CANADA
Vision 2020 and Beyond

The Need for

Nuclear Research & Development

in the

21st Century

Revised January 2003

Vision 2020 and Beyond:

The Need for Nuclear Research and Development in Canada in the 21st Century

Revised 2003 January

by

The R&D Advisory Panel

to

The Board of Directors

of

Atomic Energy of Canada Limited

Publié aussi en français

Canada's investment in nuclear science and engineering research and development (R&D) for more than half a century has greatly improved the lives of Canadians through the production of environmentally friendly and cost-effective electricity as well as through important contributions in medicine, agriculture, manufacturing and resource exploitation. Continued investment in nuclear research and development is of vital importance if Canada is to maintain its scientific, technological, commercial and international standing while continuing to support long-term national goals.

CANADA'S NUCLEAR ACHIEVEMENTS

The excellence of Canadian nuclear science and technology throughout the last half century, under the leadership of Atomic Energy of Canada Limited (AECL), has been recognized internationally for many reasons, including:

- development of the CANDU® power reactor;
- production of radioisotopes for medical diagnoses and treatment;
- development of products that improve our quality of life;
- participation in the control of nuclear weapons proliferation; and
- the award of a Nobel Prize in physics.

Despite this international reputation, most Canadians are largely unaware of the extent to which the products of nuclear science and engineering support their daily lives. Many of these are shown in Figure 1. (See page 3).

Tens of thousands of Canadians derive their employment from the investment in nuclear science and engineering R&D, and its main product—environmentally friendly and cost-effective electricity—has helped drive Canada's economy for more than 30 years. Overseas sales of CANDU reactors also contribute substantially to both Canada's economy and to global environmental protection.

The contribution of nuclear R&D through the development and use of radioisotopes is important in many aspects of our lives. Canada is the world's leading producer and supplier of cobalt-60 used in cancer therapy irradiators, a device developed in Canada 50 years ago. Canada is also the leading producer and supplier of short-lived radioisotopes for nuclear medicine, which are used to perform over 12 million diagnostic tests and treatments a year worldwide. In biology, radioisotopes have made possible the revolution in our understanding of life at the molecular level, which has led to highly effective new treatments for diseases.

Cobalt-60 irradiators, produced in Canada, are also used in such diverse applications as the sterilization of medical devices and products, insect control in agriculture, and the destruction of potentially lethal microbial contaminants in food. Radioisotopes have many other applications, including well-logging in the oil industry; analysis of ore samples in the mining industry; radiography, process control and quality assurance in manufacturing; detection and measurement of industrial pollutants; and smoke detectors in the home.

In 1994, Bertram Brockhouse was awarded a Nobel Prize for work that commenced in the 1950s using the NRX (now shut down) and NRU research reactors at AECL's Chalk River Laboratories (CRL). This work led to the neutron scattering techniques that are widely used in many industries, including aerospace, automotive, oil and gas, biological, pharmaceutical and manufacturing, to assess the behavior and properties of materials. This technology is now an essential requirement for the development of advanced materials and is an example of the long-term payback that comes from investment in basic research.

