel waste disposal program comes into operation.

Figure 4 Residual Heat Decrease of a Fuel Bundle



Source : adapted from Di6, Figure 3.2.

Options Examined by the Proponent

To support its proposal, the proponent assessed four temporary storage options. These are: underwater storage in a new storage pool, dry storage in CIC and AECL silos, and CANSTOR modules.

New Storage Pool

Underwater storage in a fuel storage pool is the only type of storage currently in use at Gentilly 2. It is a proven technology but, unlike dry storage, requires constant surveillance and maintenance. Radiological *shielding** is provided by approximately four metres of water above the irradiated fuel and by the concrete walls of the storage pool. The proponent claims that a new storage pool, twice as large as the first, would meet the needs of the power station for an additional 20 years, with a capacity of 84,000 fuel bundles. Underwater storage in the two pools could thus meet the power station's storage needs for its entire estimated service life of 30 years.

CIC Silos

Ontario Hydro has developed *CIC silos** (Concrete Integrated Canisters) for its Pickering nuclear power station. A CIC silo can hold 284 fuel bundles and does not require stainless steel *fuel baskets**, since the fuel bundles are placed on plates inside the silo. The plates holding the irradiated fuel bundles are loaded directly into the silo, which is first placed in the transfer pool. The silos are stored in a controlled-atmosphere warehouse. *Containment** is ensured by two airtight barriers: the cladding tube surrounding the fuel and the metal wall of the silo. Shielding is provided by 0.52 m of concrete and steel. The heat of the fuel is dissipated by natural *conduction** and *convection**.

AECL Silos

The *AECL silo** developed by Atomic Energy of Canada Limited is a cylindrical structure of reinforced concrete which can hold nine baskets. Irradiated fuel bundles which have been stored in the pool for a minimum of six years are placed in airtight cylindrical stainless steel baskets (Figure 5). Each basket contains 60 fuel bundles, for a total of 540 fuel bundles per silo. These baskets are then stacked in an airtight metal cylinder with its own concrete radiological shielding. Containment of the radioactive products is ensured by three airtight barriers: the fuel rod, the basket and the cylinder. The heat of the fuel is dissipated by conduction through the metal and concrete walls (Figure 6). The silo is designed to have a service life of at least 50 years.

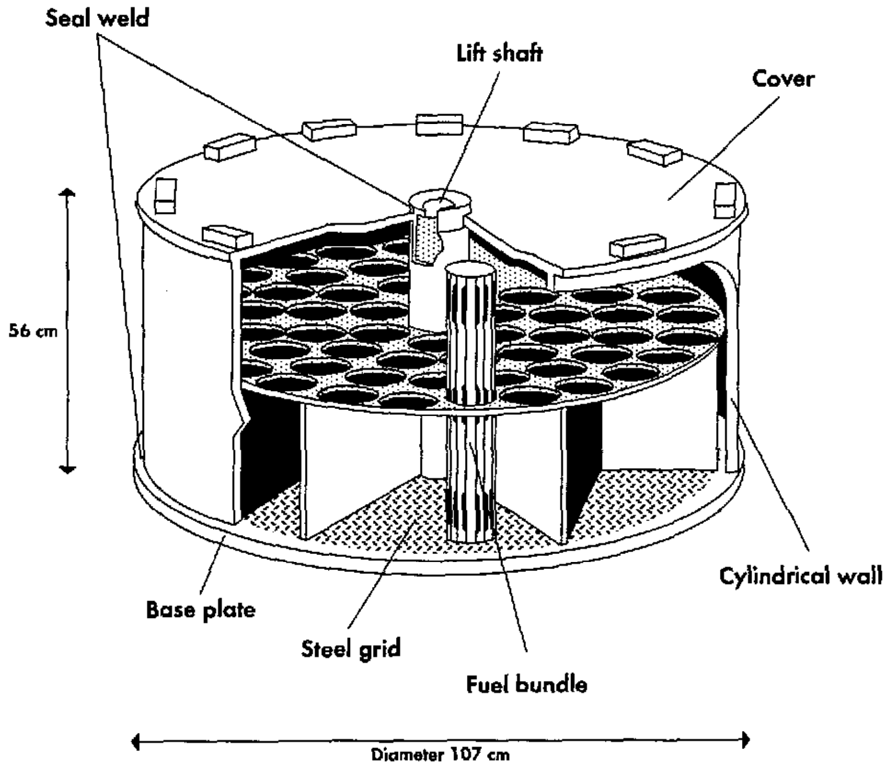
CANSTOR Module

The concept of dry storage in the *CANSTOR module**, as proposed by AECL, is a variant of the silo storage technique. This new technology is not yet on the market. Fuel bundles which have been stored in the pool for a minimum of six years are placed in stainless steel baskets, welded and stacked in an airtight galvanized steel cylinder. The module is a concrete structure holding two rows of ten vertical *airtight cylinders**. Each cylinder holds 10 baskets of 60 fuel bundles, for a total of 12,000 fuel bundles per module. Shielding from radiation is provided by the concrete walls of the module structure. The heat of the fuel is dissipated primarily by natural convection through ventilation pipes extending through the concrete walls. The pipes' air intakes and outlets are located 1.3 m and 5.6 m respectively from the base of the module and fitted with stainless steel grids welded in position. The pipes are arranged in a series of baffles to eliminate direct gamma radiation (Figure 6).

Following the public sessions, the proponent modified the original plan by adding a reinforced concrete caisson to support the module. Each module is designed for a service life of at least 50 years.

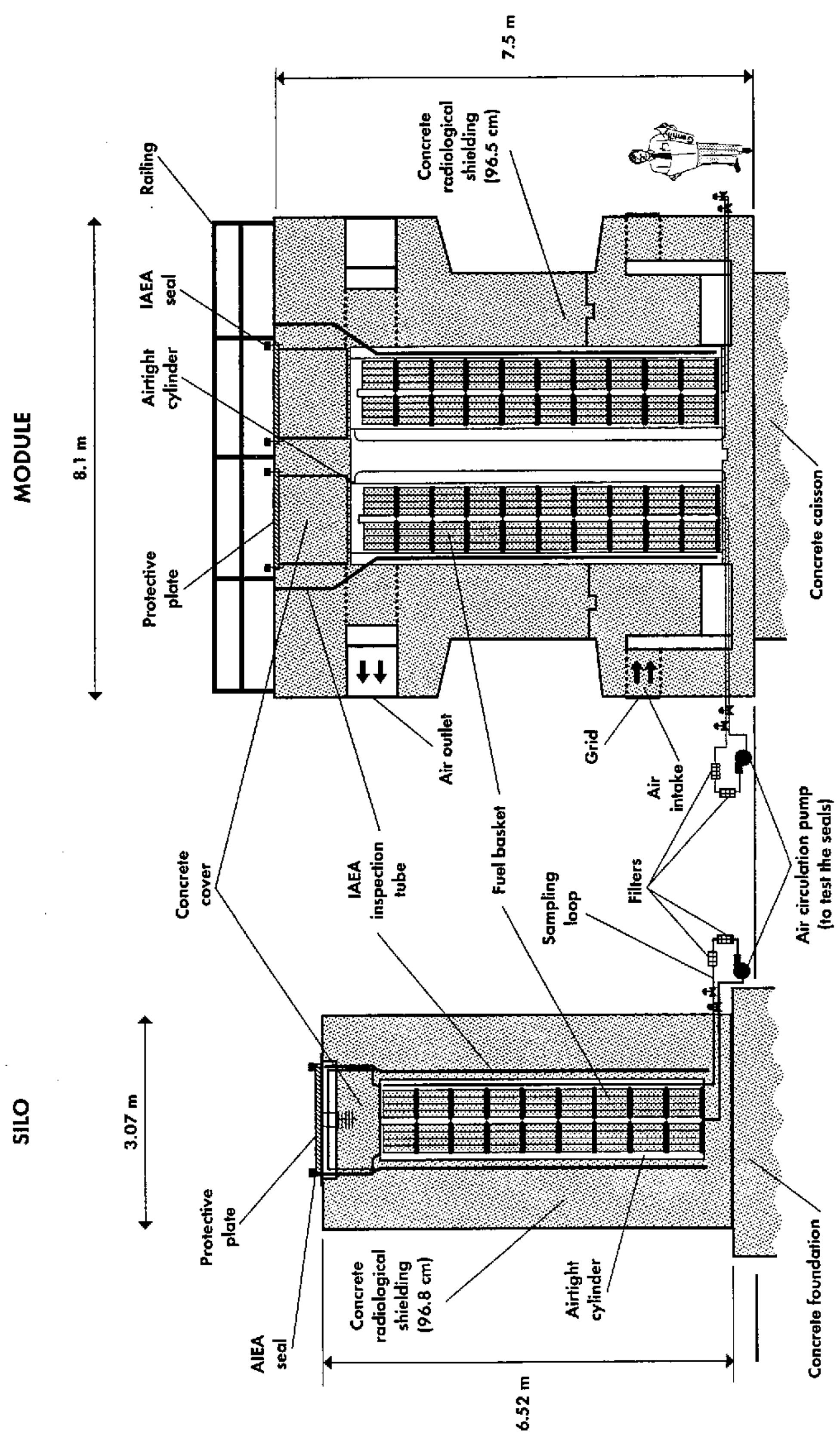
Figure 5 Irradiated Nuclear Fuel Dry Storage Basket

The stainless steel basket can hold 60 irradiated nuclear fuel bundles.



Source : adapted from Di6, Figure 3.11.

Figure 6 Cross Section of AECL Silo and CANSTOR Module



Source : adapted from Di6, Figures 3.3 et 3.6.

Options Proposed by Hydro-Québec

Following assessment of the different technologies, Hydro-Québec has selected the AECL silo and the CANSTOR module (options studied in detail in Chapter 4) because of the advantages which they offer in terms of environmental protection, radiological safety, proven technology, and lowest cost.

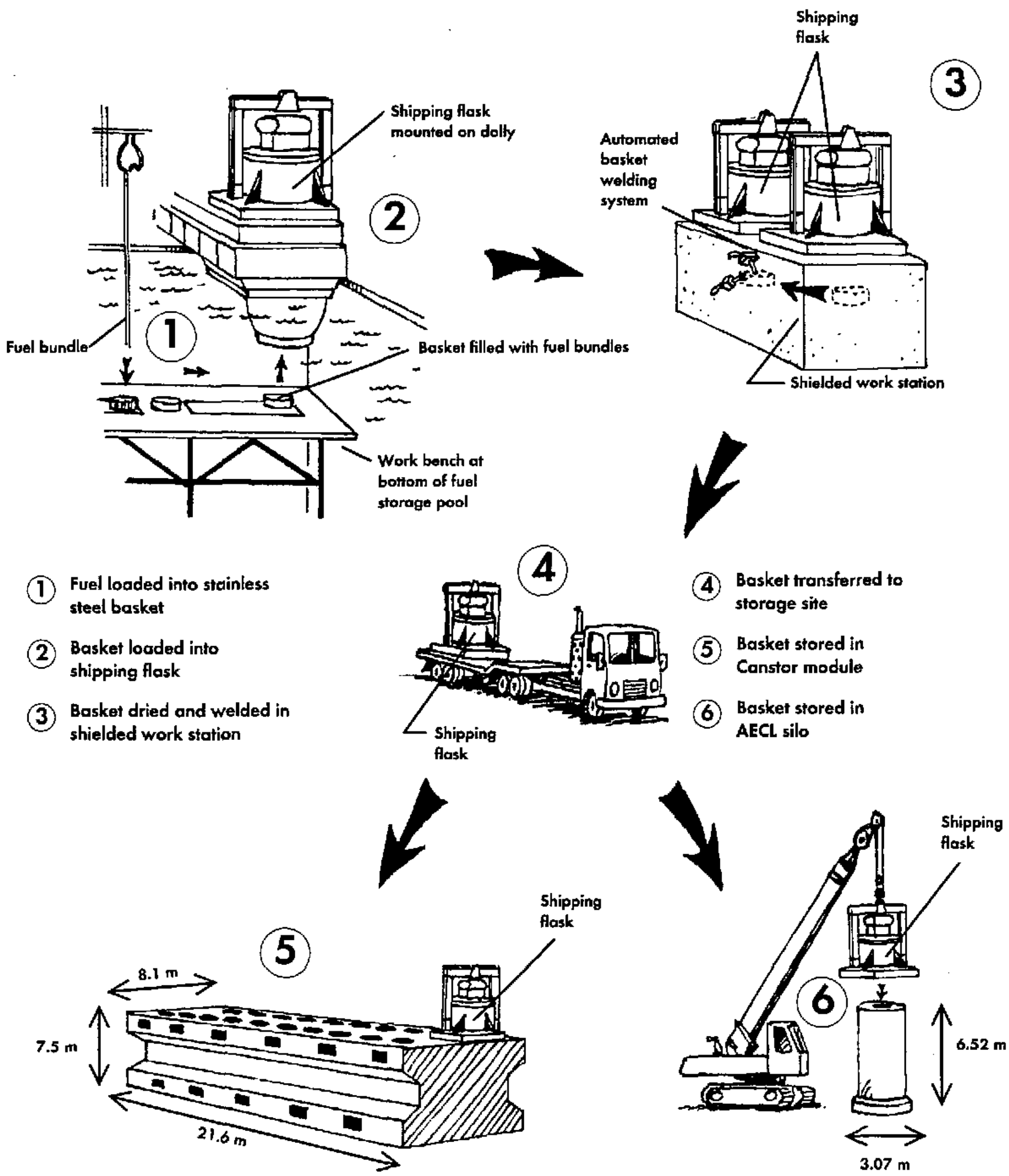
In both cases, the proponent states that the fuel bundles would have to be prepared and transported in specially designed containment systems (Figure 7).

The dry storage facilities would come into service in 1995 and would hold 5000 irradiated fuel bundles in the first year of operation. According to the proponent's plan, 12,000 assemblies would be stored on site in 1996, then the amount of irradiated fuel transferred to the storage site would vary with the power station's production.

Choice of a Site

The two sites proposed for dry storage of irradiated fuel are located on Hydro-Québec property within the *exclusion area** of the power station. Site 1 lies within the *protected area**; it includes the former control post for Gentilly 1 and an area to the west of this. Site 2 is located south of the RWSA for low-level radioactive wastes (Figure 1). According to the proponent's environmental, technical and economic assessments, Site 1 is the best choice, regardless of the dry storage option selected. The use of Site 1 would avoid the destruction of a wooded area and potential wildlife habitat, and make use of a control post site which is no longer in operation. In addition, it would facilitate surveillance and inspection of the site, since it is located inside the fenced, protected area. Site 1 offers yet another advantage since irradiated fuel would have to be transported over a distance of only 350 m, between the services building and the dry storage site, compared to 900 m to Site 2. The cost associated with this operation is estimated at approximately $917,000 for Site 1, compared to $1.8 million for Site 2. In addition, Site 1 would require the excavation and replacement of only about half as much soil as Site 2. Finally, according to the proponent, this site would require only minimal changes to the road system and would allow the use of existing security systems.

Figure 7 Sequence of Operations Involved in Dry Storage of Irradiated Nuclear Fuel



Source : adapted from Di6, Figure 3.19.

Assessment of Environmental Impact, Environmental Surveillance and Monitoring

The proponent feels that the most important impact during the operational phase is the public perception of the risk associated with the storage of irradiated fuel. The Crown corporation considers this impact to be of moderate importance, while all other impacts on the natural environment and public health in the area are considered minor. Hydro-Québec believes that the absence of radioactive wastes under normal operating conditions, and compliance with maximum radiation doses at the surface of the structures and at the fence around the protected site would help to limit the risks of exposure for workers and the public.

Hydro-Québec would take advantage of the fact that the dry storage facilities would be located on a nuclear site already subject to periodic inspection by the AECB. For example, the proponent would use existing infrastructures to ensure compliance with the principles of safety and *radiological protection** applicable to this type of facility. The nuclear power station's existing procedures for radiological testing and monitoring of the environment, the radiological protection program, the quality assurance program, the access control system, and the emergency measures plan would be applied to the storage facilities or adapted, as required.

Economic Impact of the Proposal

The total cost of the initial phase of the proposal, extending to the end of 1996, is estimated at $21.3 million for the CANSTOR module storage option and $23.1 million for the AECL silos. The subsequent two- to three-year phases would require investments of $22.4 million and $23.9 million for the modules and silos respectively. Implementation of the first phase of the proposal, i.e., construction of the facilities, would create approximately 60 person-years of employment in Quebec out of a total of 115 person-years. Handling and transfer of the irradiated fuel during phase 1 of the project would create 4 person-years of employment, including one person-year for the staff of the power station.

Chapter 2 Concerns of the Participants

The mandate for the review and public hearings began on August 15, 1994. The seven public sessions of the first part of the hearing were held at Bécancour, between August 24 and September 1, 1994, with an average of 35 people attending. A total of 242 documents were tabled in support of the exchanges, including 76 by the proponent, 60 by members of the public and 106 by government departments and ministries and/or agencies. The five public sessions of the second part of the hearing, which was devoted to the expression of opinion, were held at Bécancour, from September 27 to 29, 1994, with an average attendance of over 40 people.

During the sessions of the first part of the public hearing, when the proponent's proposal was examined, and of the second part, when briefs were submitted to the panel, members of the public and agencies expressed concern regarding nuclear energy in general, the operation and safety of the power station, the risks related to the health of workers and of the public, the emergency plans, the *dismantling** of the power station, and the social, economic and environmental advantages and disadvantages of producing nuclear energy in Quebec. As for the actual storage of irradiated nuclear fuel, the concerns were mainly related to the temporary or permanent nature of such storage, and to the *safety** and *security** of the silos and modules proposed by Hydro-Québec. A number of participants expressed concern over the role played by the Atomic Energy Control Board (AECB) and the resources available to it, while others had doubts on the effectiveness of the procedure of public impact assessment and the impartiality of the panel.

Concerns Related to Nuclear Power

A number of organizations, including Greenpeace Quebec, Les Ami-es de la Terre de Québec, the Mouvement Vert Mauricie inc. and the Canadian Coalition for Nuclear Responsibility, expressed their philosophical and, in some cases, militant opposition to the use of nuclear power in Canada and Quebec, except for medical purposes. These groups, together with a number of individual participants, also insisted that the Government of Quebec's 1988 decision not to become involved in the production of nuclear energy should be interpreted as a moratorium on nuclear energy in Quebec. Other organizations, including the Groupe de Recherche Appliquée en Macroécologie and ENvironnement JEUnesse, stated that the development or maintenance of nuclear facilities was inappropriate because of the financial, ecological, technical and social impact on future generations. The Groupe de Recherche Appliquée en Macroécologie expressed its position as follows:

> *In view of the abundant hydroelectric resources available to Quebec, the dry storage methods currently proposed for nuclear wastes are acceptable only with the provision that the nuclear energy sector will end, in Quebec, with the service life of Gentilly 2.*
>
> *The nuclear energy sector must be terminated because it transfers its problems to future generations, in clear contradiction with the requirements of sustainable development (particularly when another source of energy is financially more than competitive).*
> (Brief submitted by the Groupe de Recherche Appliquée en Macroécologie, p. 21)

A number of participants expressed profound concern, while others referred to the recent accidents at Chernobyl in Ukraine and Three Mile Island in the United States to confirm their fears and justify their conviction that nuclear energy should be abandoned in Quebec. One member of the public described the source of his fear of nuclear energy, which he believed dated from the construction of Gentilly 2 in the early 1980s.

