

The CANDU System: A Canadian Achievement

Adam McLean

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Outline of Presentation

- **What does CANDU mean?**
- **What sets the CANDU apart?**
- **What effect has CANDU had on Canada?**
 - The technological achievements
 - The economic impact
 - The environmental impact
- **How does the CANDU compare?**
 - At home and around the world
- **The future of CANDU**
- **Closing**

What Does CANDU Mean?

- **CANadian**

- designed, engineered and built in Canada by Canadian engineers and scientists
- history of success with nuclear for peaceful purposes
 - » ZEEP reactor - first nuclear pile to operate outside the US, September 5, 1945
 - » NRX - first large scale (40MWt) research reactor in the world, operated for 44 years in Chalk River
 - » NRU - source of 85% of world's supply of medical isotopes, sole testbed for CANDU fuel, operating since 1957
 - » NPD - prototype Canadian power reactor operated from 1962 - 1987
 - » Douglas Point - evolutionary CANDU design 10x the power of NPD
 - » Led to construction of first 4 Pickering Units 1971 - 1973

What Does CANDU Mean (cont)?

- **Deuterium**
 - isotope of Hydrogen containing one proton and one neutron
 - replaces the H atom in H₂O to make D₂O or Heavy Water
 - 10% heavier than ordinary water
 - occurs in natural water 1 part in 7000
 - has a moderating ratio 80 times higher than ordinary water
 - separated by a gas-bubbled hydrogen sulfide exchange tower or by electrolytic hydrogen catalyst
 - 1000 tonnes on loan to the Sudbury Neutrino Observatory
- **Uranium**
 - CANDU uses natural uranium - 0.7% fissionable (useful) fuel
 - no enrichment required to higher levels
 - Canada has over 353,000 tonnes of reserves and 1/4 of world production (85% exported)

What Sets the CANDU Apart?

- **Natural Uranium fuel and Heavy Water moderator**
 - only reactor system in which no fuel enrichment required
 - highest neutron economy of all commercial reactor systems
- **Online, full power refueling**
 - only reactor system with this capability
 - extremely high capability factors possible
- **Fuel cycle flexibility**
 - CANDU's can run with natU, SEU, Spent PWR fuel (DUPIC, Oreox process), recovered Uranium from LWR fuel, MOX, actinide matrix fuel, Th/U233 near breeder cycle
 - unparalleled in other reactor systems
- **Safest reactor design in the world**
 - 2 shutdown systems + ECC + large heat sink+ full containment + vacuum building = Defence In Depth

What Effect Has CANDU Had on Canada?

- **since 1952, Canada has invested \$5B in nuclear power R&D**
- **in the same time, the nuclear industry has contributed at least \$40B to the Canadian GNP and saved ~\$20B in foreign exchange by using uranium instead of coal**
- **\$4B in energy production per year**
- **\$1B in uranium sales exports per year**
- **currently employs 26,000 people directly and a further 10,000 indirectly**
- **over 150 companies involved in Canadian nuclear**
- **1 reactor sale abroad ~ \$1,485,000,000 CAN**

What Effect Has CANDU Had on Canada?

- **Technological Effect**

- Brain Gain! throughout 48 year history of nuclear industry
- major advancements and contributions in mining, nuclear engineering, evolutionary nuclear design, nuclear safety, computer simulation, robotics risk assessment, nuclear waste storage, radiation therapy, turn-key project management, etc.

- **Environmental Effect**

- OPG's reactors alone avoids 55 million tonnes of CO₂ emission per year (>10% of Canada's 500 million tonne total) or the same as 24 million automobiles
- without nuclear, Ontario's greenhouse gas emission from power production would double
- energy from one CANDU fuel bundle would require 400 tonnes of coal or 270,000 litres of oil or 300 million litres of natural gas

How Does the CANDU Perform?

- In 1980s, as many as 8 of the top 10 reactors were CANDU (including all PWRs, BWR's, GCR's, RBMK's)
- In 1999, only 3 of the top 20 were CANDU's
- Lifetime performance rates CANDU 6's 11% higher in rated capacity factor than next highest PWR's (at 82%)
- World-wide there are CANDU's in:
 - Argentina (1 named Embalse - the first CANDU to use SEU)
 - Canada (14 in use, 8 layed up)
 - China (2 under construction at Qinshan)
 - India (2 CANDU's named RAPS operating, 9 'clone' reactors also)
 - Pakistan (1 reactor named Kanupp)
 - Romania (1 reactor operating, 4 under construction at Cernavoda)
 - South Korea (4 reactors operating at Wolsong)

The Future of CANDU

- Pickering A, B ~ 2010
- Bruce A (2 units), B - 2018
- Darlington - 2020 - 2025+
- 2 new MAPLE type isotope production reactors are now running in Chalk River (MMIR 1-2)
- The CNF (Canadian Neutron Facility) is currently proposed to replace the research functions of NRU
- CANDU 9 sales to Korea very likely
- Additional sales to Vietnam, China, Turkey?
- CANDU X program very strong at AECL
- Deep geological disposal awaiting approval

In Closing

- **We should be very proud of the CANDU system**
- **Developed domestically by a small group of dedicated Canadian researchers and visionaries**
- **Most flexible, most advanced, safest power reactor available worldwide**

- **Thank you for your time!**