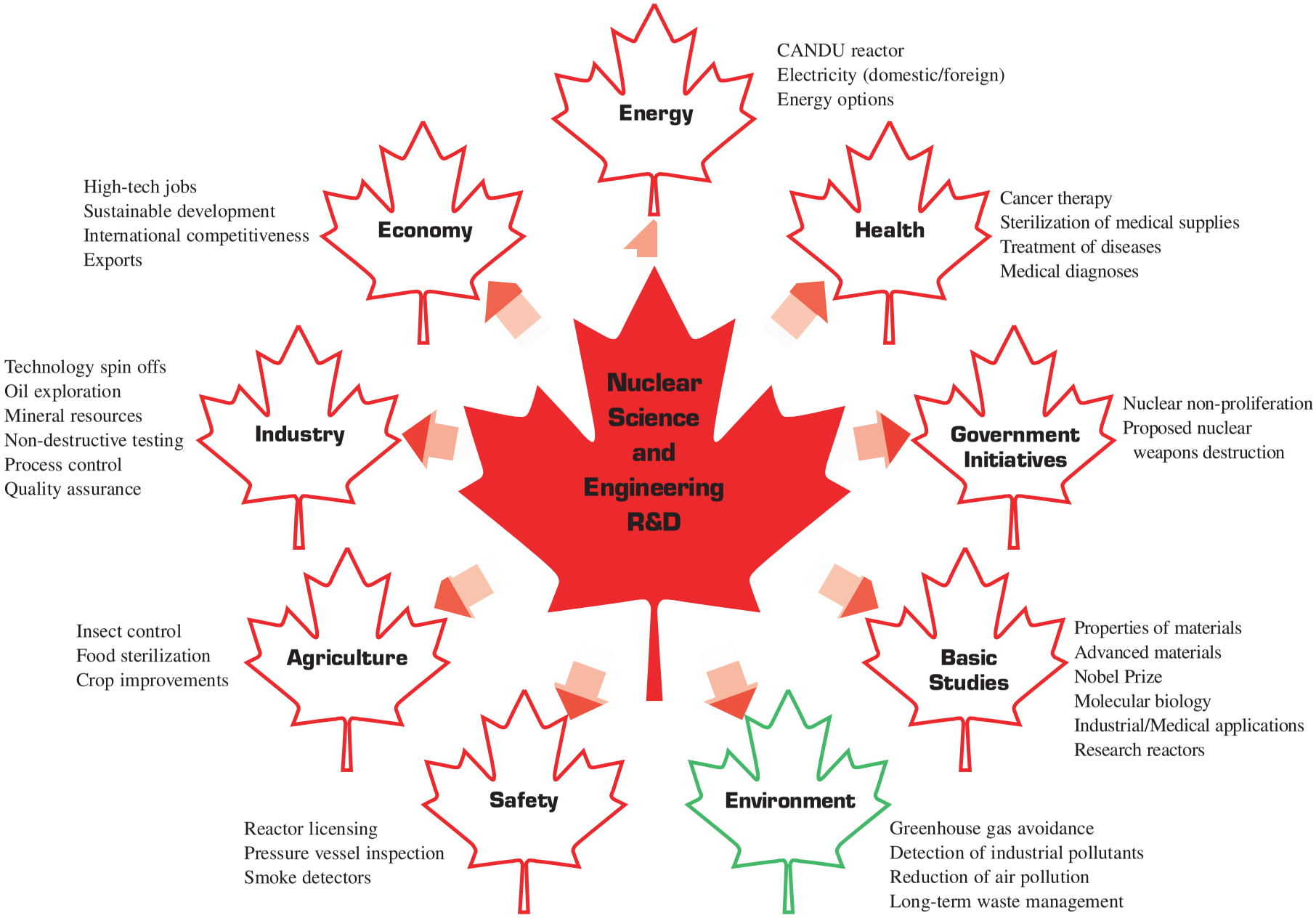

FIGURE 1 : CONTRIBUTIONS OF NUCLEAR SCIENCE AND ENGINEERING R&D TO CANADA

CONTINUING BENEFITS OF NUCLEAR R&D

Government support for R&D constitutes a long-term investment in future technology that private industry, dependent on short-term return on investment, is not able to make. There is ample evidence to show that the benefits still to be realized by government investment in nuclear science and engineering R&D in Canada will be even more significant than those already achieved. The consequences of not supporting this R&D would be to reduce our industrial competitiveness in both nuclear and non-nuclear sectors. On the other hand, supporting nuclear science and engineering R&D will result in economic, environmental, safety, energy policy, international initiative, and technological advantages for Canada in the future, and will allow the government to make choices not available to countries without nuclear R&D.

Economic Development

Maintenance of a high living standard and sustained wealth creation for Canadians require the assurance of an adequate, reliable, diverse and competitive energy supply. Nuclear electricity has contributed significantly to Canada's energy supply through the effective use of nuclear R&D funding. Canada's CANDU reactors have produced more electricity per R&D dollar spent than reactors of any other country with a significant nuclear power program. The cumulative contribution of nuclear electricity to GDP has been $71.8 billion to 2002, while Federal Government support to AECL research to that date has been about $6.0 billion. Nuclear generation currently produces 12% of Canada's electricity, and about 40% 0f Ontario's, rising to about 17% and 60%, respectively, when the laid-up reactors in Ontario are returned to service. By using nuclear fuel, Ontario has saved more than $36 billion in foreign exchange by avoiding costs of imported coal. Historically, the cost of electricity from Ontario's nuclear reactors has been less than that for coal-fired plants, and studies show that electricity generation from existing nuclear plants and from new plants will continue to be competitive.