... My concern about nuclear energy is completely unscientific, it is visceral, it is latent and it is permanent, and I have finally identified the source of this concern that I have had for so long! ... Someone asked what would happen to the public in the event of an accident, and Hydro-Québec answered that, because of the low density of the population, a major accident at Gentilly would not be a national disaster. ... But there has been a relatively major accident in Russia, and I decided at that time that, even with a low population density, since the prevailing winds are always in this direction, if a nuclear accident did occur, the radioactive cloud would obviously reach Quebec City in a very short time.
(Mr. Yves Beauchesne, August 31, 1994, afternoon session, p. 109)

The Ligue des femmes du Québec argued that there is no room for error in nuclear energy. Human nature being what it is, the world being imperfect, and the consequences being so serious, they urged that the nuclear energy sector be abandoned. A representative of this group expressed women's fear of nuclear energy in the following terms:

In terms of reproduction, for example, we know that if we act in such and such a manner, we will end up with a contract with a baby for 20 years.

So this is why we are careful, and when we think about nuclear energy, it's the same kind of thing. What are the consequences of a nuclear power station thirty years down the road? There will be wastes, and the wastes will be there for tens of thousands of years.

So biologically, we are more inclined to be cautious when we are looking at long-term consequences.
(Mrs. Claudette Jobin, September 29, 1994, afternoon session, p. 44)

Finally, the application of nuclear energy to military purposes, using irradiated fuel from CANDU power stations like Gentilly 2, has led a number of organizations, including Les Ami-es de la Terre de Québec, and numerous members of the public to oppose nuclear energy.

The panel received 51 briefs, including 30 petitions signed by 264 individuals from across Quebec. These individuals reiterated the concept of a moratorium on the expansion of nuclear energy in Quebec, opposed the storage of nuclear wastes on Quebec soil, urged increased research and development of new clean technologies consistent with the principles of integrated resource planning and, finally, suggested that Hydro-Québec convert and develop its expertise in decommissioning and decontaminating nuclear power stations. Their arguments are based on the dangers of nuclear energy to health and to the environment, on the refusal of the Government of Quebec to allow a permanent disposal site within the province, and on the risk of proliferation of nuclear weapons created by the operation of a nuclear power station.

Of the 60 documents tabled by participants to the public hearing, 47 came from newspapers or periodicals and reported facts relating to the medical and environmental consequences of various nuclear accidents, the risk that irradiated nuclear fuel and plutonium will be used for military or subversive purposes, the expansion of nuclear capacity in the world through the use of various systems, including the Canadian system, control of the traffic in radioactive products, and temporary or permanent storage of irradiated fuel at Gentilly and elsewhere in Canada. The other documents tabled consisted of books, extracts from reports, scientific articles, correspondence, extracts from a radio broadcast, a film on the uranium cycle, administrative documents, and an assessment of the state of the environment in the municipality of Bécancour.

Concerns Related to the Gentilly 2 Power Station

The Bécancour area is dotted with nuclear facilities, from AECL's Gentilly 1 and Hydro-Québec's Gentilly 2 power stations to the nearby Laprade heavy water plant. Their presence is a highly visible reminder of the activities they involve, activities which generate fear in some individuals, and familiarity, indifference or even satisfaction in others. The participants expressed a number of concerns related to the health of workers and members of the public, the security of the power station, the Emergency Plan, and the economic costs and benefits associated with maintaining or closing down the power station and its activities.

Human and Environmental Health

Despite the data and information provided by the Direction de la santé publique de Mauricie—Bois-Francs, the Mouvement Vert Mauricie inc. and Les Ami-es de la terre de Québec reiterated their concern with respect to the birth defects observed in children and animals, and the high miscarriage rate in the municipality of Gentilly. The potential increase in cancer and leukemia together with the impossibility of conducting epidemiological surveys also concerns these organizations. One participant was particularly interested in the effects of the *tritium** released by the power station on health in general and on the fetuses of pregnant women. The Syndicat des employé-es de métiers d'Hydro-Québec, whose primary concern is a safe and secure environment for workers, indicated that all current operating conditions at the power station are safe for its members and for the local population.

Safety and Security of the Power Station

Greenpeace Quebec, the Mouvement Vert Mauricie inc., the Ligue des femmes du Québec, and numerous members of the public expressed concern over the various incidents that have occurred at the Gentilly 2 power station since it came into operation, and which have been reported in the local press. These groups feel that any incident reflects the continuing danger associated with the operation of a nuclear power station, and the possibility of an eventual disaster. They believe that workers at the power station require improved training and skills, and that the review of the station's operating procedures must be accelerated.

Emergency Plan

Members of the public and of environmental organizations expressed concern about the consequences of a major accident at the power station requiring the implementation of emergency measures or even the evacuation of the local population. The same individuals questioned the role of the host municipalities in the event of evacuation. One woman asked, among other things, about the length of the evacuation period, and the criteria and conditions governing the return of those evacuated. Environmental organizations questioned the progress on the revision of the Emergency Plan by the Ministry of Public Security, and its coordination with the emergency plans of the power station and the various ministries responsible for responding. The Mouvement Vert Mauricie inc. expressed concern about insurance coverage and specific conditions of civil liability protecting the Gentilly 2 power station.

Cost and Economic Impact

Various residents of Gentilly and some groups, including the Canadian Coalition for Nuclear Responsibility, ENvironnement JEUnesse and the Groupe de Recherche Appliquée en Macroécologie, expressed concern with respect to the cost of the continued operation of the power station. Some citizens were concerned about the absence of concrete economic benefits to Gentilly to offset, at least partially, the risks of accidents incurred by the local population. ENvironnement JEUnesse concluded, on the basis of integrated resource planning, that the financial, social and environmental costs involved in continuing to operate the power station beyond 1995 would be prohibitive. The Canadian Coalition for Nuclear Responsibility felt that the cost of the power station has been too high since its opening and that future maintenance expenditures as it ages will be excessive. The Chambre de commerce du district de Trois-Rivières, AECL and the Syndicat des employé-es de métiers d'Hydro-Québec urged continued operation of the power station, not only to maintain current economic benefits and jobs in the regional municipalities of Bécancour and Francheville, but also to keep the highly skilled jobs in the field of nuclear energy. The Mouvement Vert Mauricie inc., the Canadian Coalition for Nuclear Responsibility, and a representative from the Association québécoise de lutte contre la pollution atmosphérique expressed their concern about the extension of the power station's service life, the retubing operations and their potential cost, and the eventual decommissioning of the power station.

Concerns Related to the Storage of Irradiated Fuel

Temporary Nature of the Storage

A number of individuals and organizations expressed their concern that the temporary storage may become permanent. These participants suggested two possible situations in which this might occur: a delay in the final selection and approval of a permanent disposal site or a change in the political context which would prevent the export of irradiated fuel from Gentilly to a potential permanent site elsewhere in Canada. One resident of Gentilly expressed his concern in these words:

> *I am certainly no prophet, but I think it is clear to everyone that, in the short or medium term, or, in any event, within a few years, the silos will probably not be finished and the state of Quebec will have become a reality.*
>
> *And when we want to move these wastes to the permanent disposal site, we will have to negotiate with a foreign country to do so.*
> (Mr. Yves Beauchesne, August 31, 1994, afternoon session, p. 119)

Another citizen asked about the possibility that irradiated fuel or nuclear wastes produced outside Quebec might be brought in to Gentilly, and expressed grave concern regarding the legal measures available to prevent such an event. A representative of the Mouvement Vert Mauricie inc. asked for details on the economic links between AECL's partners in the research on permanent disposal in the Canadian shield and their rights to "dispose of their own wastes as well and to make Canada a world disposal site" (Mrs. Marie-Claude Lacourse, September 1, 1994, evening session, p. 120). The Canadian Coalition for Nuclear Responsibility expressed concern about the astronomical cost to Hydro-Québec should it be required to develop its own permanent disposal site for irradiated fuel.

An expert from the Nuclear Engineering Institute at the École Polytechnique pointed out to the panel that the irradiated fuel still contains 97% fissile material which, if recycled, could provide 50 to 60 times more energy than the first time around. In his opinion, reprocessing the fuel is a conceivable solution in the medium to long term.

Security and Health

Some representatives of environmental organizations felt that the proponent's impact study was somewhat vague in its examination of events which might damage the silos or modules (aircraft crashes, meteorites, earthquakes, terrorism). A number of organizations, and members of the public were concerned about the radiotoxicity of the irradiated fuel bundles from the power station and the lack of data to estimate their total toxicity to the environment and to health. The Canadian Coalition for Nuclear Responsibility called for a complete inventory of the radioactive and toxic materials present in the irradiated fuel bundles, to allow assessment of their potential impact on health. One participant was particularly concerned with the management of defective irradiated fuel bundles stored in the storage pool, and by the treatment of the pool's water and ambient air. The representative of the CLSC from Du Rivage wanted to make sure that worker exposure and security measures would be monitored during the construction of the silos and the modules.

Concerns Related to the Atomic Energy Control Board

A number of environmental organizations questioned the ability of the AECB to ensure compliance with its standards and provide adequate monitoring of the power station's activities. Their concerns arose primarily from a request submitted by the AECB to the federal Treasury Board in 1989, describing the difficulties the agency was experiencing in meeting its responsibilities as a result of inadequate human and financial resources. While corrective measures have been taken, a number of environmental organizations noted certain recent incidents, including one involving the reactor at McMaster University on January 4, 1994. Mr. Nicolas Tremblay of ENvironnement JEUnesse made the following statement:

> *In view of the means currently available to the AECB and the fact that this is an event which occurred this year, in 1994, not five years ago, does the AECB now have the resources required to ensure the safety of those living in the vicinity of nuclear facilities ?*
> (Mr. Nicolas Tremblay, August 30, 1994, evening session, p. 156)

The same groups are suspicious of the fact that the AECB's surveillance of the power station is in large part supported by the licensing fees paid by the proponent.

Concerns Related to the Impartiality of the Inquiry and Public Hearing Panel

The Canadian Coalition for Nuclear Responsibility, although they did not question the honesty and integrity of the panel, expressed concern that one of the members of the panel had worked for many years in the nuclear industry and in training engineers in this field. He noted that two of the three members had previously worked for the AECB, the agency responsible for issuing one of the licences Hydro-Québec needs to implement this proposal.

While the BAPE has established documentation centres, the Canadian Coalition for Nuclear Responsibility considered it unacceptable that complete copies of the impact study were not made available to participants requesting them. At the beginning of the public sessions of the hearing, the Canadian Coalition for Nuclear Responsibility and the Mouvement Vert Mauricie inc. reserved the right not to participate in Quebec's public examination of the impacts, a right they chose not to exercise.

Explanations were offered with respect to:

- the public hearings procedure;
- the joint public review of the proposal;
- the composition of the panel;
- and the procedure for appointment of the panel members.

Chapter 3 Context and Scope of the Project

In this chapter, the panel analyses various modes of operation for the Gentilly 2 power station and their impact on the temporary storage proposal. Next, it examines the role played by the nuclear energy sector in Quebec, both in the Energy Policy and in Hydro-Québec's Development Plan. Finally, it examines the potential role of integrated resource planning in decision-making on energy issues.

Waste Storage and the Gentilly 2 Power Station

From an Accessory Concern to the Central Issue

In its assessment of social impact, Hydro-Québec indicated that it was difficult to predict whether the storage of irradiated fuel would be perceived as an issue by the public. It stated, however: "A number of surveys show that the operation of the power station is definitely an environmental issue for a number of regional stakeholders and a segment of the population of the Shawinigan-Bécancour area" (Di6, p. 7-13).

In the course of the public hearings, the panel noted that the vast majority of the local, regional and provincial participants considered the operation of the Gentilly 2 power station to be the main issue or primary objective of the public consultation, rather than the storage proposal, which, in fact, they viewed as a relatively secondary or accessory concern. This view was expressed in the previous chapter, dealing with the concerns of the participants.

Therefore, the panel examined a number of aspects of Hydro-Québec's storage proposal related to the operation of the Gentilly 2 power station. The panel felt that it was essential to examine the possibility of an immediate shutdown of the Gentilly 2 power station, since its operation is at the heart of the justification of the storage proposal. The panel felt that it was also necessary to consider the possible refurbishing of the power station and the operation of the facility at a reduced capacity, because of the impact such operations would have on the size of the temporary storage facilities and the need for action in this area.

Immediate Shutdown of the Gentilly 2 Power Station

Considering the fact that the Gentilly 2 power station has reached the one-third point of its estimated 30-year service life, which is expected to run to the year 2013 (Di6, p. 2-2), the panel examined the economic impact of a shutdown.

The cost of closing the power station was debated in the course of the public hearings. According to Hydro-Québec, this action would cost $1.865 billion (current dollars) over the period 1995-2010 and would result in an increase in rates of approximately 1.2% over the same period (tabled document A47). Table 2 indicates that most of this figure relates to the $3040 million cost of replacing the power station, which is largely what it would cost Hydro-Québec to acquire production facilities of similar capacity to Gentilly 2, based on the avoided cost. This cost would not be incurred until 1999 since Hydro-Québec's energy planning forecast indicates that new means of production will not be required until the year 2000. In view of the anticipated energy surplus between 1995 and 1999, Hydro-Québec estimates that it would lose $455 million in profits on foregone additional sales. At the same time, it would save $1615 million on the costs of operating the power station, including labour and the costs of fuel, heavy water and maintenance. The financial analysis also indicates that decommissioning and removal of irradiated fuel would produce savings of $295 M, taking into account the costs of early decommissioning and the savings associated with the removal of a smaller quantity of irradiated fuel.

Table 2 Financial Impact, 1995-2010, of Closing Gentilly 2 in 1995, According to Hydro-Québec

	Current Dollars (millions)
Net impact of writing off non-amortized power station costs	+ 10
Net impact of decommissioning and fuel removal costs	– 295
Lost profits (additional sales)	+ 455
Cost of replacing power station as of 1999	+ 3,340
Reduction of power station operating costs	– 1,615
Cost of placing irradiated fuel in dry storage	+ 30
Total	**+ 1,865**

\+ Cost – Saving

Source: adapted from tabled document A47.

ENVironnement JEUnesse indicated that the immediate closure and decommissioning of the power station would generate savings of $889 million (1993 dollars) over 15 years. The group got this result by comparing the social cost of the proposal, that is, the total operating cost of Gentilly 2, $4102 million, with the cost of halting waste production, to determine the total cost of closing the power station, $3213 million (Table 3).

Table 3 Estimated Cost of Operating and Closing the Gentilly 2 Power Station (millions of 1993 dollars), According to ENVironnement JEUnesse

	Operation	Closure
Business cost	2,076	3,193
External cost	2,026	20
Total	**4,102**	**3,213**
Difference	**889**	

Source: adapted from the brief submitted by ENVironnement JEUnesse, p. 31.

To calculate the estimated social cost of the proposal, the group added a total of $2026 million for a number of externalities to the business cost of operating the power station ($2076 million). The business cost includes a replacement cost for the energy not produced as the power plant ages ($294 million), assuming that once the point of optimal production is over, the power station's utilization factor would decrease. The panel defines externalities as costs which, while real and sometimes difficult to quantify, are not taken into account in determining the true cost of a proposal. As a result, they are often assumed by the community, as when water purification costs are borne by the government. These external costs may be positive or negative. Those submitted by ENvironnement JEUnesse, while their accuracy cannot be confirmed, relate to health, the risk of accidents, impact on the environment and the financing of the nuclear industry (Table 4).

The cost of closing the nuclear power station ($3213 million) corresponds to its replacement cost. It consists of a business cost ($3193 million) which includes lost export sales ($394 million) and the cost of equivalent energy production, based on the avoided cost ($2799 million). According to ENvironnement JEUnesse, the external cost is low ($20 million) if the alternative system considered is wind energy, or nil, in the case of energy saving measures. The group concludes: "Despite higher financial costs for Hydro-Québec, the social cost of decommissioning is lower" (brief submitted by ENvironnement JEUnesse, p. 31).

The panel notes that, according to the hypotheses advanced by ENvironnement JEUnesse and excluding externalities, this group estimates that closing the Gentilly 2 power station would entail an additional cost of \$1117 million, representing the business cost of closing the power station (\$3193) minus the business cost of operating the power station for 15 years (\$2076 million). This estimate is similar to the Hydro-Québec figure of \$1171 million (1993 dollars).

The Groupe de Recherche Appliquée en Macroécologie estimates that, including positive and negative externalities, the financial cost of operating the power station is higher by 2.4¢/kWh (US), or 2.43¢/kWh (Canadian) (1993) (Table 4). This organization considers a number of negative externalities relating to health, property damage, cost to the environment, and the costs of waste management and dismantling the power station. The positive externalities in terms of air pollution are evident in any comparison of nuclear energy with thermal energy. The group concludes: "This balance sheet clearly indicates that nuclear energy is not a valid option when significant hydroelectric potential is available, as it is in Quebec" (brief submitted by the Groupe de Recherche Appliquée en Macroécologie, p. 20).

In replying to the ENvironnement JEUnesse brief, Hydro-Québec recommends caution in the use of externalities and draws the following general conclusion: "Externalities are always site- or project-specific" (tabled document A75, Appendix 1). The corporation refers to an Ontario Hydro study of its nuclear power stations, indicating very low externalities of from 0.0015 to 0.119¢/kWh (1992) (tabled document A75, Appendix 1).

Table 4 Estimated Cost of Positive and Negative Externalities in ¢ / kWh (1993), According to ENvironnement JEUnesse and the Groupe de Recherche Appliquée en Macroécologie

ENvironnement JEUnesse:	
Federal subsidies to AECL	– 0.16
Health risks associated with the power station	– 0.09
Health risks associated with uranium production	– 0.17
Health risks associated with wastes	0.01
Risk of serious nuclear accidents	– 2.26
Impact on aquatic ecosystem	– 0.01
Auxiliary TAG nuclear power station at Bécancour	NE
Contribution to greenhouse effect	NE
Uncertainty regarding future costs of the nuclear industry	NE
Risk of nuclear proliferation	NE
Impact of stress on public health	NE
Balance	**– 2.70**
Groupe de Recherche Appliquée en Macroécologie:	
Cost to health	– 2.02
Damage to property, cost to environment and natural resources and costs of waste management and dismantling power stations	– 0.92
Avoided atmospheric emissions (CO_2)	+ 0.51
Transportation infrastructure	NE
Geological modifications	NE
Balance	

NE: not estimated

\+ positive externality
– negative externality

Sources: adapted from the briefs submitted by ENvironnement JEUnesse and the Groupe de Recherche Appliquée en Macroécologie.

Examination of the externalities clearly demonstrates some of the difficulties inherent in their use. Those participants using them do so with caution. Some externalities vary widely with the authors cited. In addition, it is often difficult, if not impossible, to express in financial terms some of the externalities relating to the value of human life. Finally, the problem of their actual application to the case in question remains unresolved since the calculation and application of these costs to Gentilly 2 is eminently desirable. However, while the externalities used are, in some instances, dissimilar, contradictory or not estimated, both groups have arrived at similar significant values. Externalities are equivalent to 2.43¢/kWh, according to the Groupe de Recherche Appliquée en Macroécologie, and 2.70¢/kWh, according to ENvironnement JEUnesse. Hydro-Québec also is concerned with externalities. Following the adoption of its 1993 Development Plan, it undertook a study of these costs. Hydro-Québec's spokesperson offered the following information in this regard:

> *This study program has been underway for over a year. Externalities are one of the major themes in the public consultation process currently being conducted with some one hundred interest groups, environmental groups, industrial groups, educational groups ..., for the purpose of discussing and producing the next Development Plan for 1996.*
> (Mr. Michel Rhéaume, September 29, 1994, afternoon session, p. 116)

An expert consulted by the panel on the question of externalities stated that he could "offer no opinion on the list of proposed externalities and still less on the financial values assigned to them" (tabled document B103, p. 19). He later added: "Unfortunately, there is no consensus on the use of this information" (tabled document B103, p. 20).

