University Network of Excellence in Nuclear Engineering (UNENE); Its Role in Canada's Nuclear Research, Innovation and Education

Submission to Canada's Federal R&D Review Panel
February 2011

Table of Contents

1.0 Purpose of Submission

The intent of this submission is to apprise the Panel of the University Network of Excellence in Nuclear Engineering (known as UNENE) of its well established and successful model for industry – academia partnership and to discuss the possibility of increased federal funding, through NSERC, to a higher than current level. UNENE/NSERC is a $2.8M/yr research program equally shared between both organizations. Should such increase is deemed possible by the Panel a call to industry through UNENE Board of Directors will be made seeking matching industrial funding. This will increase the R&D base within universities; increase the level of knowledge and innovation that can be also leveraged to other industries such as medical, aerospace, material sciences and others.

2.0 Introduction/Background

Canada's nuclear industry is currently a $6B/yr industry with nearly 70,000 jobs in science engineering, manufacturing, construction and delivery of related products and services. It started in 1945 with experimental and research reactors to what is now the established CANDU – PHWR (Pressurized Heavy Water Reactor) technology – with a current market share of 8-10% of the world-wide commercial Nuclear Power Plants (NPP) (Figure 1).

Nuclear power in Canada now provides 15% of the national electricity supply, with Nuclear Power Plants (NPP) in New Brunswick, Quebec and Ontario. More than half of the electricity supply in Ontario is from nuclear. Most of the plants are Generation II vintage, coming on stream from the mid-1970s (Pickering A Units 1 to 4) to the mid-1990s (Darlington Units 1 to 4). Some of the CANDUs have been life-extended beyond their original 30-year design life while others are being (or are planned to be) refurbished for a 50 to 60-year life. Such examples are Pickering A, Bruce A Units 1&2 in Ontario and Point Lepreau in New Brunswick and Darlington 1-4 starting 2016. Future nuclear construction of Generation III and Generation III+ plants is expected to replace retired nuclear capacity and to meet clean energy targets (Figure1)