Historically, the cost of electricity from Ontario's nuclear reactors has been less than that for coal-fired plants.

As existing CANDU plants age, they continue to need R&D support to ensure safe and economic operation and to cope with unexpected events. The speedy resolution, by AECL and the utilities, of problems that emerged at the Darlington and Point Lepreau Nuclear Generating Stations in the 1990s demonstrates the importance of this R&D support in protecting these major

capital investments. Maintaining and extending the lifetimes of nuclear power plants, such as by the refurbishment of the Pickering-A Station of Ontario Power Generation and of two of the four reactors at the Bruce-A Station of Bruce Power, also require continued R&D support. In the USA, extension of the lifetimes of current reactors to 60 years is a competitive reality; to date 10 reactors have had their operating licenses extended to 60 years. For CANDU reactors to achieve similar life-time targets, continuing R&D by AECL and the utilities will be necessary. If R&D funding is curtailed, Canada's investment in nuclear power could be prematurely written off, leading to major expenditures for replacement power, largely from fossil-fired plants, resulting in increased air pollution. Furthermore, international marketing of CANDU reactors would be seriously jeopardized, since CANDU customers need and expect after-sale R&D support from AECL.

High-tech jobs result from Canada's investment in nuclear science and engineering R&D. About 150 firms and a further 3,000 subcontractors across Canada benefit from each foreign CANDU sale. To ensure that CANDU reactors remain competitive, AECL is developing a new CANDU design, the Advanced CANDU Reactor® (ACR®), with significantly reduced capital and operating costs, improved efficiency and enhanced safety features. The ACR will be market-ready by 2006. In the international market, the ACR must compete against advanced reactor designs of other vendors, based on R&D done in the national laboratories of countries such as the USA, France, Germany and Japan. The ACR has already attracted considerable international attention. British Energy, the major operator of nuclear power plants in the UK, in proposing to replace its aging gas-cooled reactors with advanced, economical designs beginning about 2010, has identified the ACR as one of only two reactor designs that could be suitable for this purpose. AECL and British Energy began a joint study in November 2001, now completed, to assess the feasibility of introducing the ACR in the UK. In the USA, AECL and the architect-engineer firm Bechtel have agreed to work together on the deployment of the ACR. Also in the USA, three utilities that are pursuing an Early Siting Process with the US Nuclear Regulatory Commission have included the ACR as a potential reactor design for new power plant construction. In the global energy market in which nuclear power is re-emerging as a preferred choice, Canada's international competitiveness will suffer if CANDU does not continue to have strong R&D support.

Its nuclear power program and nuclear R&D expertise also give Canada political, diplomatic and technological options not available to countries without such expertise.

In addition to the generation of electricity, CANDU reactors, in particular the ACR, can be used for other purposes. A recent study by AECL and a leading oil company have shown that ACR shows economic promise for the recovery of oil from the Athabasca tar sands, providing steam, electricity and electrolytic hydrogen for the proven Steam-Assisted Gravity Drainage recovery technology. Such an application would help to realize the immense energy potential of the oil sands for Canada and the world. It would also reduce the substantial need for natural gas for this purpose, thus reducing air pollution and greenhouse gas (GHG) emissions.

Environmental Protection

Because of perceived adverse global climate changes resulting from the increasing quantities of CO_2 and other greenhouse gases in the atmosphere, an international agreement was drafted at the Kyoto Climate Change Conference in 1997 which set targets for GHG emissions in industrialized countries. Under the Kyoto Protocol, Canada has a target of 6% reduction in GHG emissions below 1990 levels by the year 2010. The importance of nuclear electricity generation in reducing greenhouse gas emissions and air pollution is clearly demonstrated by events in Ontario in the 1990s. Significant reduction in nuclear generation over the period 1994 to 1998 occurred because of maintenance difficulties at the Pickering-A and Bruce-A nuclear generating stations which culminated in their eventual lay-up. The displaced nuclear generation was replaced mainly by coal-fired generation which resulted in increased emissions of CO_2, the main GHG, and air pollutants, mainly sulfur and nitrogen oxides, from the coal-fired units. The return to service of six of the laid-up reactors, in progress now, must be completed and the reactors returned to service as soon as possible to help Canada meet its Kyoto target and to reduce atmospheric pollution.