While the panel believes that it is not in a position to assess the accuracy of the figures suggested for externalities, it is of the opinion that they should be taken into account when calculating production costs.

Rigorous methodological development will be required in the calculation of externalities.

The panel also asked an expert, Mr. Joseph Doucet, to perform an economic analysis of an early shutdown of the power station, in 1995 (tabled document B103). The expert's analysis indicates that closing the Gentilly 2 power station would cost approximately $800 million more in 1995 than at the end of its service life in 2013. The panel recognizes that this assessment does not contradict that presented by Hydro-Québec, since the objectives of the two are different.

In support of his assessment, the expert performed a sensitivity analysis using exaggerated hypotheses in favour of an early shutdown, which still shows a higher cost than that of a shutdown in 2013. According to the expert: "...if decommissioning in 1995 remains more costly under these conditions, we can conclude, on the basis of the available data, that the economic cost of decommissioning in 1995 will probably always be higher than the cost of the reference scenario" (tabled document B103, p. 25). This economic analysis appears to confirm the cost levels indicated by Hydro-Québec's financial analysis.

Finally, according to the same expert, replacement of the power production of Gentilly 2 is crucial. "We must keep in mind that the replacement of Gentilly 2 would be a real problem" (tabled document B103, p. 23).

Based on these assessments and the available studies, the panel concludes that, in addition to the problem of replacing the power production of Gentilly 2, an immediate shutdown of the power station would entail additional costs in the range of one billion dollars.

Moreover, the fuel storage pool is almost entirely full. The Groupe de Recherche Appliquée en Macroécologie feels that more efficient management of this storage would delay the need for a decision on dry storage by only a few months. According to this group, "denying the need for storage would be ecologically irresponsible because the power station exists and would continue to produce wastes even if it were dismantled immediately" (brief submitted by the Groupe de Recherche Appliquée en Macroécologie, p. 9). Moreover, the representatives of the Syndicat des employé-es de métiers d'Hydro-Québec feel that, in the event of a shutdown, the power station would still have to be decommissioned. This would involve moving the irradiated fuel presently stored in the pool and in the reactor into dry storage (brief submitted by the Syndicat des employé-es de métiers d'Hydro-Québec). The fuel storage pool itself would have to be decontaminated on decommissioning.

The panel notes that, even if the power station is shut down immediately, the irradiated fuel dry storage proposal remains necessary.

Retubing Operations

During the public hearings, the panel learned that repairs to the pressure tubes (retubing) may be required if Gentilly 2 is to continue operating. The *pressure tubes** are cylinders which extend through the reactor vessel and in which the fuel bundles are placed (Figure 2). These operations may be costly or even prohibitive, given the cost of operating a power station as compared to the network's other means of production. With some reservations, this was certainly one of the factors considered by Ontario Hydro when it announced in February 1994 that it was suspending operation of one of the four reactors of the Bruce A power station in September 1995, while keeping the option of replacing the pressure tubes (tabled document B11).

According to a representative of Hydro-Québec, "present conditions indicate that we will be in a very good position to maintain the integrity of our pressure tubes for the next 20 years and to continue using them as planned until the year 2013" (Mr. Louis Cloutier, August 25, 1994, evening session, p. 145). Some participants expressed doubt about this statement, and felt that retubing would be required before this date, a belief disputed by Hydro-Québec.

Hydro-Québec plans to use an inspection and maintenance program to ensure the integrity of the pressure tubes of the Gentilly 2 reactor for its full 30-year service life. Under this program, the periodic inspections of the pressure tubes are scheduled at six-years intervals in 1997, 2003 and 2009.

Hydro-Québec estimates that retubing will require 12 to 18 months and cost $500 million (1994 dollars) (tabled document A60).

As for the retubing operations required to extend the service life of the power station, the panel makes the following observations:

- retubing operations are costly;
- some participants feel that they will be needed in the very near future;
- they involve a degree of uncertainty inherent in the technical studies, this suggests the need for caution with respect to the proposed date, 2013;
- they are not taken into account in the assessments of the cost of closing the power station in 1995;
- the participants have had difficulty obtaining access to information on these operations.

The panel is of the opinion that the decision-making process concerning possible repairs on the pressure tubes must be more open. It also recommends that, because of changes over time and the periodic nature of the inspections, the technical and economic studies on retubing should be made public, more thoroughly documented, and included in the annual report of the Gentilly 2 power station.

Operation of the Gentilly 2 Power Station at a Reduced Capacity

The possibility of operating the power station at a reduced capacity was also examined, since this would reduce the urgency for dry storage.

The 1993-1995 Development Plan indicates that, "for technical and economic reasons, nuclear power stations operate at a constant level" (tabled document A57, p. 46). The panel asked whether the Gentilly 2 power station could be operated at a constant but reduced capacity. The Hydro-Québec representative answered: "A nuclear power station, at Gentilly or Pickering or anywhere else, is an element of production that has to be operated on a regular basis and with the highest factor of production" (Mr. Michel Rhéaume, August 31, 1994, evening session, p. 36). Obviously, the corporation does not plan to operate the power station at a reduced capacity. The power station did, however, operate at a reduced capacity from 1983 to 1987. The panel does not feel that it is in a position to reach a conclusion on this point.

The panel also notes that the arguments of the Groupe de Recherche Appliquée en Macroécologie and of the Syndicat des employé-es de métiers d'Hydro-Québec with respect to the need for dry storage even in the event of an immediate shutdown of the nuclear power station are applicable to operation at a reduced capacity. Therefore, operating at a reduced capacity would hardly delay the need for non-underwater storage.

Quebec's Nuclear Energy Sector

Quebec's Energy Policy

In 1988, Quebec adopted an energy policy entitled *L'énergie, force motrice du développement économique. Politique énergétique pour les années 1990* [Energy, the Power Behind Economic Development. An Energy Policy for the 1990s] (tabled document B66). This government policy makes virtually no reference to nuclear production, with the exception of a statement of the government's intention not to undertake further generation of electrical energy by nuclear fission in the foreseeable future. Three reasons are given: the accumulation of radioactive wastes, the potential risk associated with operating defects, and the need for evacuation in the event of an emergency (tabled document B66).

The policy thus touches on the problem of managing radioactive wastes, but is totally silent as to their disposal. The public hearings clearly demonstrated that, in the absence of a clear assignment of responsibilities, the government was tacitly relying on Hydro-Québec.

The panel is of the opinion that the Government of Quebec, in its energy policy, should indicate its intentions with respect to the management of irradiated fuel.

Hydro-Québec's Development Plan for 1993-1995

Hydro-Québec's most recent Development Plan examines all the means of electrical production and concludes that hydroelectricity and nuclear power are preferable to traditional thermal power stations for base-load power production. Nonetheless, Hydro-Québec favours hydroelectricity. It states: "Technical, economic and environmental reviews of the various means of production lead us to conclude that hydroelectricity is, in the long term, the most desirable option for Quebec" (Development Plan, *Moyens de production* [Means of Production], p. 87).

On the environmental level, Hydro-Québec notes that, with the exception of hydroelectricity, nuclear energy appears to be the least damaging power generating system. At the same time, it states: "This is a regulated form of energy; the major related environmental issues, in particular the security of the power stations and the management of radioactive wastes, must be the object of a social consensus" (Development Plan, *Moyens de production* [Means of production], p. 83).

After analyzing the various means of production on the basis of a number of criteria, including technical and economic aspects, environmental issues, economic impact, and planning flexibility, Hydro-Québec rejects this system: "The nuclear system has not been selected: it is clearly more costly and more time-consuming to establish than the hydroelectric system, and is generally poorly perceived by the public" (tabled document A57, p. 63).

The panel notes that, while Hydro-Québec recognizes some of the advantages of the nuclear energy sector, it has not been selected as a means of production, in part because of its higher cost and lower flexibility, but also because of the lack of a social consensus. A public debate on the choices available to Quebec might shed more light on this question.

The panel therefore recommends that Hydro-Québec's next Development Plan (1996-1998) should clearly define the role it intends to assign to nuclear energy as a means of power production, and indicate the criteria to be used in determining whether or not the Gentilly 2 power station will remain in operation.

Integrated Resource Planning

Since May 1994, the Government of Quebec has been conducting public consultation on a proposed process for integrated resource planning (IRP) on priority issues: energy efficiency, heating, dual energy, cogeneration and transportation. The proposal defines the four characteristics of IRP as: analysis of all energy supply and demand strategies; integration of economic, social and environmental viewpoints; systematic public participation; and recognition of the risks inherent in projections. The panel has examined this proposal because a number of questions were raised during the public hearings.

Some feel that public examination of the storage proposal should include examination of the nuclear power station producing the wastes. The use of IRP would provide a more complete picture including the social costs currently borne by society as a whole. It is this overall view that the government hopes to achieve through the use of IRP. The current consultation on IRP should thus improve familiarity with it and, according to the Ministry of Natural Resources representative, "... define how integrated resource planning could be used, for example, in establishing new energy policies" (Mr. Réal Carbonneau, August 31, 1994, afternoon session, p. 88).

Hydro-Québec is currently involved in public consultations in preparation for the examination of its Development Plan. The government proposal states that "it is time to continue in this direction and to take advantage of the opportunities offered by an approach such as integrated resource planning" (tabled document B6, p. 25).

Systematic public participation in the analysis of energy options is an essential component of IRP. In addition, IRP offers a more complete view because it must include an examination of both energy supply and demand, and of the means of controlling them. IRP thus requires examination of the risks associated with the different systems and of the environmental, economic and social consequences of the options, including externalities. These costs, examined above, will require strong methodological development. As the panel expert notes: "While a consensus exists as to the philosophical merits of IRP and the inclusion of externalities in energy analyses, I do not believe it can be said that a consensus exists within the scientific community as to the method by which IRP is to be applied, and still less as to the evaluation of the costs of the various externalities" (tabled document B103, p. 18).

The panel believes that Quebec's energy policy should reflect the fundamental elements of integrated resource planning (IRP).

The model proposed by the government relates to various uses of energy. Informed choices depend equally on comparisons of the various forms of energy. The proposal discusses electricity, natural gas and petroleum separately. Further dissection of power production is essential "... where a number of energy systems must be analyzed simultaneously" (tabled document B6, p. 31). Consequently, hydroelectricity must be distinguished from other means of power production (nuclear, thermal, wind generation).

The panel recommends that the government's proposal for integrated resource planning should distinguish between the various sources of power production to allow adequate analysis of the issues associated with nuclear power.

Chapter 4 Technological Aspects

In an effort to put the proposal in context, the panel examined the issue of dry storage of irradiated nuclear fuel in the general Canadian context. It looked at the storage options examined by the promoter and the technical characteristics of the options selected. Finally, it examined a number of aspects regarding storage system security and compliance with the provisions of the non-proliferation treaty for irradiated fuel.

Storage of Irradiated Fuel in Canada

The Issue

In 1952, the Federal Government created a Crown corporation known as Atomic Energy of Canada Limited (AECL). Its mandate was to develop peaceful applications of nuclear energy and, in particular, a CANDU energy system based on the use of natural uranium and heavy water. The first nuclear fuel wastes were produced by AECL's research reactors at Chalk River, Ontario (tabled document B46).

During the 1950s, AECL believed that the CANDU system could become competitive if the plutonium formed in the irradiated fuel was recovered through reprocessing, and reused. For long-term disposal, the wastes vitrified during this process were studied to assess the capacity of the soil to prevent the migration of the remaining radioactive products (ACNS-18, 1992).

With the development of the CANDU system and the falling price of uranium, reprocessing in Canada became less and less economically feasible. Nonetheless, since the situation might change with time, AECL proposed to develop the concept of reprocessing, while conducting a research and development program on the dry storage of irradiated fuel in concrete containers. This temporary dry storage would allow the Federal Government to postpone the decision on whether to proceed with fuel reprocessing. Dry storage would also serve as an intermediate step between initial storage in a pool and the subsequent stage of reprocessing, or permanent disposal of, the irradiated fuel (ACNS-18, 1992).

In 1975, AECL proposed a research program on disposal of irradiated fuel in stable geological formations. In 1978, the governments of Canada and Ontario, the province most deeply involved in the operation of nuclear power stations, announced a joint research and assessment program: AECL was to be responsible for the development and assessment of the concept of storage in the Canadian Shield, and Ontario Hydro for the development of technologies for medium-term storage and transportation of irradiated fuel. The reprocessing option was set aside (ACNS-18, 1992).

Over the next ten years, research and assessment activities continued, and frequent consultations were conducted with scientific and regulatory groups and with interested public groups. In 1981, the two governments defined the process for examination of the concept of permanent disposal and appointed a committee, under the supervision of the Atomic Energy Control Board (AECB), to explore the option. The AECB is the federal government agency responsible for ensuring that the use of nuclear energy in Canada poses no undue risk to health, safety, security, and the environment (tabled document B9).

In 1988, the assessment process was transferred to an environmental assessment panel under the authority of the federal Minister of the Environment, in the context of the newly established federal Environmental Assessment and Review Process (EARP) administered by the Federal Environmental Assessment Review Office (FEARO) (ACNS-18, 1992). As part of this process, FEARO held a public consultation in 1990 on the guidelines for the impact study of the AECL proposal. In August 1994, the environmental assessment panel announced its intention to hold public hearings as early as possible in the fall of 1995, to consider the proposed storage concept. In October 1994, AECL submitted its environmental impact statement for the concept of nuclear fuel waste disposal.

The next steps would include the selection of a site, construction of the storage facility and confirmation of the accuracy of the calculations. According to AECL, this may require another 30 years, or until approximately 2025 (tabled document B46).

The research on the permanent disposal concept has been in progress for approximately fifteen years. The cost has been estimated by AECL at approximately $400 million, divided between AECL ($300 million), Ontario Hydro ($70 million) and a number of foreign governments, including the United States, Japan, etc ($30 million) (Mr. Michael Stephens, August 30, 1994, evening session, p. 40). It should be noted that neither Hydro-Québec nor New Brunswick Power are contributing financially to the development of the disposal concept (tabled document A75).

In 1987, the AECB defined its regulatory requirements for the approval of a permanent disposal site (tabled document A8). These requirements can be summarized as follows:

The burden on future generations must be minimized:

A. by selecting storage methods which do not require long-term institutional controls;

B. by implementing these methods at the appropriate time, taking into account technical, economic and social factors;

C. by ensuring that no future generations will be exposed to risks that are considered unacceptable today.

In addition to its work on the concept of permanent disposal, AECL has continued to develop its system of temporary dry storage in reinforced concrete silos. As part of its contribution under the terms of the Canada-Ontario agreement, Ontario Hydro recently submitted a report on the disposal of Canada's nuclear fuel waste (tabled document B77.7). This study deals with construction of the site, transportation of irradiated fuel to the site and operation for the period required to ensure that the storage system is operating properly before its final closure. This is a conceptual model; the exact location of the site will be determined later. Finally, the transportation system provides for the use of silos similar to the CIC silos already approved by the AECB for the temporary storage of irradiated fuel.

The Panel's Analysis

When it examined this question, the panel made the following observations:

- the Canadian effort to find a solution to the problem of long-term disposal of irradiated fuels shows logic and continuity;
- despite the scope of this effort, the program is already several years behind the original schedule;
- the technical complexity of the problem, combined with the stringent requirements of the AECB and the unfavourable reactions which can be anticipated from some segments of the public, may well lead to further delays in the implementation of the proposal or even compromise its success;
- two public organizations working separately, AECL and Ontario Hydro, have developed two different approaches to temporary dry storage.

Hydro-Québec did not consider the possibility of a delay of the permanent disposal project beyond the year 2045, when the minimum service life of the proposed temporary storage facility ends, or the possible failure of the proposal. During the public hearings, however, its representative indicated that it is technically feasible to transfer baskets of irradiated fuel from an old silo or module which has reached the end of its service life to a new silo or module on the existing Gentilly site, and thus to extend the period of on-site storage (Mr. Michel Rhéaume, August 25, 1994, evening session, p. 20).

The Government of Quebec appears to have dismissed the possibility of a permanent disposal site in Quebec (tabled documents B14 and B15). A number of participants drew the panel's attention on the fact that the Government of Quebec has not concluded an agreement with the Federal Government on the problem of permanent disposal, a situation which, according to the Direction de santé publique de Mauricie—Bois-Francs, places it in a position of ambiguity or weakness:

> *It seems there is an incongruity in Quebec between the evident desire not to take responsibility for the permanent disposal of its own nuclear wastes within the province, and the status quo meaning, which allows production to continue. The dependency thus created, or this lack of an overall vision, casts doubt on our ability to manage these wastes in the long term.*
> (Brief submitted by the Direction de la santé publique de Mauricie—Bois-Francs, p. 27)

The panel is of the view that the Government of Quebec should provide a policy on the storage of irradiated fuel, and assign responsibility for such a policy to the Ministry of the Environment and Wildlife and to the Ministry of Natural Resources. It also recommends that the Government of Quebec should conclude an agreement with the Federal Government regarding permanent disposal of irradiated fuel from the Gentilly 2 power station. Finally, the panel believes that Hydro-Québec should participate in the research and development being conducted, in order to find an acceptable solution to the problem of permanent disposal of these wastes.

Storage Options

Hydro-Québec has examined a number of options selected by other nuclear operators and has summarized international experience in the field of dry storage (Di6, p. 3-21, and tabled document A51). It has considered systems involving vaults, silos, metal flasks and modules tested in Europe, Asia and the United States. It has selected the dry storage options developed specifically for the CANDU system.

A number of other possibilities were suggested to the panel by participants in the public hearings. These included:

A. storage in the Gentilly 1 fuel storage pool

The Gentilly 1 nuclear power station is currently being dismantled. Its fuel storage pool has been decontaminated and its protective equipment removed, and it is now being used for other operations. According to the promoter, it is no longer functional for storage purposes (Mr. Michel Rhéaume, August 31, 1994, evening session, p. 102).

B. shipment of irradiated fuel to other storage sites

This scenario involves a number of difficulties:

- there is no national or provincial site capable of handling irradiated fuel from several power stations;
- the AECB grants temporary storage licences only for irradiated fuel produced on site;
- the actual policy of Canadian power companies is to keep irradiated fuel on site;
- no means of transporting irradiated fuel have yet been authorized in Canada;
- the cost of such a solution has not yet been estimated.

C. other options

In the United States, fuel rods have been placed closer together to allow the storage of larger quantities of irradiated fuel in the same volume. In Canada, different storage arrangements have been developed (tabled document A65). During the public hearings, the promoter stated that it had examined the possibility of rearranging the fuel bundles in the fuel storage pool. However, this option would raise safety problems, would be costly and would merely postpone the need for dry storage by one year (Mr. Louis Cloutier, August 31, 1994, afternoon session, p. 124). Further details on this subject are provided in tabled document A75.