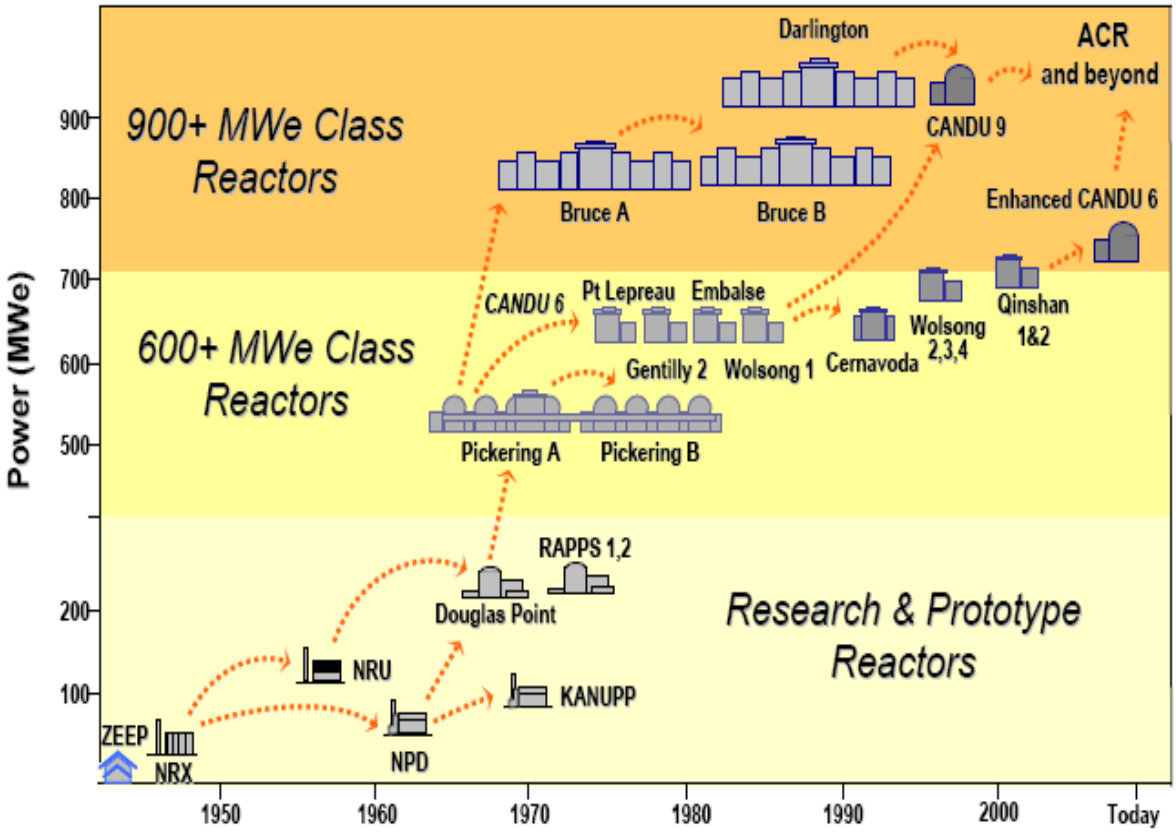

Figure 1: CANDU Genealogy

As with any industry, an NPP is a complex project with long lead times and multifaceted in nature, making knowledge and continual innovation one of its key enablers and a vital component to its safe and economic performance over its entire lifecycle: design, licensing, construction, operation, decommissioning and long term waste management. This is even more crucial in view of life extension or life doubling where nuclear competencies, continuity in knowledge and innovation need to be maintained for two to three generations (Figure 2).

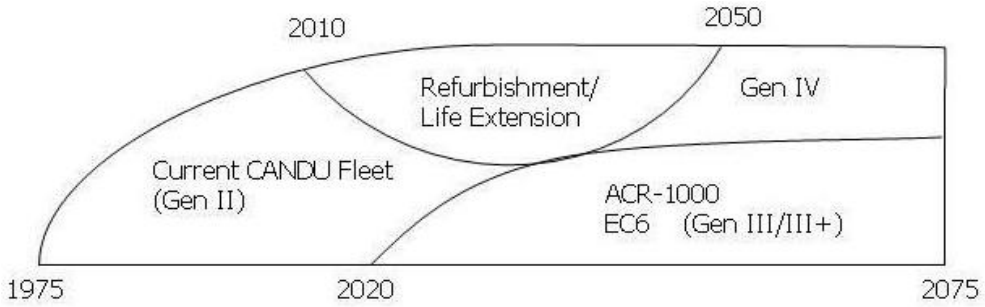

Figure 2: Nuclear R&D and Industry Challenges

The industry recognises the role of knowledge preservation and continuous competence-building in order to meet the following strategic priorities:

1. Maintain the safe and economic Long Term Operation of its current nuclear plant fleet.
2. Maintain knowledge of the design and licensing basis of current plants.
3. Advance knowledge and innovation towards successful design, licensing and delivery of future Gen III+ plants (such as the Enhanced CANDU 6 and the ACR-1000) to Canada and off shore.

3.0 UNENE: A Partnership

With these priorities UNENE (University Network of Excellence in Nuclear Engineering) was established in 2002 as a not for profit partnership between the nuclear industry and universities with the objectives of:

1. Establishing university research in key areas of interest to the nuclear industry.
2. Developing a sustainable supply of Highly Qualified Personnel (HQP) to address demographic gaps in the industry.
3. Providing an independent university–based source of scientific expertise for public and industry consultation. UNENE members are listed in Figure 3

UNENE Members

- Atomic Energy of Canada Limited (AECL)
- Bruce Power (BP)
- Ontario Power Generation (OPG)
- Canadian Nuclear Safety Commission (CNSC)
- CANDU Owners Group (COG)
- Nuclear Safety Solution (AMEC-NSS)
- CAMECO
- McMaster University
- Queen's University
- University of Ontario Institute of Technology
- University of Saskatchewan
- University of Toronto
- University of Waterloo
- University of Western Ontario
- University of Windsor
- École Polytechnique
- University of New Brunswick
- Royal Military College
- University of Guelph

Figure 3: UNENE Members (Government /Industry and Academia)

Eight years into its creation, UNENE is now a well established and fully functional framework with programs mainly focussing on education and research serving the industry at large. The educational component is in the form of a M.Eng. program mainly catering for working professionals with courses offered on weekends and using distance learning tools. It is intended for competence building and knowledge transfer to relatively young industry professionals. The R&D programs are led by Industrial Research Chairs (IRCs) and other prominent researchers in areas of importance to industry.

4.0 Achievements to Date

A review and assessment of progress in the last two fiscal years 2007 to Sept 2009 have identified many benefits documented in Annex 1 of this submission. Some of the notable ones are:

1. UNENE through its IRCs and research programs has succeeded in leveraging some additional funding of ~$43M from provincial and federal research and innovation agencies.

2. These have enabled the establishment of new facilities with state-of-the-art equipment and thus increasing the scope of research and size of research teams.

3. Ongoing research programs continue to yield innovations and advance knowledge in all areas of the technology. Some of the developed technologies have been successfully deployed by utilities in support of their safe and economic NPP operation:

    - A successful example is the application of risk-based methodologies to Life Cycle Management (LCM) issues. These, when applied to feeder replacement have reduced the number of feeders requiring replacement by nearly 70 feeders, reducing the cost of such replacement by many millions of dollars. [Note: Typically there are 760 nuclear grade coolant pipes in a NPP (known as feeders)]

    - Development of advanced safety analysis methodologies in the area of Best Estimate methodology and advanced thermal hydraulics in support of phenomena characterization, modeling and code validation. This in the future, if adopted as a methodology, will reduce some excessive conservatism applied in analysis methodologies.