In addition, to avoid further emissions of air pollutants and GHG, Canada must also build new reactors to replace obsolete coal-fired power plants and to meet increases in electricity demand. While new renewable energy sources may be able to contribute about 5% or 6% of Canada's electrical energy supply by 2040, only nuclear energy can make the necessary contribution to large-scale base-load electricity production while ensuring reduction of air pollutants and GHG emissions.

Environmental pollution is a world-wide problem. Large populous developing countries, such as China, which are heavily dependent on coal, will continue to be among the world's major atmospheric polluters. It is in Canada's and the world's economic and environmental interest to encourage these countries to include nuclear power in their energy mix, as a contribution to sustainable development. With the start-up, ahead of schedule and on budget, of the first of two 700-MWe CANDU reactors in China, Canada, through AECL, has taken an important step towards this end.

Present practices for nuclear fuel waste management and storage in Canada are safe and economical and these practices could be safely continued indefinitely. The concept for long-term deep geological disposal of nuclear fuel waste, developed by AECL, has been judged to be safe by an independent panel. Recently, Parliament has passed legislation establishing a Nuclear Waste Management Organization, financed by the utilities and AECL, to be responsible for developing and implementing a nuclear fuel waste disposal strategy for Canada. Thus, concerns about the safety of nuclear fuel waste management and disposal should not impose constraints on the future growth of nuclear power in Canada.

It is important to recognize that continuing R&D by AECL on nuclear waste management and disposal would be necessary, even if all other nuclear activities in Canada were halted now, so that Canadians would continue to be adequately protected from radiation exposures from wastes already generated.

Safety and Regulation

Nuclear R&D capability is a requirement for the licensing and safe operation of nuclear power plants. The Canadian Nuclear Safety Commission (CNSC), formerly known as the Atomic Energy Control Board, the independent federal regulator, requires that licensees have the capacity to perform the R&D essential to safe operation of nuclear power plants in Canada. The facilities of AECL serve as a shared resource for the utilities through which questions from the regulator can be addressed. The CNSC also contracts some research at these facilities. The CANDU Owners' Group (COG) has responded to earlier CNSC questions about the adequacy of safety-related R&D funding by recommending actions to be taken on an industry-wide basis to ensure the R&D capability of the

nuclear industry in Canada . These recommendations emphasize the need to provide continuing government support for long-term safety-related research by AECL.

Energy Policy

Energy is one of the most important resources for modern society. Events such as the 1973 oil embargo and potential threats to critical infrastructure in the wake of the terrorist attacks on the USA in September 2001 illustrate the importance of a national policy that will safeguard Canada's energy supply while supporting global objectives. Canada's decision to develop nuclear energy has benefited the nation by providing up to 17% of our electrical energy from an essentially non-polluting source. This contribution. added to that of the 60% from hydro sources, provides Canada with economic and reliable electricity with much lower emissions of greenhouse gases and air pollutants per unit of electricity generated than almost any other industrialized country. Its nuclear power program and nuclear R&D expertise also give Canada political, diplomatic and technological options not available to countries without such expertise.

International Initiatives

Canada is a member of the G-8, a position from which it can contribute broadly to the development and well-being of the world community and assist in meeting international objectives. Canada's contribution to international safeguards and foreign policy initiatives, such as the proposal to destroy weapons-grade plutonium in CANDU reactors, are only possible because Canada has a successful nuclear power program.

The World Bank projects that the world population will increase to about 9 billion by 2050. Nuclear energy can make significant contributions to newly developing societies in the future. CANDU reactors can not only produce electricity, but can also be used for desalination to provide fresh water from sea water on a scale sufficient for the agricultural, industrial and personal needs of large populations in developing nations.