These documents indicate that a structure would have to be built around each stack of fuel bundles to meet AECB requirements.

As for using waste-storage wells, Hydro-Québec feels that Canadian experience in this field has not yet reached commercial levels (Mr. Louis Cloutier, August 31, 1994, afternoon session, p. 128).

Other options, including shipment of the irradiated fuel to a national temporary storage centre or to France for reprocessing, were suggested during the public hearings. The panel considers them impractical, since they deviate widely from current nuclear management procedures in Canada in terms of both reprocessing and cross-border transport.

The panel therefore concludes that the preference showed by Hydro-Quebec for a dry storage option developed specifically for the CANDU system fuel is justified.

Existing Storage Options for the CANDU System

The promoter assessed the following existing storage options for the CANDU system (Di6, p. 3-6):

- underwater storage in a new fuel storage pool;
- dry storage in AECL silos;
- dry storage in CANSTOR modules;
- dry storage in CIC silos.

The main selection criteria were summarized during the public hearings (Mr. Louis Cloutier, August 30, 1994, evening session, p. 62). They are:

- technical simplicity;
- protection of the environment, the public and workers;

- ease of implementation;
- cost of construction;
- area required to store the fuel;
- future flexibility.

Based on these criteria, the promoter has selected the CANSTOR module as the principal method of temporary storage. To provide flexibility, however, particularly when the power station reaches the end of its service life, the promoter has selected the AECL silo as an auxiliary means of storage.

The panel notes that the AECL silos and CANSTOR modules represent the best Canadian options.

Characteristics of the Two Storage Systems Proposed by the Proponent

The AECL silos and the CANSTOR modules will meet well-defined design criteria. The panel is interested in these criteria and in the procedures used to ensure compliance with them.

Design Criteria

According to tabled document B9, the design criteria AECB chose for a dry storage system are:

- structural integrity of at least 50 years;
- a *dose** rate of less than 25 $_{\mu}$Sv/h at a distance of 1 m from the concrete walls;
- no loss of shielding;
- no release of radioactive contaminants;

- resistance to earthquakes and strong winds;
- physical security of the contents of the storage structures;
- guarantees acceptable to the International Atomic Energy Agency (IAEA).

For radiological protection, Hydro-Québec adds two design criteria that are more stringent than those of the AECB:

- a dose rate of less than 25 μSv/h at the actual surface of the walls;
- a dose rate of less than 2.5 μSv/h at the fence around the storage site (Mr. Michel Rhéaume, August 26, 1994, afternoon session, p. 59).

Analysis of the tabled documents and of the presentations has enabled the panel to make the following observations:

- the AECB has authorized the use of AECL silos at the Gentilly 1 power station in Quebec and at the Point Lepreau power station in New Brunswick. This confirms that the silos meet all AECB criteria;
- the AECB has not yet completed its technical assessment of the CANSTOR module;
- the storage systems selected by Hydro-Québec use three airtight barriers to prevent any release of radioactive contaminants:
  - a sealed zirconium alloy cladding tube around the fuel;
  - a sealed stainless steel basket to hold the fuel bundles;
  - a sealed steel cylinder to hold the baskets.

It should be noted that the outer wall of the steel cylinder in an AECL silo is covered with concrete, while a portion of the outer wall of each cylinder in a CANSTOR module is in direct contact with the air, creating a risk of oxidation. To avoid this problem, the interior and exterior walls of the cylinders in each CANSTOR module would be hot galvanized.

- As for the criterion of the maximum dose rate at the surface of the containment structures, experience at Point Lepreau power station in New Brunswick clearly indicates that the dose at the surface of

AECL silos for fuels stored for seven years in the storage pool is 16 $_{\mu}$Sv/h (Di6, p. 3-26). This value is lower than the reference dose of 25 $_{\mu}$Sv/h established by Hydro-Québec. For the CANSTOR modules the calculations are not sufficient to confirm the criterion will be met: *the estimated dose rates at the ventilation grids 5 m above ground level slightly exceed the design dose rate (25 $_{\mu}$Sv/h).* These calculations will have to be experimentally verified before these structures are loaded with fuel cooled for 6, 7 or 8 years (tabled document A69, p. 56).

- Moreover, Hydro-Québec made the following commitment:

  The first module will be loaded exclusively with fuel which has been cooled for eight to twelve years. The experimental dose rates will be compared with those produced by modelling. These results will be used to calibrate the model and thus permit management of this parameter in loading subsequent modules. (Tabled document A75)

The panel believes that the AECL silo meets all design criteria of the AECB. The compliance of the module with these criteria must be confirmed by technical assessments of the AECB.

Hydro-Québec has requested authorization to store fuel cooled in the storage pool for six years. Considering the above observations, the panel believes this request is premature.

On analysis, the panel concludes that the AECL silo selected by Hydro-Québec is a proven storage method for fuel which has spent seven years in the fuel storage pool. The module, however, is a new storage method and its use must be approved by the AECB, which may also have to specify the minimum storage period that fuel must be previously stored in the storage pool.

Security

Security includes all measures required to prevent malicious activities such as the theft of irradiated fuel or the release of the radioactive substances which it contains. A country or determined group might attempt to steal or misappropriate irradiated fuel in an effort to recover the plutonium in the fuel. The IAEA, the AECB, and Hydro-Québec, in cooperation with the Ministry of Public Security, apply all security measures required to prevent attempted misappropriations of irradiated material and to ensure the physical security of the storage site.

The panel believes that the modules, in their present form, would be more vulnerable than the silos.

Comparison of AECL Silos and CANSTOR Modules

In this section, the panel offers a brief comparison of AECL silos and CANSTOR modules in relation to the elements analyzed above.

The promoter notes that CANSTOR modules have three advantages over AECL silos:

- lower cost: $167 per fuel bundle, compared to $194;
- smaller storage area: 11,600 m^2, compared to 18,700 m^2;
- better performance in terms of heat dissipation.

The panel believes, however, that CANSTOR modules have the following disadvantages:

- the technology is not yet proven;
- the exposure dose at the outlets from the ventilation pipes is believed to be higher than the design criterion for irradiated fuel stored in the fuel storage pool for eight years;
- the ventilation openings require further attention;
- they are potentially more vulnerable;
- they require stronger foundations.

During the review, the panel learned that the cost of the modules would be higher than anticipated, because there is a need for a caisson-type reinforced concrete foundation that was not included in the original design (tabled document A74). Moreover, the technical characteristics of this foundation are not yet determined. The panel questions the economic consequences of this additional foundation and its impact on the technical concept itself, especially if the soil analyses require a change in the site initially proposed within the protected area.

Considering the potential impact of the uncertainties remaining with respect to the foundations required to support the CANSTOR modules and the bearing capacity of the initial site, the panel considers the economic advantages are slight. Moreover, it does not consider the other advantages significant. Finally, the silos represent a technology which is proven, mature, less vulnerable and easier to inspect than the modules.

Therefore, the panel concludes that, under existing circumstances, the selection of the module should not be considered final. It recommends that the uncertainties remaining with respect to the true cost of the modules, the suitability of the site selected because of the new constraints, and the security of the new design be solved to the satisfaction of the AECB before the government approves the option of the modules.

Chapter 5 Radiological Risks

This chapter begins with a brief description of the nature and effects of radioactivity. The concepts of exposure dose and radiological risk are defined. The principles of radiological protection are then examined as the basis for an introduction to the standards relating to environmental discharges and human health.

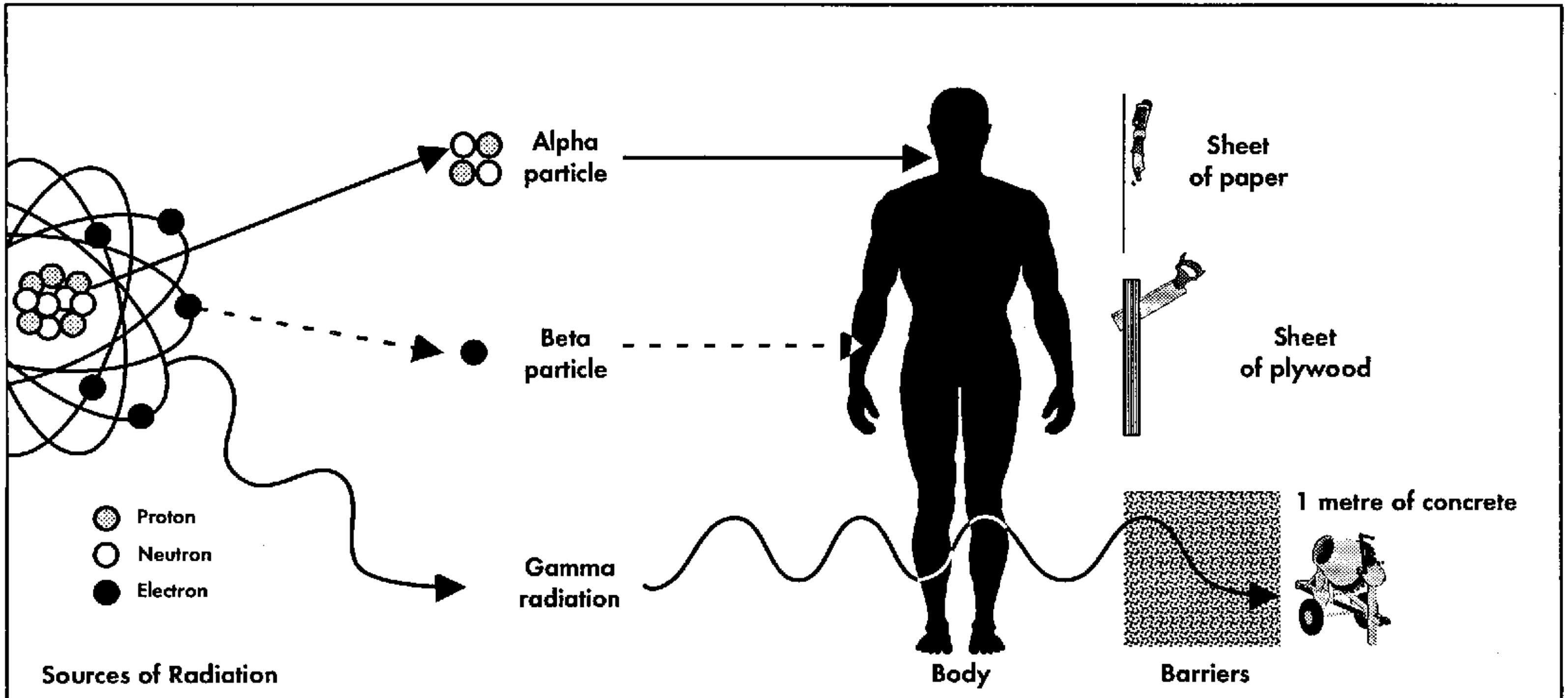
The second part of the chapter deals with the risks associated with the proposal for workers and the public. To place the results of the analysis in perspective, the calculated exposure doses are compared to the corresponding values for the nuclear power station and to background radiation within the environment. This comparison will be performed on a quantitative basis for normal operations. Due to the lack of specific reference points, the comparison will be done on a qualitative basis for accidents.

Radioactivity and Radiological Effects

Radioactivity

All the chemical compounds found in nature are made up of 92 fundamental elements, the lightest being hydrogen and the heaviest uranium. Most elements occur in a stable form. The unstable elements are known as radioactive elements or radioelements. They decay, emitting alpha, beta or gamma radiation. Alpha particles, positively charged, consist of helium nuclei; beta particles, negatively charged, consist of electrons; and gamma rays, neutral, consist of electromagnetic waves (Figure 8).

Figure 8 The Three Types of Radiation and their Power of Penetration



TYPE	Distance Travelled in Air	Power of Penetration
ALPHA	1 to 10 cm	Stopped at the surface of the skin or by a sheet of paper
BETA	Up to 16 metres	Penetrates the skin for 1 to 2 cm; stopped by 2 layers of clothing
GAMMA	Several hundred metres	Passes through the body; almost completely stopped by 1 m of concrete

Sources : adapted from Hydro-Québec, 1992 and tabled document B21, p. 1.

A radioelement is characterized by:

- the type of radiation emitted;
- its activity, i.e., the number of *decays**(disintegrations) per second;
- its *half-life**, i.e., the time required for 50% of the atoms to decay;
- the energy of radiation.

Activity is measured in *Becquerels** (Bq). One Becquerel is equivalent to one disintegration per second. The half-lives of radioactive elements vary over an extremely wide range, from 0.00016 seconds for polonium-214 to 12.3 years for tritium, a heavy form of hydrogen, and 4.5 billion years for uranium-238.

The Concept of Dose

Emitted radiation is slowed down and its energy is absorbed by surrounding materials. The distance travelled varies with the type of radiation and the type of environment involved. For example, an alpha particle can be stopped by a sheet of paper, and a beta particle by a sheet of plywood, while a gamma ray is almost completely absorbed by one metre of concrete (Figure 8). When they collide with atoms in the environment, the various forms of radiations surrender their energy to the materials they are passing through. The quantity of energy absorbed is measured in *grays** (Gy) or milligrays (1 mGy = 1/1000 Gy).

The effect of radiation on a living organism depends on the amount of energy absorbed, the type of radiation and the organ affected. A physical weighting factor, varying from 1 for beta particles and gamma rays to 20 for alpha particles, is used to reflect the type of radiation. A biological weighting factor, varying from one organ to another (0.011 for the skin, 0.20 for the gonads and 1 for the entire body) reflects the type of organ. The energy absorbed is multiplied by the two weighting factors to determine the effective dose. The effective dose is measured in *sieverts** (Sv), *millisieverts**, mSv (1/1000 Sv) or *microsieverts**, μSv (1/1,000,000 Sv). If a radioelement, such as strontium-90 or cesium-137, penetrates the body and attaches itself to an organ, it is important to know for how long it will remain in the body, in order to calculate its contribution to the individual's total exposure dose. This contribution is described as the committed dose.

Finally, the *collective dose** is defined as the sum of the doses received by each of the members of a group exposed to radiation. The collective dose is measured in person-sieverts.

Sources of Radiation

Radioactivity originates from numerous sources, both natural and artificial. Natural sources include cosmic rays, radon (a gas released by the soil), uranium, and other radioactive elements found in the earth's crust or in construction materials. In addition, certain elements, such as potassium-40, are present in all cells. Artificial sources include medicine (X-rays and radioactive tracers), industry (irradiators), energy production (uranium mining and processing, nuclear power stations), and consumer goods (smoke detectors, television sets).

Table 5 presents the sources of radiation for the population of the United States: 82% of all effective doses come from nature, 18% from services such as medicine, and less than 0.12% from other sources, including nuclear energy.

The maximum dose to which the public is exposed through the operation of the Gentilly 2 power station is believed to be 0.0017 millisieverts a year (mSv/yr). Some radioactive materials are emitted during the operation of the CANDU reactors. These include small quantities of tritium, *rare gases**, iodine-131, aerosols (Sr-90) and carbon-14 (tabled document A25).

As a comparison, a person living near a Canadian nuclear power station for one year would receive less radiation than during a chest X-ray (0.1 mSv) (tabled document B10).

Table 5 Average Annual Effective Doses

Source of Radiation	Effective Annual Dose	
	mSv/yr	%
Natural		
Radon	2.0	55
Cosmic	0.3	8.0
Earth's crust	0.3	8.0
Within human body	0.4	11
Partial total: natural origin	3.0	82
Artificial		
Medical X-rays	0.4	11
Nuclear medicine	0.1	4.0
Consumer products	0.1	3.0
Non-medical sources	< 0.01	< 0.03
Occupational exposure	< 0.01	< 0.03
Nuclear fuel cycle	< 0.01	< 0.03
Radioactive fallout	< 0.01	< 0.03
Partial total: artificial origin	0.6	18
Grand total: natural and artificial origin	**3.6**	**100**

Source: BEIR V, p. 18.

Effects of Radiation

Human beings are constantly exposed to ionizing radiation which is not perceived by the senses. Nonetheless, such radiation has an effect on living organisms. When ionizing radiation penetrates living tissues, the ions created can modify the structure of the chemical components of the living cells. The absorption of a certain quantity of radiation can transform or destroy the cell. Human tissues are capable of regeneration but, in certain cases, these cell changes can become cancerous. Radiation can also cause genetic abnormalities or birth defects.

The biological effects of irradiation on the cells fall into two categories:

- effects produced systematically when the body is exposed to a dose of radiation above a certain level;
- effects not related to a specific dose, but which become more probable as the dose increases.

The first type of effects develop in the short term, the second one in the long term.

Thus, high doses absorbed as a result of a single event have direct, predictable effects ranging from nausea to death (Table 6). Sufficiently high doses, absorbed regularly over a long period of time, also have direct perceptible effects. For example, reddening of the skin is considered to be one of the effects of prolonged radiation therapy. However, direct predictable effects requiring doses above a certain threshold are directly proportional to the dose absorbed and the length of exposure. As an analogy, exposure to the sun produces an inevitable burn at a certain dose, and extremely high doses can even lead to death as a result of sunstroke. The sequence of the effects of irradiation on a cell is presented in Figure 9.

Low doses can also have serious effects on health since, under certain circumstances, radiation can theoretically alter molecules such as DNA or modify certain genes. Cancer is a commonly observed effect. Sex cells can be altered, transmitting hereditary effects to offspring. In addition, some effects may appear in children following fetal exposure during pregnancy. The most probable effects in this case appear to be leukemia and mental retardation (IAEA, Bulletin 2/1994, p. 4).