    - Research in modelling of phenomena and processes related to severe accident progression in CANDU plants and to identify and quantify accident mitigation measures. This research is contributing to industry efforts in severe accident analysis that are being called for under m

    - Research on effects of current manufacturing processes on Pressure Tube (PT) properties, textures and creep characteristics, on current and future PT alloys. If research outcomes succeed in this area this will be an international success for Canada in the field of nuclear materials.

    - Advanced Fuel research and increased knowledge of its thermo mechanical and chemical properties under normal and postulated accident conditions with outcomes reflected in various code developments, assistance to utilities on fuel performance analyses and on-line fuel defect monitoring. All such results are readily transferred to industry via technical reports. Other research activities are ongoing on advanced fuels and the ability for actinide burning in multispectral CANDU cores etc. The outcomes of fuel cycle studies continue to be of interest to current and future CANDU countries (such as China, India and others).

    - The IRC established in UWO has built an advanced Control and Instrumentation lab in 2009, with six projection monitors mimicking NPP human-machine interface with full connectivity to NPP control systems. The lab is used for application development /validation of numerous advanced diagnostic tools and control technologies aimed at reducing the number of safety system channels and common mode failures.

4. Development of Highly Qualified Personnel (HQP) through research and education continues to yield high calibre graduate students who, upon successful completion of their theses, have been recruited by industry, universities and government.

   As of Sept 2009, the current complement of graduate students in the UNENE research program is reported to be over 130 graduate students.

   A large number of Masters and PhD graduates to date have been successfully recruited by industry, universities and federal government departments (e.g. DND etc.) while some proceeded further into a PhD program.

5. Over ninety (90) industry – university consultation/interactions and technical exchanges have been reported in the last two years by all UNENE universities. Most of these were on joint industry technical committees, panels and review teams, as well as with various federal and provincial departments and panels. Some of the notable ones are noted in Annex 1 of this submission.

6. The UNENE education program has also experienced an increased enrolment in the last two years. There are currently over 50 active students in the M.Eng. program. The program is also gaining credibility as a means of competency building (for career advancement), and knowledge transfer and preservation to young industry professionals. To date over forty (40) students have graduated from the M.Eng. program out of 110 enrolled. New courses are being added to the program, along with an increased number of courses offered on a quarterly basis.

Other Outcomes

National & international collaborations are forged within the university itself across many engineering disciplines and scientific departments and among different universities, and with industry on specific research programs.

International collaborations are established with many US universities and the US Department of Energy (DOE) National Labs, and some European Union (EU) universities in areas such as thermal hydraulics (between McMaster/University of Pisa and Trinity College) and development of integrated fuel performance codes between Royal Military College and Oak Ridge National Laboratory.

Equipment and Facilities

A High Performance Computing Center (HPCC) set up at McMaster enabling Safety Analysis code coupling and code development. The HPCC is accessible by users university wide.

A Nuclear Materials Testing (NMT) Lab with state of the art equipment that is currently under construction at Queen's University with commissioning expected in 2012.

A new thermal hydraulic test facility: Water Quench Facility (WQF) to investigate heat transfer characteristics between the subcooled moderator and high temperature fuel channel surfaces during postulated accidents.

5.0 Summary

UNENE is a not for profit partnership industry – university partnership funded by industry at the level of $1.5 M /year that is equally matched by NSERC for a total annual budget of $ 2.8 M. This partnership was established in 2002 with the objectives of establishing a university based R&D program in technology areas of importance to industry, providing a sustainable supply of HQP to industry and creating a respected pool of scientific experts for independent industry and public consultation. Review of outcomes of the partnership in the period between 2007-2009 concluded that the objectives set for this partnership have been addressed while leveraging an additional $43M that enabled expansion of the R&D base, construction of new research facilities providing industry with a sustainable supply of highly qualified personnel and extensive technical consultations and exchanges with government and industry. Advances in knowledge in all areas of the technology have been noted in this submission and its annexes. The derived knowledge when applied to industry issues helped addressing regulatory queries and optimization of refurbishment timing and replacement of key nuclear power plant components.

Some of the elements that have led to such outcomes are:

Equal funding share between Industry and Government (an annual budget of $2.8 M between Industry and NSERC).

Placing Industrial Research Chairs in member universities as “anchors” for building a strong research team, most IRCs came from industry and are well respected scientist within the industry and internationally .Their intimate knowledge of industry needs was instrumental in defining the framework of the required research.

A close integration of the University research with other industry programs was fostered through different forums; a Research Advisory Committee, Technical Advisory Committees and regular workshops and meetings. All intended to confirm direction of programs and assure of it meeting industry objectives.