Advanced Technology

Many countries with successful nuclear programs have National Laboratories, where governments support the laboratory infrastructure and provide direct funding for activities that are in the national interest. Since some of

AECL's R&D resources and programs are of interest to government Ministries, the CNSC, non-nuclear industries, research organizations and universities, they should be treated as a national asset and funded separately from the commercial activities of AECL. This was the case for AECL's Materials Science Program, which has been reorganized under the National Research Council.

AECL is undertaking modifications to the 45-year old NRU reactor at Chalk River Laboratories to ensure its availability for the essential R&D needed for the design of the Advanced CANDU Reactor. Eventually, NRU must be replaced by a new research reactor, the Canadian Neutron Facility (CNF), which is intended to meet the needs of fundamental research on industrial and biological materials as well as to support R&D on existing CANDU reactors, the ACR and other future CANDU design concepts. Because of its dual-purpose function, AECL will be participating with the National Research Council in approaching the Federal Government for funding for the design and construction of the CNF. In the long term, the CNF will be essential to both CANDU R&D and materials science research in Canada.

CANDU and the Hydrogen Economy

Ensuring that Canada has adequate energy in the 21st Century will require new thinking about traditional means of meeting the various demands for energy. In this respect, an exciting opportunity exists for the future conversion of Canada's transportation system from a fossil-fuel base to an electrolytic-hydrogen base. With the help of federal funding, and other public and private-sector investment, Canada is now well positioned to play a major role, both technical and economic, in a world revolution in transportation technology. CANDU nuclear reactors could produce the electricity for Canadian-developed high-efficiency electrolysis cells, to provide hydrogen for Canada's world-leading fuel cell technology to power cars, buses and trucks. For this initiative to proceed on a large scale, it will be necessary to build additional CANDU reactors and to develop the necessary infrastructure. This revolution would significantly reduce air pollution and CO_2 emissions in the transportation sector. Such an initiative would also provide the potential for a substantial export industry.

SUMMARY AND CONCLUSIONS

• To ensure that Canadians continue to enjoy the many benefits of nuclear technology, government investment in nuclear science and engineering R&D must be maintained. There is ample evidence to show that the benefits still to be realized will be more significant than those already achieved.

• The generation of nuclear electricity will continue to be economically viable, and it will play an essential role in driving the nation's economy while protecting the environment by avoiding the emission of air pollutants and greenhouse gases. Continuing research is needed to support and extend the productive lifetimes of existing CANDU reactors in Canada and abroad, and to develop the Advanced CANDU Reactor as well as long-term future design concepts.

• Canada's nuclear expertise supports the nation's strategic and international initiatives, including safeguarding nuclear material and the possibility of destroying weapons plutonium in Canadian reactors. It could also support other initiatives by providing electricity and fresh water to developing regions of the world.

• To ensure that the benefits of nuclear technology continue, Canada must maintain the research base as a national asset. In the long term, the NRU reactor will be replaced by the Canadian Neutron Facility, a dual-purpose facility that will support both CANDU-related research and the study of advanced industrial and biological materials.

• The use of nuclear power to generate hydrogen fuel would revolutionize transportation and would dramatically curtail the emission of air pollutants and greenhouse gases. The use of nuclear energy to recover oil economically from the Athabasca oil sands will reduce the need for natural gas for this purpose and thus reduce air pollution and CHG emissions.

The R&D Advisory Panel to the Board of Directors of Atomic Energy of Canada Limited (AECL)

Dr. David A. Armstrong
Faculty Professor
Department of Chemistry
University of Calgary

Dr. Robin L. Armstrong
Professor Emeritus
Department of Physics
University of Toronto

Dr. David J. Burns
Vice President Academic
Conestoga College

Dr. Albert A. Driedger
Professor, Faculty of Medicine
University of Western Ontario

Mr. Jon H.F. Jennekens
Jonor & Associates

Dr. John J. Jonas
Birks Professor of Metallurgy
McGill University

Dr. Derek H. Lister
Chair, Nuclear Engineering
University of New Brunswick

Dr. Ernest A. McCulloch
Senior Scientist Emeritus
The Ontario Cancer Institute
Princess Margaret Hospital

Dr. J. Terry Rogers
Professor Emeritus
Mechanical and Aerospace
Engineering
Carleton University

Dr. Daniel Rozon, Directeur
Département de génie physique
École Polytechnique de Montréal

Printed in Canada. February 2003. D1322