Table 6 Effects of Radiation on the Human Body

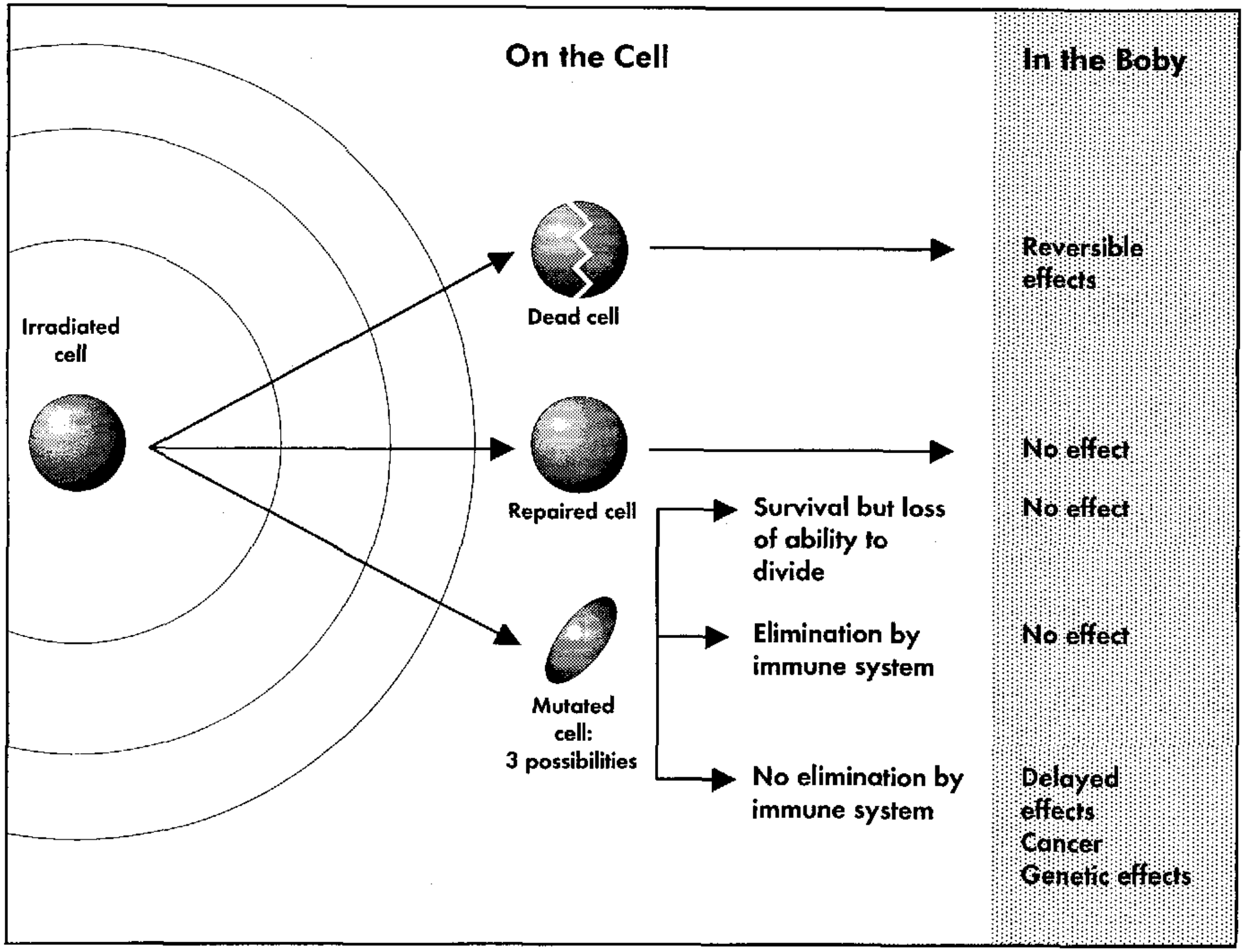
Single Whole-Body Doses	Effects on the Body
150 mSv	First perceptible physiological effects
250 - 1,000 mSv	Changes in blood composition
1,000 - 3,000 mSv	Nausea, vomiting, weakness
4,500 mSv	Death in 50% of those exposed
10,000 mSv	Death within weeks

Sources: tabled documents B21, p. 7, and B10, p. 3.

The risk of contracting terminal cancer is estimated at 5/100,000 per millisievert. This means that, if every member of a population of 100,000 persons is exposed to a dose of 1 mSv, an additional 5 deaths will be attributable to cancer. This figure is based on observed mortality rates in the populations of Hiroshima and Nagasaki. In fact, fatal effects of radiation have not been observed at doses below 50 mSv (ICRP Publication 60, p. 16). It is considered prudent, however, in the field of radiological protection, to assume that these effects persist even at lower doses.

In order to take into account all the effects of radiation, in addition to cancer, the ICRP has defined the total radiobiological risk at twice this level: 10/100,000, or 1/10,000 per mSv. Hydro-Québec uses this value in its risk estimates (Di11, p. 9-2).

Figure 9 Effects of Irradiation on the Cell and on the Body



Source : adapted from Électricité de France *Les effets biologiques des rayonnements ionisants.*

The effects of irradiation on the body depend on a number of factors, including the type of radiation, the absorbed dose and the lenght of exposure.

The biological effects of irradiation on the body fall into two categories: effects produced systematically when the body is exposed to a given dose of radiation (reversible effects) and effects not related to a specific dose (delayed effects).

Radiological Protection Standards

Principles of Radiological Protection

The management of radiological risks is based on three basic principles:

- **justification**: no practice may be adopted unless it produces a positive net benefit;
- **limitation**: all radiation doses must be kept as low as reasonably achievable, considering economic and social factors;
- **control**: the doses received must not exceed the established limits.

Standards of the Atomic Energy Control Board

The Atomic Energy Control Board establishes Canada's *maximum allowable doses** (MAD) for workers and for the public (Table 7). These standards are based on the recommendations of the International Commission on Radiological Protection (ICRP), a non-governmental scientific agency established in 1928. Its most recent recommendations were published in 1990 (Publication 60, Annals of the ICRP, Vol. 21, Nos. 1-3) and are the basis for the maximum allowable doses. The maximum exposure proposed by the ICRP is defined as the exposure which produces no immediate effects and does not exceed the allowable limits for long-term effects.

The recommendations are based on the study of three generations of Hiroshima and Nagasaki survivors and on experiments on laboratory animals. They also reflect monitoring of occupational exposure to radiation. The standards are periodically revised as new information becomes available.

The ICRP has proposed lowering the dose limits, based on reassessments of the radiation doses to which the Japanese victims were exposed and a redefinition of radiological risk. To have the force of law, the proposals must be approved by the regulatory authorities in each country.

Table 7 Maximum Allowable Doses for Individuals

Category of Individual		Dose Limits: Current Regulations	Dose Limits: Proposed Regulations
Worker	Annual limit	50 mSv	50 mSv
	Quarterly limit	30 mSv	none
	5-year average	—	20 mSv
Public	Annual limit	5 mSv	1 mSv
Pregnant worker	After 8th week	10 mSv	2 mSv

Sources: adapted from tabled documents A5, p. 7, and A7, p. 2.

In its risk analysis, Hydro-Québec used the new standards proposed by the AECB (draft regulations) for the maximum allowable doses. It indicates, however, that some of the AECB requirements for workers may bring about management problems. In addition, the proposed requirement for a pregnant worker to report her pregnancy to avoid exceeding the proposed new dose limits may conflict with the Charter of Rights (tabled document A7).

In addition to the standards, and in accordance with the principle of limiting exposure, the AECB regulations require licence holders and employers to "establish and apply measures to keep all radiation doses to workers and the public as low as reasonably achievable (ALARA principle)" (tabled document B18, p. 1).

Implementation of the ALARA principle is an effective method of reducing exposure doses to well below the limits. It requires judgments based on cost-benefit calculations and social factors to determine what are reasonably achievable limits. The AECB is prepared to consider exposures to be consistent with the ALARA requirement if the following criteria are met:

- individual doses to workers do not exceed 1 mSv/yr;
- individual doses to the public do not exceed 0.050 mSv/yr;
- the annual collective dose (workers and public) does not exceed 1 person-Sv.

(Tabled document B18)

Limits on Environmental Discharges

To protect the environment and by extension the public, the power station is subject to standards, known as derived operational limits (DOLs), governing liquid wastes and atmosphere emissions. These are restrictions on the release of radioelements in liquid wastes and gas emissions. An environmental transfer model which traces the possible pathway of radioelements through the air, soil, and food chain and is used to calculate release limits for each radioelement which, if maintained for a full year, would subject the most exposed member of the population to the maximum allowable dose as defined by the AECB.

Table 8 gives several DOLs. It is important, when monitoring the operation of a nuclear power station, to compare the rate at which radioactive substances are released by the power station with the DOLs. If the measured rates are below the calculated limits, the discharge rates are considered safe. Otherwise, the operator is required to take corrective measures. Since the Gentilly 2 power station went into operation, the recorded discharge level has remained below the operating objective of 1% of the DOL (tabled document A25).

Maximum allowable concentrations, corresponding to the maximum concentrations of a radioelement in air, water or food which would expose an individual to the maximum allowable dose, are also defined in association with the DOLs. Maximum allowable concentrations are measured in Becquerels per cubic metre (Bq/m^3), Becquerels per litre (Bq/l) or Becquerels per kilogram (Bq/kg).

Table 8 Some Derived Operational Limits

Radioelement	Released in Air (Bq/week)	Released in Water (Bq/month)
Acrosols	3.7×10^{10}	N/A
Rare gases	3.2×10^{15}	N/A
Iodine-131	2.5×10^{10}	1.5×10^{13}
Tritium-3	8.5×10^{15}	1.0×10^{17}
Carbon-14	1.7×10^{13}	8.6×10^{12}
Cesium-137	N/A	6.2×10^{11}
Strontium-90	N/A	7.2×10^{11}
Cobalt-60	N/A	2.1×10^{12}

N/A: not applicable

Source: adapted from tabled document A25, pp. 3 and 5.

Levels of Intervention

In the event of a serious accident requiring the implementation of an emergency plan, the actions of the authorities are based on the doses to which they can avoid exposing the population (avoidable dose). For example, short-term actions (Table 9), such as home confinement, distribution of iodine capsules or evacuation, are based on such avoidable doses. In addition, long-term actions, such as temporary or permanent relocation, are specified. The Emergency Plan for the Gentilly 2 power station includes measures of this type to avoid exposure through contaminated air or food. International guidelines have been developed on the withdrawal and replacement of contaminated foods for adults and infants (IAEA Bulletin, Vol. 36, No. 2, 1994, p. 10).

Table 9 Emergency Protection Measures

	Avoidable Dose
Short-Term Actions	
Home confinement	10 mSv for a maximum of two days
Distribution of iodine capsules	100 mSv (dose commitment absorbed by thyroid)
Evacuation	50 mSv for a maximum of one week
Long-Term Actions	
Beginning of temporary relocation	30 mSv in one month
End of temporary relocation	10 mSv in one month
Possible permanent relocation	1 Sv over entire service life

Source: IAEA Bulletin, Vol. 36, No. 2, 1994, p. 10.

Assessment of Radiological Risks

Method Used by Hydro-Québec

Hydro-Québec considers that a radiological risk is acceptable if one of the following two conditions is met (Di6, p. 9-3):

- the dose to which a member of the public is exposed in a given scenario is equal to or less than 1 mSv/yr;
- the probability of the exposure scenario is less than, or equal to, one in a million per year.

The Direction de la santé publique de Mauricie—Bois-Francs criticizes this approach, noting first that "the criterion of 1 mSv/yr ... applies to all human activities generating additional exposure for the public ..." and not merely to the storage site (brief submitted by the Direction de la santé publique de Mauricie—Bois-Francs, p. 9). In fact, during the public hearings, the AECB representative confirmed that this criterion of 1 mSv/yr applies to all activities arising from the operation of the Gentilly 2 power station.

The Direction de la santé publique de Mauricie—Bois-Francs also feels that accident analysis should be raised to a probability of at least one in ten million "... to provide a safety margin for the uncertainty associated with this type of calculation..." (brief submitted by the Direction de la santé publique de Mauricie—Bois-Francs, p. 12). The AECB, on the other hand, considers acceptable Hydro-Québec's approach to accidents having a probability of less than one in a million per year (Mr. André Joyal, August 26, 1994, evening session, p. 118).

Notwithstanding this argument, the panel is of the view that the AECB could examine the proposal by the Direction de la santé publique de Mauricie—Bois-Francs to raise accident analysis to a probability of one in ten million.

Analysis of the Risks Associated with Dry Storage

Hydro-Québec divided the risks associated with dry storage into four categories (Di6, p. 9-3 to 9-13):

- construction activities;
- operating activities;
- natural disasters;
- human activities.

Hydro-Québec analyzed each of the risks, determining the exposure dose for workers and for the most exposed members of the public outside the exclusion area of the power station (700 m from the proposed storage site) and, in some cases, giving the probability of the event.

Risks to Workers

The dose rate attributable to the presence of the storage facilities during construction is estimated at 4 μSv/h at a distance of 10 m for construction workers. In order to control the dose level to which these workers are exposed, Hydro-Québec has committed itself to consider them radiation workers. This means that the construction workers will receive training in radiological protection and the doses to which they are exposed will be measured.

The panel notes that New Brunswick Power established an operational safety limit of 10 μSv/h for silo construction workers at the Point Lepreau power station (tabled document A14). This limit was observed by keeping workers at a distance of at least four metres from the silos, or by placing a row of empty silos between the silos under construction and those being loaded (tabled document A14). New Brunswick Power later decided, for economic reasons, to install two rows of empty silos (Mrs. Simone Godin, August 30, 1994, evening session, p. 78).

Hydro-Québec does not deal explicitly with this subject, but the construction timetable provides for the installation of a single CANSTOR module or 30 AECL silos in the first year (Di6, p. 3-57). While the proposed number of silos allows the creation of a protective screen for construction workers, the same is not true for the modules. Even if the modules are farther apart than the silos, only more precise calculations of the dose rates can determine whether a protective screen is required.

During normal operations (handling and transfer of irradiated fuel), the highest irradiation levels may occur when loading a fuel bundle into a CANSTOR module. During the public hearings, the Hydro-Québec representative stated that enough space is available on the module platform to allow the operator to move away from the opening. He also stated that the dose rates the operator would be exposed to is therefore acceptable (Mr. Michel Rhéaume, August 30, 1994, evening session, p. 131).

The panel notes that, under normal conditions, the only operations involving risks to workers are the construction of the storage facilities and the loading of baskets into these structures. It notes that Hydro-Québec has agreed to consider construction workers radiation workers and to apply the same rules of radiological protection to them as to workers at the Gentilly 2 power station. It also notes that an expert in radiological protection will measure actual doses at the various work stations when the facility becomes operational, to ensure that these doses are consistent with the estimated figures or to propose corrective measures, if necessary (Mr. Michel Rhéaume, September 1, 1994, evening session, p. 43). Finally, the panel points out there are means to minimize exposure doses for the most dangerous operations.

The panel concludes that, under normal operating conditions, the radiological risk to workers would be very low, that it could be controlled by the standard means of radiological protection developed at the Gentilly 2 power station and that, if need be, such risk could be further reduced.

The collective dose, i.e., the sum of the doses received by all of the workers involved in the construction and operation of the storage site, would total a maximum of 0.52 person-sievert over the 30-year service life of the Gentilly 2 power station (Di11, p. 35), or the equivalent of 0.017 person-sievert per year.

The panel notes that this dose is negligible in comparison to the annual average collective dose produced by the operation of the power station, which has totalled 0.8 person-sievert per year for the past 10 years (tabled document A53).

As to risks arising from accidents, the worst scenario would involve the loss of shielding around a fuel basket. At a distance of one metre from an unshielded basket, the anticipated dose rate would be 2 Sv/h, and an operator would have 90 seconds to move 100 metres away from the basket before exceeding the maximum allowable dose for radiation workers (Di9, p. 98).

The panel concludes that the radiological risk for workers of accidents during the various stages of fuel handling would not be greater than those encountered in the operation of the Gentilly 2 power station.

Such accidents could be dealt with in accordance with the procedures established for accidents in the power station.

Risks to the Public

Under normal operating conditions, Hydro-Québec feels that the storage proposal does not create any perceptible radiological risk for the most exposed members of the local population (Di11, p. 27).

The most serious accidents would involve either a loss of shielding, or the simultaneous rupture of two of the protective barriers around the fuel. The first situation could occur if a basket of fuel bundles was left unprotected as a result of improper handling or mechanical failure. The second could occur if a basket broke as a result of a blow or in combination with a rupture of the cladding tube around the fuel. The first situation would produce a dose rate of 0.1 μSv/h (Di11, p. 98), while the second would produce a maximum dose of 1 μSv (Di6, p. 9-5).

Table 10 gives the exposure doses (in mSv) for a full range of accidents resulting from different types of falls. These doses have been calculated for a person at the boundary of the exclusion area.

The worst conceivable accident would involve the simultaneous failure of the three containment barriers (fuel rod, basket and cylinder). In this case, all the radioactive gases present (tritium and krypton) would escape, producing the following maximum doses (Di6, p. 9-15):

- for an AECL silo: 0.012 mSv;
- for a CANSTOR module: 0.260 mSv.

These doses are still below the annual standard of 1 mSv.

Table 10 Maximum Population Exposure Doses

Type of Accident	Exposure Dose (mSv)
Dropped fuel bundle	0.000007
Dropped fuel bundle plate	0.000180
Dropped basket:	
• in the storage pool	0.000440
• in the building	0.001300
• during transfer	0.001 (max)
• in the storage area	0.001 (max)
Dropped shipping flask	<0.01

Sources: Di11, p. 47, and Di6, p. 9-15.

The probability or consequences of accidents (of natural or human origin) originating off-site are considered negligible. In the case of flooding, for example, the waste disposal site is believed to be above the decamillenary flood level (the level reached once in every 10,000 years) of the St. Lawrence River (tabled document A67). In any event, the radiological consequences of flooding would be negligible. The probability of an earthquake, catastrophic tornado, aircraft crash, or impact by a projectile from the Gentilly 2 turbine is less than one in a million per year. The probability of traffic accidents on the power station site is insignificant, while damage by lightning or nearby industries is considered non-existent. Finally, a landslide is considered highly improbable.

Following full examination of the matter, the panel notes the following considerations:

- under normal operating conditions, the risk to the public would be extremely low;
- the list of accidents considered appears to be exhaustive;

- handling accidents leading to a loss of shielding around the fuel bundles would involve little risk of exposing the public to significant doses, considering the distance between the disposal site and the boundary of the exclusion area;
- accidents involving the release of volatile radioactive substances could not expose the public to significant doses because of the limited quantity of these substances;
- no accident that could result in the release of solid radioactive substances appears plausible;
- the probability of an aircraft crash on the disposal site could increase as traffic increases;
- the other accident scenarios would not appear to pose any radiological risks.

Comparison of the Risks Associated with the Storage Proposal and with the Nuclear Power Station

Generally, the only radiological risk arising from the disposal site involves gamma radiation (external irradiation). The dose rate from this irradiation decreases rapidly with distance. It has been calculated to be under 0.0035 mSv/yr at the boundary of the exclusion area (Di11, p. 98).

In comparison, the dose rate generated by all radioactive substances produced by the Gentilly 2 power station, including atmospheric emissions and liquid wastes, has been estimated at 0.0171 mSv/yr (1993) for the most exposed member of the public (tabled document A25). The same figure for the disposal site would be 0.0035 mSv/yr, as indicated above. Total exposure (power station + disposal area) would be 0.0206 mSv/yr, 100 times less than the average natural background radiation, estimated at 2 mSv/yr (brief submitted by the Direction de la santé publique de Mauricie—Bois-Francs, p. 8), and 50 times less than the new standard proposed by the AECB (1 mSv/yr). In fact, the 0.0206 mSv/yr value is below the limit proposed by the AECB (0.050 mSv/yr) for corrective measures on the basis of the ALARA principle. These results are summarized in Table 11.

Table 11 Exposure Doses, Standards and ALARA Limit

Origin/Situation	Exposure Dose (mSv/yr)
Gentilly 2 power station	0.0171
Storage proposal	0.0035
Total	**0.0206**
Limit under the ALARA principle	0.0500
Limit proposed by the AECB	1.0
Current limit	5.0
Natural background radiation	2.0

Sources: Tabled documents A25, B18, p. 3, Di11, p. 98, and brief submitted by the Direction de la santé publique de Mauricie—Bois-Francs, p. 8.

During the public hearings, various questions were raised regarding the tritium produced in large quantities by the CANDU system as a result of the effect of neutrons on heavy water. Some participants questioned the possible role of tritium in the birth defects observed in Gentilly. Others drew the attention of the panel members to a proposal by an environmental advisory committee in Ontario (ACES) to immediately reduce the maximum allowable concentration of tritium in liquid effluents from 7000 Bq/l to 100 Bq/l, and eventually to 20 Bq/l. The panel notes that tritium represents only a small proportion of total radioactive emissions (0.7%) and that the tritium emitted by the power station is equivalent to 1% of the level produced by atmospheric fallout from nuclear testing (tabled document B105). The AECB does not appear to be prepared to modify the standards for tritium on this basis (tabled document B105).

It is still necessary to examine the possible doses generated by hypothetical accidents which, while not probable, could have serious consequences. As seen before, exposure doses would remain low in the worst conceivable situation involving AECL silos and CANSTOR modules (0.26 mSv in the event of the complete failure of a module). When dealing with a nuclear power station, one would not refer to the worst conceivable accidents, but rather to conceivable scenarios based on their probability of occurrence.

In the case of the nuclear power station, it is difficult to offer a precise figure on the probability of hypothetical accidents with catastrophic consequences. First of all, expert opinion varies on this subject; secondly, the AECB provides no guidance. In fact, all of its regulations are designed precisely to prevent such accidents. Given this situation, the panel considers itself satisfied with the fact that the AECB has taken measures to ensure that the events which have given rise to accidents like those at Three Mile Island and Chernobyl have not been neglected in the safety analysis of Canada's nuclear power stations (AECB, INFO-0010, 1990, and INFO-0234-1(F), 1990).

A number of incidents that occurred in nuclear power stations in general and at Gentilly 2 in particular were brought to the attention of the panel (tabled document B60 and brief submitted by Greenpeace Quebec). Some individuals feel that these incidents demonstrate the hazardous nature of nuclear power plants in general (Mr. Stéphane Gingras, September 29, 1994, afternoon session, p. 60) and of the Gentilly 2 power station in particular (brief submitted by the Mouvement Vert Mauricie inc., p. 7). Hydro-Québec, on the other hand, feels that these are incidents which can adequately be dealt with by the established safety systems, and that the risks to the public are negligible (Mr. Michel Rhéaume, September 28, 1994, evening session, p. 93).

The panel noted the detailed incident reports submitted to the AECB. Seven "significant" incidents, i.e., events possibly involving increased risks, have been observed since 1980. These events have been reported to the European Nuclear Energy Agency, which maintains records of this kind. The panel made sure that each of these events was investigated by the AECB at the time of its occurrence, and that specific recommendations were made and implemented as a result of these investigations. This approach ensures that incidents are reported and analyzed and that the results of these analyses are made public. According to the panel, the way these incidents were handled shows a close control over the operation of the power station.

The AECB's 1993 assessment on the operation of the power station (tabled document B19) and its recommendations regarding the renewal of the operating licence for Gentilly 2 (tabled document B20) offer the panel further reassurance in this regard. The AECB's recent renewal of the operating licence of the power station (October 6, 1994) reinforces this conviction.

Analysis of the radiological risks to the public associated with the temporary dry storage system indicates to the panel that the doses to which the public would be exposed during the normal operations of the dry storage facility would be five times lower than those produced by the power station, or fifteen times lower than required by the ALARA principle. The risk of potential accidents appears to be low. The panel recommends, however, that such risk should be verified periodically by the AECB.

Chapter 6 Perception of Risk

According to the proponent, the most important impact of the proposal for dry storage of irradiated nuclear fuel from the Gentilly power station is the public perception of the risks associated with the proposal. The panel therefore attempted to determine the level of social acceptance for this proposal. To do so, the panel has investigated a number of different approaches to the perception of risk, including the one used by Hydro-Québec. The panel proposes a systemic approach which may lead to a better balance between the risks associated with the Gentilly 2 site and the way they are perceived.

Different Approaches to the Perception of Risk

There are, generally speaking, two approaches to the perception of risk:

- the cognitive, or quantitative, approach, used by scientists;
- the intuitive approach, also described as the emotional or qualitative approach, normally used by the public (tabled document A33).

Both types of perception are best considered within a dynamic system involving interaction between the participants.

Cognitive Approach

In its impact study, the proponent uses the term "risk" in its most common sense, meaning the possibility of accidents. More precisely, the radiological risks can be summarized by a mathematical formula:

$$\text{Radiological risk} = \text{consequences of exposure} \times \text{probability of exposure}$$

In the case of the proposal for dry storage of irradiated nuclear fuel, the potential danger is the possibility of exposure to radiation. Exposure to low doses may result in an increased probability of adverse effects on health; the risk may then be expressed as follows:

Radiological risk	=	probability of delayed effects by unit dose	x	dose for exposure scenario	x	probability of exposure scenario

(Di6, p. 9-2 et Di11, p. 5)

This approach makes it possible to calculate the risk in a way that can be communicated to the scientific community. Most members of the public, however, have difficulty grasping the scientific argument because of the complex reasoning involved and their unfamiliarity with the basic concepts essential to its understanding. This approach is described as cognitive because, in theory, it excludes all emotion and is based on rigorous logic developed on the basis of hypotheses considered credible. Nonetheless, Hamel *et al.* (BAPE, 1986, p. 11) state that "the assessment of environmental impacts was originally assumed to be a purely scientific and technical exercise. It is now recognized that social values permeate and implicitly direct each of the stages of the assessment process". It is also recognized that scientists cannot, in fact, set aside their personal, cultural or philosophical values in assessing risk.

Intuitive Approach

The perception of risk is intimately related to the individual's perception of reality. Each person is unique and sees the world in a different way; as a result, perceptions of risk vary. The perception of risk is therefore defined as an intuitive assessment of the understanding of risk. With respect to nuclear power, for example, members of the public may consider the Gentilly 2 power station as a source of risk. They do so because of what they fear to be the consequences of an accident or on the basis of the proponent's calculated probabilities that an accident can indeed occur.

Individuals and groups are influenced by various factors: background, knowledge of the field, emotion, tolerance of uncertainty, personal concerns and culture. These factors contribute to a comprehension based primarily on personal experience. Other factors, including degree of control over the risk or impact on lifestyle, may also have an influence. The risk will thus assume a different significance in the eyes of specific individuals or groups depending on the relative value assigned to each of these factors. Many disagreements between experts and members of the public are attributable to these differences of opinion. They demonstrate the need for open and public debates.

The Dynamic Nature of Perception

The panel recognizes the reality of the perception gap between the cognitive view and the various intuitive perceptions. It also recognizes the dynamic nature of perception: that viewpoints and attitudes can evolve over time with events and knowledge, moving closer together and thus reaching a degree of consensus, or farther apart and thus amplifying differences to the point of confrontation. Recognition of the dynamic nature of perceptual changes allows for the development of mechanisms which, through feedback, fosters reconciliation between the views and attitudes of the actors in the debate.

Population Surveys

Surveys Conducted in Quebec

Hydro-Québec considers the perception of the risk associated with the proposal for dry storage of nuclear fuel from the Gentilly power station to be "moderate", i.e., of local scope and of moderate duration and intensity (Di6, p. 6-20). This conclusion is likely based on surveys conducted in the form of polls and interviews.

Hydro-Québec refers, in its impact study, to a number of polls and interviews conducted to determine the public attitude towards nuclear energy in general and the storage proposal in particular. In addition, the proponent mentions "the public's difficulty in distinguishing between the risks attributable to the power station and those relating to the storage proposal" (Di6, p. 7-4). The panel too was made aware of this difficulty during the public hearings. The panel has therefore decided to examine the problem as a whole.

According to information provided to the panel, three telephone polls have been conducted so far in the Gentilly region regarding public perceptions of nuclear energy in general and the Gentilly 2 power station in particular. The first poll was conducted by Hydro-Québec in 1986, in the wake of the Chernobyl accident. The second was conducted in 1991, by the Sainte-Marie Hospital Community Health Department, as a result of the controversy over the cause of the birth defects and as part of the assessment of the information campaign on the power station Emergency Plan. The third poll was performed by CROP in 1993 to update Hydro-Québec's knowledge of public attitudes and perceptions with respect to the Gentilly 2 nuclear power station (tabled document A66).

The results of these polls reveal the following points:

- more than half the population surveyed feels that a nuclear power station represents a source of danger (Di6, p. 5-49, and tabled document A66);
- less than one in four person feels that the presence of the power station involves serious risks (tabled document A66);
- the percentage of people who believe that an accident is somewhat likely or very likely varies with time and has decreased since 1986;
- concern increases with distance from the power station but decreases with familiarity, education and socioeconomic status;
- certain groups, particularly women and the elderly, show higher levels of concern (Di6, p. 5-49 and 5-50).

CROP classifies members of the public in five groups on the basis of their attitudes towards nuclear power:

– *Opponents, accounting for 19% of the population, are characterized by their strong concern regarding the risks created by the presence of a nuclear power station and their strong prejudice against it. They are primarily members of the 45-54 age group, professionals/administrators, managers/semi-professionals, or university graduates.*
(Tabled document A66, p. 93)

- *The tolerant group, accounting for 30% of the population, ... appears to be somewhat concerned ... [and opposed to] nuclear energy but has a certain degree of tolerance for it. They tend to be primarily white collar workers or college graduates.*
  (Tabled document A66, p. 95)

- *The uninterested but favourable (21% of those questioned) ... This segment is less characterized by its favourable attitude than by its lack of interest in the power station. Members tend to be women, blue collar workers and those with less education.*
  (Tabled document A66, p. 97)

- *Unconditional supporters. This segment, representing 25% of all respondents, includes those interested in learning more about Gentilly 2 and those favouring its presence. ... they are found primarily among the following subgroups: residents of Trois-Rivières ... and Bécancour; men; professionals/managers/ administrators/semi-professionals.*
  (Tabled document A66, p. 100)

- *The uninformed. This segment includes the 5% of those surveyed claiming to be unaware of regional environmental issues, the majority of whom (79%) are unaware of the existence of the Gentilly 2 power station. The uninformed tend to have the following sociodemographic profile: residents of the Victoriaville region; women; those 65 and over; non-members of the labour force; those with little education.*
  (Tabled document A66, p. 103)

The sample was limited to the neighbouring regions: Bécancour, Champlain, Trois-Rivières and Victoriaville. It is not representative of the population of Quebec as a whole.

The results of the group interviews conducted for the public consultation on the storage proposal itself are summarized by Hydro-Québec as follows:

- concerns related to the operation of the power station fall into three categories: "the risks involved in its operation, environmental surveillance and the safety of the facilities" (Di6, p. 5-52);

- concerns relating to the dry storage proposal focused on the integrity and impermeability of the silos or modules. In addition, those interviewed questioned the validity of the decision-making process, because of the perceived unavoidable nature of the proposal. Finally, they were concerned about how long the exposure to radiation will continue if no solution is found to the problem of long-term storage of irradiated fuel (Di6, p. 7-12).

Surveys Conducted Elsewhere in Canada

During the public hearings, the panel examined the results of other similar surveys on perceptions of the risks associated with storage proposals and with nuclear energy in general. It learned that:

- Ontario Hydro's polls of people living in the vicinity of the Pickering power station, conducted for its application to authorize usage of CIC silos for temporary storage of irradiated fuel, indicated that, in general, neither the power station nor the storage proposal was an issue or a concern for the public. The same polls indicated that the storage proposal was unlikely to become an issue (tabled document A15);

- according to the proponent, "... silo storage at Point Lepreau does not appear to have given rise to any particular reactions or concerns from the neighbouring population" (Di6, p. 7-7). However, during the public hearings, the representative of the New Brunswick Ministry of the Environment noted that public reaction had forced the AECB to hold a public hearing on the subject in Saint John, New Brunswick (Mrs. Simone Godin, August 30, 1994, evening session, p. 75);

- in general, the public's principal concerns with respect to the use of nuclear energy appear to be the consequences of a catastrophic accident, the unsolved problem of long-term storage of irradiated fuel, the possibility of nuclear proliferation, and the risks associated with exposure to low doses of radiation;

- the perception of the degree of risk appears to vary over time and from one country and community to another.

The panel notes that the perceptions of risk, as shown by polls and interviews of those living in the vicinity of the Gentilly 2 site, indicate the diversity and complexity of public concerns with respect to nuclear energy.

Reactions of Participants in the Public Hearings

During the public hearings, the panel examined the concerns, fears and anxieties of the participants, described in Chapter 2. In this section, the panel analyses the concerns relating to the perception of risk, pointing out some factors influencing this perception and the discrepancy sometimes found between expert opinion and public fears.

Factors Influencing the Perception of Risk

The panel notes the following concerns, expressed in numerous presentations of the public hearings:

A. The inaccessibility of information and complexity of nuclear energy

A number of individuals mentioned that information on nuclear energy is not easily accessible, that the administrative processes are not transparent, and that nuclear energy, radiological toxicity and radiological protection are complex fields. The vocabulary is highly specialized and the units of measurement are specific to the field, preventing easy comparisons. It is difficult for the public to understand the proposal in detail and to participate actively in the debate.

B. Mistrust of the responsible institutions

First of all, people see the problems associated with the operation of the Gentilly 2 power station (unforeseen incidents, design flaws, delays in procedural reviews, etc). Secondly, there is some doubt as to the ability of the AECB to fulfil its responsibilities because of a lack of resources (brief submitted by the Mouvement Vert Mauricie inc., p. 5-6 and 14). The credibility of the institutions responsible for the safety of the facilities is in doubt. These doubts are intensified by the fact that many individuals feel they cannot control the risks they are exposed to.

C. Fear of serious accidents

The negative perception of nuclear energy has been intensified by fear of the consequences of a serious accident at the power station, in the wake of the accidents at Three Mile Island and Chernobyl, which demonstrate the extent of the consequences of human errors. This raises doubt as to the risk levels calculated on the basis of the technical data. Because of human error, accidents are sometimes more frequent than theoretical probabilities would suggest and their consequences are sometimes more serious than those anticipated by designers.

D. Responsibility to future generations

The fact that the problem of long-term storage has not been solved indicates to some participants that the current generation is taking advantage of nuclear energy but leaving future generations in charge of the problem of wastes. Briefly, "... we get the energy, they get the mess" (brief submitted by the Mouvement Vert Mauricie inc., p. 18).

The Direction de la santé publique de Mauricie—Bois-Francs observes, in more nuanced terms:

> *In the case of nuclear power, using a temporary or interim solution for disposal involves an unusual element of risk, because of the extremely long lifetime of radioactive wastes, which is far greater than the service life of the structures currently responsible for their management.*
> (Brief submitted by the Direction de la santé publique de Mauricie—Bois-Francs, p. 27)

Differences of Opinion

The following examples illustrate some possible discrepancies between expert opinion and public fears:

A. Incidence of leukemia

Some participants expressed concern about the long-term effects of radiation, particularly the higher incidence of cancer around some nuclear facilities. While studies have not yet established a cause-and-effect relationship, some continue to report associations between higher incidences of leukemia and internal exposure of the father to radiation in the six months preceding conception, suggesting that the question has not been resolved (tabled documents B29, B30, B40, B49 and C59).

Studies dealing with the incidence of leukemia are the most sensitive because of the relatively early appearance of this disease after intense radiation. A large survey, covering two million deaths, has been conducted by the National Cancer Institute on populations in the vicinity of 62 nuclear facilities in the United States. The risk of infant mortality as a result of leukemia was never significantly higher. On the contrary, the relative risk actually declined after certain power stations came into service (IAEA Bulletin, 1991).

B. Birth defects

In the spring of 1990, cases of birth defects in children born in the vicinity of the Gentilly 2 power station intensified the public's negative perception of radiation. Regional public health authorities were alerted and conducted an investigation which failed to implicate radiation from the power station, since this represents less than 0.5% of natural ambient radioactivity, at 0.01 mSv/yr compared to 2.4 mSv/yr (tabled document B22). Nonetheless, some participants still consider the Gentilly 2 power station responsible. In addition, the scientific impossibility of conducting a meaningful epidemiological study increases the uncertainty, since the experts appear to the public as having no answers to the problem.

C. Emergency plan

The AECB requires the development of an Emergency Plan so that authorities are prepared to provide information to the public in the event of a crisis resulting from an unforeseen accident in a nuclear power station, and are prepared to deal with it. In theory, the Emergency Plan should reassure the public by demonstrating that the authorities are prepared to deal with the situation. However, even awareness of plans for temporary confinement, evacuation, distribution of stable iodine capsules, and other measures can create insecurity in some segments of the public, which sees such a plan as an indication of the danger associated with the power station.

The Panel's Analysis

According to Hydro-Québec, it was "... difficult to predict whether the storage facilities will be perceived as an environmental issue in the region". It also felt that: "the regional public might have difficulty, under certain circumstances, distinguishing clearly between the two power stations built on the Gentilly 2 site (including the silos and modules) and their potential impact" (Di6, p. 7-13).

The public hearings demonstrated that most of the participants were not unduly concerned about the risks relating to the proposal itself, but that they associated the proposal for dry storage of irradiated fuels with the operation of the nuclear power station.

The panel agrees with the following observations by the Direction de la santé publique de Mauricie—Bois-Francs:

- the public shows some acceptance of the proposal;
- the public does not distinguish between the proposal and the operation of the power station;
- a number of factors are involved in the public assessment of the proposal, the principal factors being the credibility of the institutions concerned, the credibility of the decision-making process in the face

of risk, the equity of risks and benefits distribution in space and time, and the degree of personal control (brief submitted by the Direction de la santé publique de Mauricie—Bois-Francs, p. 19).

Hydro-Québec does not appear to have given sufficient consideration to the need for an overall approach in dealing with the discrepancies in the perception of the risks associated with the operation of Gentilly 2, nor does it appear to have assessed the need to put the problem of fuel storage in the general context of the operation of the power station itself.

The panel notes that the question of risk perception as expressed during the public hearings went beyond the issues revealed by the earlier polls. **It is of the opinion that the perception of the risk associated with the proposal for dry storage of irradiated nuclear fuel from the Gentilly 2 power station is difficult to dissociate from that of the risk associated with the operation of the power station. It also believes that Hydro-Québec should develop a consultative approach to attenuate the discrepancies in the perceptions of the risks associated with the operation of Gentilly 2.**

Models of Risk Perception

A great deal of information is available on the perception of risk. The panel has consulted a number of reports describing studies on the perception of risk. These were selected from the bibliographies compiled by Hydro-Québec, AECL, the AECB and the Direction de la santé publique de Mauricie—Bois-Francs (tabled documents A12, A33 and B79). The panel has examined various descriptive models of risk perception including, in particular, those developed by Covello and Gartner. It has found that virtually the same factors influencing the perception of risk are identified. Because of the large number of factors involved, the panel looked for models which could group or weight these factors.

The panel examined a document prepared by the Régie régionale de la santé et des services sociaux de l'Estrie that groups the determinants influencing the perception of risk on the basis of type of risk, socioeconomic context and determinants linked to the decision-makers.

The panel looked for ways of resolving the issue and reducing the discrepancies between the various perceptions of risk. In the process, it examined the proposal submitted by the Direction de la santé publique de Mauricie—Bois-Francs, which believes that the most important factors are:

- the confidence in and the credibility of the organizations;
- the existence of a potential benefit from the proposal;
- the feeling of control the public has over the proposal.

(Mr. Guy Lévesque, September 27, 1994, evening session, p. 133)

Covello states that the four most important factors are: confidence, benefits, control and equity. He assigns them weightings of 2000, 1000, 1000 and 500 (tabled document B97.1). These four factors alone account for 87% of the importance of all factors.

The panel concludes that the main factors having a negative influence on the perception of risk are, first of all, mistrust of the technology used and the agencies responsible for its control and, secondly, possible inequities in the distribution of the risks and benefits of this technology among different segments of the population and between generations.

The Systemic Approach

Analysis of the perceptions of risk by members of the public and participants in the public hearings on dry storage of irradiated fuel has indicated that the perception of risk varies markedly depending on whether the individuals concerned base their conclusions on expert opinion or actual experience in managing nuclear risk, or on more general intuitive attitudes and feelings. The panel has used the term "actors" for the various persons or groups appearing at the public hearings. Through their attitudes, these actors play "roles" characterizing them.

These perceptions vary also depending on whether the actor receives direct benefits from the use of nuclear energy and whether the objections to nuclear energy touch a sensitive spot and challenge the individual's role. For example, power station managers and workers may consider the arguments of some opponents questionable from the outset, or not worth discussing.

The perception of risk is dynamic, however, and evolves over time. It can be visualized as an open system with feedback, in which the views of each actor are influenced by his or her knowledge, experience, beliefs, and concerns, which affect attitudes and behaviours, and thus intensify or inhibit the perception of actual risk. Depending on the type of influence to which an actor is exposed, his or her attitudes and behaviour with respect to risk may either be intensified or reduced. These differences in opinion may partially explain the frequent disagreements between members of the public and experts when characterizing risk.

During the public hearings, the panel observed a number of noteworthy changes in behaviour, indicating that fears with respect to the risks had been relieved for some, intensified for others, and remained unchanged still for others. Finally, the panel believes that attenuation measures based on open discussions would allow the actors to modify their mutual perceptions and develop a collective framework of risk management.

Recognition of the different attitudes held by the various actors that influence their perception of the risk is essential in order to understand the motivation of each of these groups and develop cooperative behaviours to promote reconciliation between the different viewpoints and strive for consensus.

Reducing Discrepancies in the Perception of Risk

Reactions at the Public Hearings

During the public hearings, the panel questioned the participants on ways of reducing the discrepancies between the risks as presented by the proponent and the public. A number of solutions were suggested.

With respect to the dry storage proposal, the Direction de la santé publique de Mauricie—Bois-Francs recommends, first:

> *That any action to reduce and monitor social impacts associated with the perception of risk be based on a global approach to the perception of nuclear risk.*
> (Brief submitted by the Direction de la santé publique de Mauricie—Bois-Francs, p. 31)

The Direction de la santé publique also notes that some approaches are more likely than others to produce results. Those selected must be based on an open and democratic process. It adds:

> *... it is vitally important that all the actors concerned be represented, ... the process must be based on participation rather than strictly on information, ... it must be transparent, ... it must be equitable.*
> (Mr. Guy Lévesque, September 27, 1994, evening session, p. 134)

Finally, the Direction de la santé publique points out that, when speaking of the consultation process, it is important to distinguish between information, consultation, and participation. In its opinion, participation means ensuring that people have a role to play in the process and even in decision-making.

The Syndicat des employé-es de métiers d'Hydro-Québec feels that the training and accessibility of those who possess such information are vital to achieve a more accurate understanding of nuclear risks. The union representative adds:

> *the nuclear world is evolving; in the past, things were more or less secret, but today, many organizations are open and prepared to provide all the necessary information as required.*
> (Mr. Robert Boisvert, September 28, 1994, evening session, p. 43)

Expert Opinions

The panel examined a number of proposals from a report entitled *The Disposal of Canada's Nuclear Fuel Waste: Public Involvement and Social Aspects* (tabled document B77.9). According to the authors, the most promising approach appears to involve attempts to adapt the controversial topic to meet public expectations. This approach, developed in tabled document B77.9, means going beyond the opinions of the experts and of the public in an attempt to make the proposal more consistent with public criteria, without in any way compromising safety.

While the approach relates to the acceptability of the permanent storage proposal, the suggestion that public perceptions can be modified through factors such as voluntarism, control, equity, confidence in institutions, and familiarity offers promising possibilities for the management of risk perception.

Covello proposes an approach based on trust and the credibility of the individual or organization transmitting the message to the public. Four major factors are identified as having a significant influence on perceived reliability and credibility (tabled document B97):

- Perceived empathy and the desire to act with care: within the first 30 seconds of contact, the public judges the communicator's concern for health, safety and social justice. If the communicator fails this initial test, he or she will have a very difficult time correcting public opinion;

- Perceived competence and expertise: the communicator's training, experience, knowledge and verbal facility will affect this perception. The previous activities and reputation of the organization he is associated with will also play a key role;

- Perceived honesty and openness: the public will also judge the communicator's actions, words and non-verbal attitudes. Failure to maintain eye contact, prejudiced vocabulary and apparent lack of openness are all negative factors;

- Perceived devotion to a cause: the communicator will be helped by a reputation as a diligent and dedicated worker for health, safety and environmental protection (brief submitted by the Direction de la santé publique de Mauricie—Bois-Francs).

The panel believes that reducing the discrepancies among the perceptions of the risk associated with a proposal is a delicate operation requiring complete openness from the agency managing the proposal and complete respect for those persons or groups questioning the

desirability of the proposal or expressing concern about it. It is of the opinion that the organization should offer participants the opportunity to have some degree of control over the implementation and monitoring of the proposal.

Hydro-Québec's Proposal

To reduce public perception of the risks associated with the proposal, Hydro-Québec proposes to implement a series of measures in the initial construction phase and in the subsequent construction and operating phases. These measures can be summarized as follows:

- information sessions in communities where the public showed the highest concern during the impact assessment;
- information sessions for environmental groups, health-care agencies and elected municipal officials;
- open houses;
- links with the Corporation Environnement-Bécancour;
- analysis of comments received on these occasions.

(Di6, p. 10-4 and 10-5)

The proponent feels that implementation of these measures will require information and cooperation. It therefore plans to establish

a committee of advisors and experts on the environment, radiological protection, health and safety, communications, public relations, and supply and services, the latter to optimize the regional economic impact. (Di6, p. 10-3 and 10-4)

The panel is surprised to note that the proposed committee does not include community representatives, at odds with the most recent trends in environmental monitoring and the objective of dialogue and consultation expressed by the proponent itself. In light of the presentations during the public hearings and the analysis developed above, the panel wonders if this committee should not instead be given responsibility for management of the risk associated with the operation of the power station or, more specifically, for developing the best assessment of the risk, considering the differences in sensitivity within the various segments of the population. If so, the committee should adopt a global approach, as recommended above. Moreover, it should work in cooperation with the various organizations also affected by the operation of the nuclear power station, including the Direction de la santé publique de Mauricie—Bois-Francs, the ministries and departments represented at the public hearings, the municipality of Bécancour, etc.

The panel considers that the measures proposed by Hydro-Québec to mitigate the perception of risk are necessary but not sufficient. Therefore, the panel recommends that the committee coordinating these measures should include community representatives. It also believes that the committee's mandate should be extended to include measures designed to reduce the discrepancies between the perceptions of the risk associated with the operation of the nuclear power station.

More specifically, the committee's mandate could include the following measures:

- monitoring the integrity of the storage structures;
- follow-up on the issue of permanent disposal;
- monitoring the pressure tube inspection program;
- assessing the results of the radiological surveillance program for the environment at the Gentilly site;
- assessing significant incidents at the Gentilly power station;
- follow-up on the Emergency Plan.

Chapter 7 Beyond the Storage Proposal

In this chapter, the panel suggests a number of proposals which go beyond the storage proposal proper and attempt to close the gap between the perceptions of risk by the various segments of the population. One of these proposals involves increasing and adapting regional benefits, six proposals relate to improving public confidence in the monitoring agencies, and the other proposals suggest ways of using information, consultation and dialogue to promote community empowerment for making decisions about nuclear energy.

Financial Compensation

During the public hearings, Hydro-Québec agreed to implement its Integrated Development Program, designed to provide financial compensation to offset the impact of its activities. This program backs proposals valued at up to 2% of the Crown corporation's project. The panel learned, during the hearings, that this program does not apply to activities associated with the power station itself. Considering the need for improved regional benefits related to the project and its duration, the panel feels that Hydro-Québec should allow the broadest possible application of this program. It also feels that priority should be given to activities designed to alleviate public concern regarding the activities of the power station.

The panel asks Hydro-Québec to allocate the maximum funding allowed under the Integrated Development Program and to give special consideration to proposals designed to alleviate public concern regarding the environmental impact of the power station activities.

Confidence in the AECB

During the public hearings, a number of participants questioned the ability of the AECB to meet its full responsibilities for inspection and control, by submitting a 1989 document signed by the president of the AECB, informing the Treasury Board of the need for more staff to ensure adequate execution of the agency's mandate (tabled document C5). When questioned, the chairman of the AECB executive committee stated that "the additional resources received by the AECB made it possible to correct the situation or at the very least to effect significant improvements in all major areas" (tabled document B26, p. 1).

Despite these comments intended to reassure, some participants remained unconvinced of the agency's ability to perform its responsibilities properly. The Direction de la santé publique de Mauricie—Bois-Francs, for example, is concerned with the problems mentioned in the 1989 document submitted to Treasury Board, and feels:

> *... that it would be in the interest of all parties to obtain a detailed update of the figures in this report ... this would enable us to identify more accurately the problems that have been corrected and the problems that have not yet been corrected.*
> (brief submitted by the Direction de la santé publique de Mauricie—Bois-Francs, p. 14)

The panel recommends that the federal government perform periodic assessments of AECB staff requirements to ensure that the Board does really have the resources it needs to execute its mandate effectively. The results of this assessment should be made public.

Confidence in the Ministry of the Environment and Wildlife

The panel learned, during the public hearings, that the Ministry of the Environment and Wildlife no longer had an expert to provide critical comment on the annual report of the Gentilly 2 power station as well as a number of other reports.

To improve public confidence in the regional monitoring agencies, the panel feels it would be advisable to develop and maintain the expertise required to ensure adequate surveillance of environmental quality in Bécancour and surrounding area.

The panel recommends the Government of Quebec allocates the human and financial resources required by the Ministry of the Environment and Wildlife to meet its full responsibilities with respect to environmental surveillance and monitoring of the nuclear power station, including the dry storage facility.

Continued Research on the Effects of Radiation

Some participants in the public hearings showed concern about the effects of low-level radiation on the individuals living in the vicinity of nuclear power stations.

While studies performed to date in Canada and around the world failed to show a causal relationship between such levels of exposure and the development of radiation-related diseases, epidemiological research is still going on (tabled document B41). The panel also notes that knowledge of the effects of tritium on the fetus is still incomplete (tabled document B41).

The panel is of the opinion that the AECB should continue to fund research on the effects of low-level radiation in general and on the possible effects of tritium on the fetus in particular.

At the regional level, in response to events linked to public health problems, the Direction de la santé publique de Mauricie—Bois-Francs, the responsible agency, has developed an impressive level of expertise in this field. Moreover, it played an active public role.

The panel hopes that the Ministry of Health and Social Services will continue to support the proactive role played by the Direction de la santé publique de Mauricie—Bois-Francs in coordinating research on the effects of industrial operations on human health.

Adaptation of the Emergency Plan to Public Concerns

Emergency measures for the Gentilly 2 power station include two major plans:

- the internal plan, consisting of emergency measures for the nuclear site, is the exclusive responsibility of Hydro-Québec;
- the external plan, or *Disaster Prevention and Emergency Measures Plan*, consisting of emergency measures beyond the nuclear site, is under the responsibility of Quebec's Ministry of Civil Security (tabled document A24).

The *internal plan* was revised in December 1993. The *external plan*, first developed in 1983, has been periodically updated. It is currently undergoing an in-depth review scheduled for completion in 1995 (Mr. Jacques Brochu, August 25, 1994, evening session, p. 54). The Ministry of Agriculture, Fisheries and Food has prepared a plan for emergency action in the event of a nuclear incident which should be integrated with the external plan (tabled document B12). This plan is designed specifically to inform farmers of decision criteria relating to human beings, livestock and crops.

The panel recommends that the Government of Quebec ensure that the Emergency Plan scheduled for completion in 1995 will really be completed within this time frame.

Hydro-Québec also prepared information for the public, consisting of a road map and explanatory folder. The content and graphics quality of the folder are adequate. However, there does not appear to be any documentation designed specifically to meet the needs of the various groups within the potentially affected population: residents, workers in the Industrial Park, farmers and others.

The panel considers that there is a need for public documentation explaining the emergency measures to be adapted to the various regional target groups concerned. This documentation should include information on the responsibilities of the various agencies.

Importance of Human and Organizational Factors

As noted in the chapter on perceptions with respect to the fear of serious accidents, in the 1990s human and organizational factors have become increasingly significant in determining the causes of major incidents. A document produced by the Advisory Committee on Nuclear Safety (ACNS-17) identifies institutional failures as one of the underlying causes of the accidents at Three Mile Island and Chernobyl. While the situation in Canada is generally more positive, the number of serious incidents reported reveal significant discrepancies between the operations proposed and prescribed, and those followed in practice. In some cases, these discrepancies resulted in damage and, in others, in higher dose levels than was anticipated.

The AECB itself acknowledges the need for a "more detailed study of the role played by human factors in relation to safety" (tabled document B26, p. 2).

The panel therefore recommends that the AECB continue its study on the role human and organizational factors play in the safety of nuclear power stations.

Aging of the Power Station

During the public hearings, questions were raised as to the impact of aging on the safety and operating cost of the Gentilly 2 power station.

The panel feels that aging of the power station may result in the following trends:

- increased need for maintenance and repairs;
- reduced utilization factor;
- increased worker exposure dose;
- false sense of security;
- general decrease of safety margins in the operation of the power station.

Possible indicators for assessing the radiological cost of aging on the staff of the power station, for example, might include the collective dose in relation to rated power output (person-sieverts/MW) or to actual production (person-sieverts/MWh).

The panel believes that the AECB should develop a rating system to reflect the aging of a nuclear power station to be used while assessing applications for the renewal of operating licences.

Accessibility of Information

During the public hearings, the panel noted that Hydro-Québec was concerned with all aspects of information on the Gentilly power station. In addition to an on-site information centre, Hydro-Québec developed a public information program on nuclear energy. Guided tours to the Gentilly 2 power station are offered during the summer months. The panel feels that the interest in nuclear energy extends throughout the year and that a dedicated toll-free telephone line (1-800 type), for example, might help to meet the concerns of some members of the public.

The panel asks Hydro-Québec to consider the use of a wide range of means of communication to deal with the public concerns regarding nuclear safety, throughout the year.

Creation of an Advisory Committee on Regional Environmental Impacts

During its review, the panel noted that a number of regional agencies, including the authorities of the Gentilly 2 power station, the regional directorates of the various ministries, the municipal authorities of the Town of Bécancour, etc., often combined their resources to meet government requirements or to deal with community concerns.

This occurred, for example, for the update of the Emergency Plan for the Gentilly 2 power station, the surveys on the causes of the birth defects observed in 1990, and the creation of the Corporation Environnement-Bécancour, which assumed responsibility for producing an annual global assessment report on regional environmental issues.

The panel feels that these joint efforts represent a promising approach which could help to reduce the discrepancy between the perceptions of risk by the various individuals and groups within the region with respect to specific concerns and to improve understanding of new and complex areas. The panel hopes that Environnement-Bécancour will continue its efforts in this direction and attempt to involve in its activities members of the public and the organizations they represent.

The panel also feels that consultative and collaborative efforts should be intensified. It suggests that regional organizations formally assume responsibility for dealing with community concerns of the risks associated with industrial development. This could be achieved through an advisory committee that would meet periodically to discuss public concerns and to propose appropriate action. The panel feels that the participation of members of the public and environmental groups in both the discussion and monitoring phases is essential. Finally, the panel feels that Hydro-Québec could play a leadership role in this initiative.

The panel believes that Hydro-Québec should take the initiative in establishing an advisory committee consisting of government agencies, environmental groups and concerned citizens, to deal with environmental issues of public concern in the Bécancour region.

Conclusion

In this chapter, the panel summarizes the main conclusions it has drawn from its joint public review of the proposal for dry storage of irradiated nuclear fuel from the Gentilly 2 power station. These conclusions relate to the proposal itself, and to more general considerations associated with the power station and with nuclear energy. The reader may refer to the previous chapters for further details.

The Storage Proposal

The panel concludes, on the basis of the public review of the proposal for temporary dry storage, that this type of storage is required, first, because permanent disposal will not be available for several decades, and the fuel storage pool used primarily to cool the irradiated fuel is almost full, and secondly, because the level of operation of the Gentilly 2 power station has little or no impact on the amount of space required in the storage pool. Moreover, even if the power station were to be shut down and dismantled immediately, the fuel currently in the reactor and in the storage pool would still have to be transferred to a dry storage facility.

Hydro-Québec has developed a proposal for dry storage involving primarily CANSTOR modules, combined with silos as required.

The panel prefers the silo option because the technology is commercially proven, both on the Gentilly site itself, with irradiated fuel from the Gentilly 1 reactor, and in New Brunswick, where silos are used to store the fuel from Point Lepreau, sister plant to Gentilly 2. Hydro-Québec would be using technology which has been improved since the construction of the Gentilly 1 silos in 1985. This appears to be the safest form of dry storage. The silos should be filled as proposed by Hydro-Québec, starting with the oldest fuel and proceeding to fuel stored for seven years in the storage pool. For fuel placed in the storage pool for less than seven years, Hydro-Québec should get AECB authorization.

The panel cannot recommend the module option at this time, since examination of the advantages attributed to this type of storage is not convincing. Uncertainties persist regarding the need for structural support in the form of concrete caissons, which may offset the principal advantages of this option, the cost savings per storage unit. The addition of these caissons alone, which were not initially included in the impact study and which did not come to the panel's attention until after the public hearings, reduces the economic advantage by half. Another anticipated advantage of the modules, their ability to dissipate heat, is partially offset by the increased vulnerability associated with a technical design requiring openings in the concrete shielding. Considering their anticipated service life of approximately fifty years, the possibility of criminal activity cannot be dismissed. Finally, this new technology is not yet approved by the AECB.

The modules' need for concrete foundations concerns the panel as to the location of the storage site. The original proposal involved the use of a site within the protected area of the power station, with a fenced perimeter and controlled access. The impact on this site is virtually nil, but this may not be true if the site is moved as a result of the geotechnical studies currently being performed and not examined by the panel.

The panel therefore feels that, under existing circumstances, selection of the module option cannot be considered final. It recommends that the uncertainties remaining with respect to this option – i.e. the true cost of the modules, the suitability of the chosen site in view of the new constraints and the safety of the new AECB design – be resolved before the government gives its approval.

The radiological risks associated with handling and storage of the irradiated fuel are relatively low, both under normal operating conditions and in the event of an accident. The panel is satisfied with the management of these risks as an integral aspect of the management of the power station itself. However, the panel recommends that the AECB standard controls and those proposed by Hydro-Québec be maintained, as they remain the best guarantee of safety. Hydro-Québec surveillance and monitoring program thus remains essential.

The panel has examined the perception of risk, which is tied to two related considerations. The panel agrees with the participants in the public hearings that the proposal for temporary storage can be examined only in conjunction with the issues associated with permanent disposal of the irradiated fuel. In addition, the risks associated with the operation of the power station producing this fuel cannot be dissociated from the storage proposal.

Hydro-Québec recognizes this latter consideration: its impact study identifies the perception of risk as the most important impact of the proposal. The study also recognizes that the public will probably fail to distinguish between the risks associated with the proposal and those associated with the power station. Yet its proposed corrective measures relate solely to the storage proposal, an approach the panel considers inadequate. Hydro-Québec should include representatives of the community on the committee responsible for developing corrective measures and should expand its mandate to include all measures designed to reduce the discrepancies between the perceptions of the risk associated with the operation of the power station.

Based on its analysis, the panel concludes that the main factors influencing the perceptions of risk are, first, mistrust of the technology involved and of the agencies responsible for monitoring it, and, secondly, possible inequities in distribution of the risks and benefits arising from the use of this technology among different segments of the population and different generations. Regardless of their roles, all these factors affect the perception of the risks associated with the Gentilly 2 power station and the proposal for the storage of irradiated nuclear fuel. Hydro-Québec's approach to risk management and perception must reflect these factors and demonstrate its willingness to deal with the public in a transparent manner.

The Power Station

The panel believes that the following issues must therefore be taken into consideration. First, the criteria and mechanisms used to determine whether the power station is to be shut down in 2013 and what is to become of it thereafter must be clarified. Retubing operations could extend the service life of the power station, just as these may equally be required before 2013. The results of the periodic inspections of the pressure tubes must therefore be made public and included in the station annual report, particularly in view of the large sums involved ($500 million — 1994 dollars).

The panel recommends that Hydro-Québec continue to anticipate and make provisions for the costs associated with dismantling and fuel removal, to ensure that they are not passed on to another generation, particularly one that will not benefit from this form of energy. The panel also recommends that Hydro-Québec participate in the studies being conducted by AECL and Ontario Hydro regarding the permanent disposal of irradiated fuel. This would give Hydro-Québec a greater role than that of a mere potential consumer of what is probably an inevitable technology.

The Nuclear Energy Sector

In general, the panel noted some imprecision with respect to the nuclear energy sector in Quebec. It hopes that the Government of Quebec will clarify its intentions with respect to the long-term management of irradiated fuel, since this is a factor in the public perception of the proposal for temporary storage. It should assign immediate responsibility for monitoring this sector to the most closely concerned ministries, the Ministry of the Environment and Wildlife and the Ministry of Natural Resources. They should ensure that an agreement is signed with the Federal Government regarding permanent disposal of irradiated fuel from Gentilly 2, to avoid indefinite extension of temporary storage.

The panel proposes that the Government of Quebec use integrated resource planning, the new tool for updating energy policy currently in the public consultation phase, to prepare a comparative review of the nuclear energy sector. This approach would offer the dual advantage of integrating a number of external costs not presently included and of systematically involving the public in energy decisions.

The panel notes the need to ensure appropriate surveillance of the environment and public health. The governments must ensure that the various monitoring agencies are in a position to fully meet their respective public health and safety responsibilities. Finally, the panel has noted that a promising climate of regional cooperation exists, which has fostered the development of a high level of expertise and social involvement.

SIGNED AT QUEBEC CITY,

ALAIN CLOUTIER, Panel member
Chairman of the Panel

WLADIMIR PASKIEVICI
Panel member

ANDRÉ ARSENAULT
Panel member

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Appendix 1

Isotopes Contained in an Irradiated Fuel Bundle

Isotopes Contained in an Irradiated Fuel Bundle

Fission Products	Actinides
Tritium-3*	Uranium-232
Krypton-85	Uranium-233
Strontium-89	Uranium-234
Strontium-90	Uranium-235
Yttrium-91	Uranium-236
Zirconium-95	Uranium-238
Niobium-95	Neptunium-237
Ruthenium-103	Neptunium-239
Ruthenium-106	Plutonium-238
Silver-110	Plutonium-239
Antimony-124	Plutonium-240
Antimony-125	Plutonium-241
Iodine-129	Plutonium-242
Cesium-134	Plutonium-244
Cesium-137	Americium-241
Cesium-141	Americium-243
Cesium-144	Curium-242
Promethium-147	Curium-244
Europium-152	
Europium-154	

* Isotope of hydrogen formed during the operation of the CANDU reactor; accumulates in heavy water.

Source: adapted from Dill, p. 91.

Appendix 2

Model Developed by the Régie régionale de la santé et des services sociaux de l'Estrie

Model Developed by the Régie régionale de la santé et des services sociaux de l'Estrie

As part of the study on the psychosocial impact of the operation of sanitary landfill sites in the Eastern Townships, the Régie régionale de la santé et des services sociaux de l'Estrie compiled, from the literature, a list of the factors believed to affect the perception of risk. These factors are grouped in three categories, making it possible to distinguish the nature of the risk from its socioeconomic context and management (Messely, 1992; Eyles, 1993; Danday, 1990; Bord and O'Connor, 1992; from Duclos and Proulx, 1994).

1. Determinants associated with the nature of the risk:

   - **the risk is unfamiliar**, as opposed to risks known for some time (for example, exposure to fumes from a new business, as opposed to toxic household products commonly used);
   - **the risk is of artificial** rather than natural **origin** (for example, radiation from a nuclear generating station, as opposed to radon from the earth's crust);
   - **exposure to the risk is not detectable** (for example, air pollution, radiation);
   - **The risk is associated with a previous dramatic event** (for example, Chernobyl or Bhopal);
   - **the potential health problems are severe** (for example, cancer or birth defects, as opposed to a cold);

2. Determinants associated with the social and economic context:

   - the risk is not voluntary, but imposed by a third party without public participation in the selection of sites or technologies;
   - the community has no control over the risk imposed, for example, by a private company;

- the distribution of risks and benefits is unfair or inequitable (benefits in one region, risk in another);
- the risks are perceived as greater than the benefits;
- there are ethical or moral objections.

3. Determinants associated with management:

- the source creating the risk is considered unreliable (previous negligence, profit motive, hope of financial gain);
- the agency responsible for monitoring the risk situation has a reputation, justified or not, for inaction;
- the experts disagree as to the degree of risk.

Appendix 3

Background Information

Background

June 30, 1992	Notice of proposal
October 28, 1992 to January 5, 1993	Interministerial consultation on guidelines
April 1, 1993	Ministry of the Environment guidelines
November 8, 1993	Hydro-Québec releases interim impact study
November 22, 1993 to January 25, 1994	Interministerial consultation on interim impact study
January 26, 1994	Hydro-Québec releases summary of impact study
January 31, 1994	Ministry of the Environment and Wildlife issues comments on interim impact study
February 2, 1994	Hydro-Québec releases *Analyse des risques*
February 8, 1994	Hydro-Québec releases the *Rapport de sûreté*
February 21, 1994	Hydro-Québec releases *Questions et commentaires sur l'étude d'impact*
February 24 to March 15, 1994	Interministerial consultation on final impact study
March 16, 1994	Ministry of the Environment and Wildlife issues notice on acceptability of impact study
April 7, 1994	Ministry of the Environment and Wildlife instructs BAPE to release impact study on April 25, 1994
April 25 to June 9, 1994	BAPE information period
June 9, 1994	Deadline for requests for public hearings regarding the proposal subject to the information period (6 applications)

Public Hearing Applicants

Greenpeace Québec

Mouvement Vert Mauricie inc.

Canadian Coalition for Nuclear Responsibility

Gouvernement
du Québec

Sainte-Foy, July 14, 1994

Mrs. Hélène Gauthier-Roy
Hydro-Québec
Planning and Government Relations
1010 St Catherine St E
6th Floor
MONTREAL, Quebec, H2L 2G3

Dear Mrs. Gauthier-Roy,

I received a number of requests for a public hearing on the Hydro-Québec proposal for dry storage of irradiated nuclear fuel from the Gentilly 2 generating station.

I therefore instructed the Bureau d'audiences publiques sur l'environnement (BAPE) to hold a hearing. I invite you to contact the BAPE to discuss your participation in this hearing.

The Bureau's mandate will begin on August 15, 1994.

I would remind you that this mandate includes examination of the effects of the proposal on the environment and of the social impacts directly related to these effects on matters under federal jurisdiction.

Sincerely,

PIERRE PARADIS

cc: Mr. Bertrand Tétreault, Chairman, BAPE
Mr. Daniel Dubeau, Vice-President, Environment

3900, rue de Marly, 6e étage
Sainte-Foy (Québec)
Téléphone : (418) 643-8259
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5199, rue Sherbrooke Est, bureau 3860
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Télécopieur : (514) 873-2413

Gouvernement du Québec
Bureau d'audience publique sur l'environnement

Quebec City, July 15, 1994

Mr. Alain Cloutier
Additional Member
Bureau d'audiences publiques sur l'environnement
625 Saint-Amable Street, 2nd Floor
Quebec City, Quebec
G1R 2G5

Dear Mr. Cloutier,

The Minister of the Environment and Wildlife, Mr. Pierre Paradis, has mandated the Bureau d'audiences publiques sur l'environnement to hold a public hearing on Hydro-Québec's proposal for dry storage of irradiated nuclear fuel from the Gentilly 2 generating station, beginning August 15, 1994.

In accordance with the provisions of Section 2 of the rules of procedure for the conduct of public hearings, you are hereby appointed chairman of the panel responsible for the inquiry and public hearing on the above proposal.

Sincerely,

BERTRAND TÉTREAULT
Chairman

cc: Mr. Alain Pépin

BAPE
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625, rue Saint-Amable, 2e étage
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Panel, Team and Collaborators

Panel

ALAIN CLOUTIER, chairman
ANDRÉ ARSENAULT, panel member*
WLADIMIR PASKIEVICI, panel member

* member recommended by the federal government

Team

LOUISON FORTIN, analyst
GINETTE GIASSON, panel secretary
DIDIER LE HÉNAFF, information officer
NATHALIE RHÉAUME, secretarial officer
JACQUES TALBOT, analyst

Collaborators

LISE CHABOT
JULIE DUMONT
SUZIE LEBRUN

Consultation Centres

Bécancour Municipal Library	**Trois-Rivières Municipal Library**
Undergraduate Library, Laval University, Sainte-Foy	**Central Library, University of Quebec at Montreal**
BAPE offices, Quebec City and Montreal	

Public Hearings

Part 1	**Part 2**
August 24, 25 and 26, 1994 August 30, 31 and September 1, 1994 Bécancour Larochelle—Saint-Grégoire Cultural Centre	September 27, 28 and 29, 1994 Bécancour Larochelle—Saint-Grégoire Cultural Centre

Theme Sessions

August 26, 1994 Radiological Protection: Public Health and Regulations

- sources, allowable doses and effects of radiation
- radiological protection principles and measures, including ALARA
- analysis of accidents
- regulation, inspection, control and monitoring

August 30, 1994 Experience in Dry Storage of Irradiated Fuel

- fuel handling
- experience at Gentilly 1, in Canada, and abroad
- advantages and disadvantages of the different types of storage
- option selected and alternative solutions
- environmental surveillance and monitoring

Special Activities

August 15 and 16, 1994	Preparatory meetings and Gentilly 2 site visit by the panel

Participants in the Public Hearing

Departments and Agency

Ministère de l'Agriculture, des Pêcheries et de l'Alimentation	Mr. Jacques Tessier, spokesperson Mr. Alain Tremblay
Ministère de la Santé et des Services sociaux, represented by the Direction de santé publique de Mauricie—Bois-Francs	Dr. Gilles Grenier, spokesperson Mr. Guy Lévesque Mr. Pierre Pelletier Dr. Maurice Poulin
Ministère de la Sécurité publique	Mr. Jacques Brochu, spokesperson Mr. Jacques Paré
Ministère de l'Environnement et de la Faune	Mr. Clément Drolet, spokesperson Mr. Pierre Chaîné Mr. Jean-Marc Légaré Mrs. Renée Loiselle
Ministère des Ressources naturelles	Mr. Réal Carbonneau, spokesperson Mr. Denis Talbot
Atomic Energy Control Board	Mrs. Cait Maloney, spokesperson Mrs. Dalsu Baris Mr. Donald Howard Mr. André Joyal Mr. Robert Potvin

Experts

Mr. Robert P. Bradley	Department of National Health and Welfare
Mr. Joseph A. Doucets	Laval University
Mrs. Simone Godin	New Brunswick Ministry of the Environment

Groups and Members of the Public Attending Part One

Mr. Philippe T. Armand	Member of the public
Mr. Yves Beauchesne	Member of the public
Mr. Fernand W. Benoît	Member of the public
Mr. Alain Charest	Mouvement Vert Mauricie inc.
Mrs. Lucie Cossette	Member of the public
Mr. André Déry	Member of the public
Mr. Gordon Edwards	Canadian Coalition for Nuclear Responsibility
Mr. Michel Fugère	Mouvement Vert Mauricie inc.
Mr. Donat Gagnon	Member of the public
Mr. Stéphane Gingras	Greenpeace

Mrs. France Houle	AQLPA Mauricie—Bois-Francs
Mrs. Marie-Claude Lacourse	Mouvement Vert Mauricie inc.
Sister Estelle Lacoursière	Member of the public
Mrs. Johanne Morissette	Les Ami-es de la Terre de Québec
Mr. Patrick Rasmussen	Mouvement Vert Mauricie inc.
Mr. Alain Saulnier	Member of the public
Mr. François Tanguay	Greenpeace
Mr. Joseph Tremblay	Envirotecheau
Mr. Nicolas Tremblay	ENvironnement JEUnesse

Groups and Members of the Public Attending Part Two

Mr. Jean-Pierre Gauvin	Canadian Radioprotection Association
Mr. Fernand W. Benoît	Benoît & associés
Mr. Philippe T. Armand	Member of the public
Mr. Yves Beauchesne	Member of the public
Mr. Christian Massé	Member of the public
Mrs. Lucie Cossette	Member of the public
Mrs. Diane Noury	Member of the public
Mr. Réal Brouillette	Chambre de commerce du district de Trois-Rivières
Mr. Joseph Tremblay	Envirotecheau

Mr. Gamil Moussalam	Atomic Energy of Canada Limited
Mr. Philippe Dunsky Mr. Nicolas Tremblay	ENvironnement JEUnesse
Mrs. Sylvie Donato Mr. Jean-François Lefebvre	Groupe de Recherche Appliquée en Macroécologie
Mr. Daniel Rozon	Institute of Nuclear Engineering, École Polytechnique de Montréal
Mrs. Margot Allen Mrs. Johanne Morissette	Les Ami-es de la Terre de Québec
Mrs. Claudette Jobin Mrs. Hortense Michaud	Ligue des femmes du Québec
Mr. Alain Charest Mr. Michel Fugère Mrs. Marie-Claude Lacourse Mr. Patrick Rasmussen	Mouvement Vert Mauricie inc.
Mr. Louis Dionne Dr. Gilles W. Grenier Mr. Guy Lévesque Dr. Maurice Poulin	Régie régionale de la santé et des services sociaux Mauricie—Bois-Francs
Mr. Gordon Edwards	Canadian Coalition for Nuclear Responsibility
Mr. Robert Boisvert Mr. André Cossette	Syndicat des Employé-es de métiers d'Hydro-Québec

Federal Financial Assistance

The Federal Environmental Assessment Review Office (FEARO), through its funding program, allocated a total of $70,000 "to assist eligible groups or individuals in preparing briefs to the panel and in participating in the public hearings" (Ottawa, press release, July 22, 1994).

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Appendix 4

Documentation

Documents from the Information Period

Di1 MINISTER OF THE ENVIRONMENT AND WILDLIFE. *Letter instructing the Bureau d'audiences publiques sur l'environnement to initiate the public information and consultation period on Hydro-Québec's proposal for dry storage of irradiated nuclear fuel from the Gentilly 2 generating station,* April 7, 1994, 1 page.

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Di5 MINISTRY OF THE ENVIRONMENT AND WILDLIFE. *Notice on the acceptability of Hydro-Québec's impact study on dry storage of irradiated nuclear fuel from the Gentilly 2 generating station,* March 1994, 4 pages.

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A4 PASKIEVICI, W. and L. ZIKOVSKY. *Public Health Risks Associated with the CANDU Nuclear Fuel Cycle - Radiological Risks*, Atomic Energy Control Board, ref. INFO-0141-1, June 1983, multiple pagination.

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A47 HYDRO-QUÉBEC. *Analyse du scénario de la fermeture de la centrale Gentilly 2 à la fin de 1995, Analyse financière et tarifaire*, August 1994, non-paginated.

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A50 HYDRO-QUÉBEC. *Videocassettes of the session of August 30, 1994*, 1 of 2 and 2 of 2 (available on request).

A51 HYDRO-QUÉBEC. *Presentation by Mr. Louis Cloutier to the panel, August 30, 1994*, overheads.

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A54 HYDRO-QUÉBEC. *Answer to a question regarding the ratio of years of use of the oldest storage concept*, August 1994, 1 page.

A55 GAGNON, Jean-Yves. *Letter to Mr. Maurice Ladouceur of Hydro-Québec concerning the frequency of actual fires in the generating station*, Atomic Energy Control Board, ref. 26-1-10-4-1, May 9, 1994, 1 page.

A56 LADOUCEUR, Maurice. *Letter to Mr. Jean-Yves Gagnon of the Atomic Energy Control Board concerning the frequency of actual fire alarms in the generating station (Reference to subject No. 941006)*, May 26, 1994, 4 pages and appendices.

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Information on Panel Members

Dr. WLADIMIR PASKIEVICI,
Panel member

Dr. Paskievici graduated from the University of Strasbourg, France, with a licence in science in 1955 and a doctorate in nuclear physics in 1957. As a postdoctoral fellow in the University of Montreal's Faculty of Science, he lectured at the École Polytechnique de Montréal, where he was appointed assistant professor in 1957 and later associate professor, full professor and professor emeritus. In 1970, he founded the Institute of Nuclear Engineering, where he conducted research in nuclear physics, reactor physics, and the control and safety of nuclear reactors. From 1976 to 1982, he served on the Atomic Energy Control Board of Canada as a member of various advisory committees on reactor safety and security. In 1982, he became director of research at the École Polytechnique, a position he held until his retirement in 1990. As an additional member of the BAPE, Dr. Paskievici has served on the panels conducting public reviews into the proposals for the construction of a gas turbine generating station at Bécancour and a biogas development plant at the City of Montreal waste sorting and disposal centre. ■

Mr. ALAIN CLOUTIER,
Chairman of the Panel

Mr. Cloutier has been a full-time additional member of the Bureau d'audiences publiques sur l'environnement (BAPE) since January 5, 1994. After obtaining his BSc in biology and a master's degree in environmental studies from the University of Quebec at Trois-Rivières, he studied law at Laval University and was called to the Quebec Bar in 1992. Since 1979, his concern with the environment has led to his employment with a number of governmental and private agencies, including, in particular, the National Capital Commission, the Woods Hole Institute of Oceanography, Parks Canada, Hydro-Québec and various consulting firms. At the time of his appointment to the BAPE, Mr. Cloutier was chief of staff to the Minister of Recreation, Hunting and Fishing. Since that time, he has served on the panel conducting a public review into the proposed Montreal East cogeneration plant. ■

Dr. ANDRÉ ARSENAULT,
Panel member

After graduating in medicine from the University of Montreal, Dr. Arsenault obtained certification as a specialist in nuclear medicine from the Professional Corporation of Physicians of Quebec in 1972. He began his career as an assistant professor in the Department of Nuclear Medicine and Radiobiology of the Faculty of Medicine at the University of Sherbrooke. An active physician at the Montreal Heart Institute since 1984, he has been involved in various medical, scientific and professional organizations, including, in particular, the Association des médecins de langue française du Canada, the American Chemical Society, the American Academy of Arts and Sciences, and the Corporation des conseillers en relations industrielles. Editor-in-chief of l'Union médicale du Canada, consulting physician, guest lecturer, and associate researcher, Dr. Arsenault is currently head of nuclear medicine at the Montreal Heart Institute. From 1984 to 1993, he served on the Atomic Energy Control Board of Canada's Advisory Committee on Radiological Protection. ■