A Human Turning Point – Nuclear Energy

AECL Atomic Energy of Canada Limited
EACL Énergie atomique du Canada limitée

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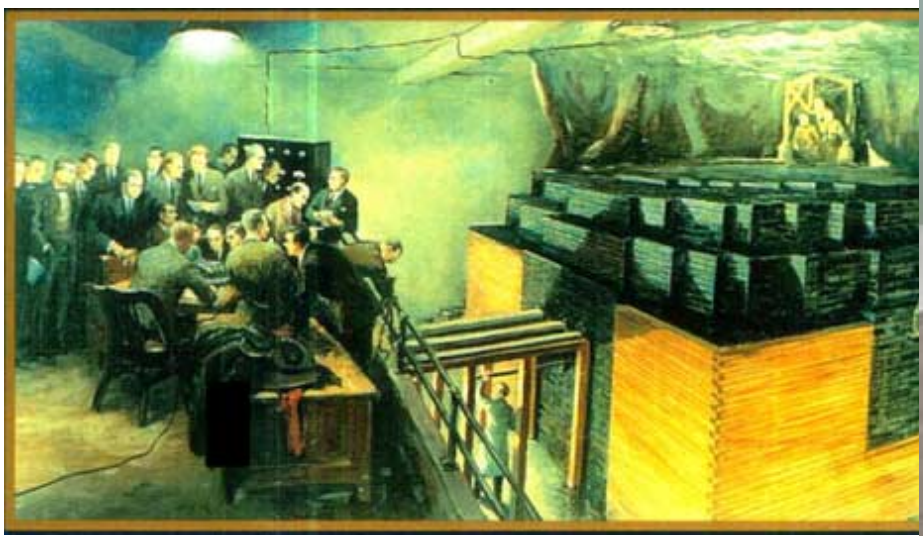
Canada

Man-Made Reactors
First in World and First in Canada

CP1 – University of Chicago

December 2, 1942

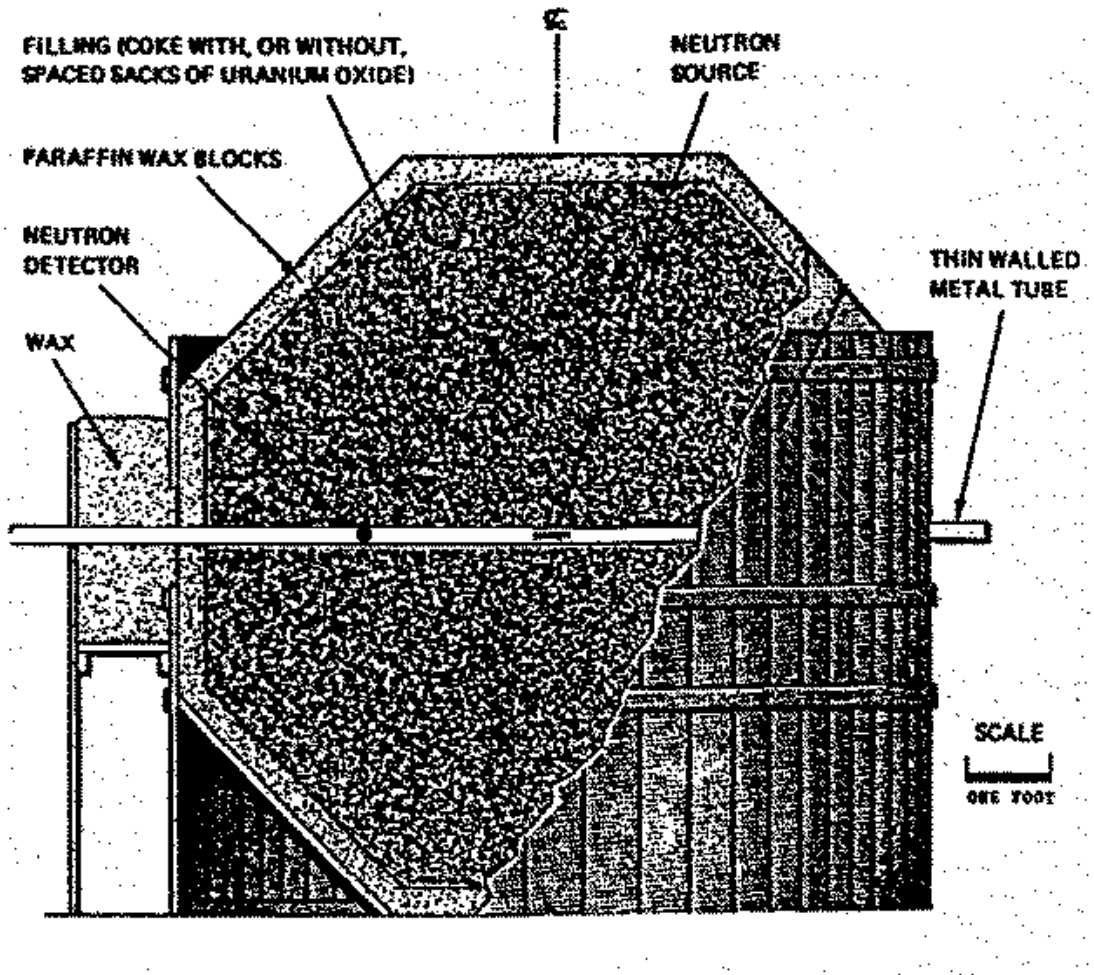


ZEEP – Chalk River Laboratory

September 5, 1945

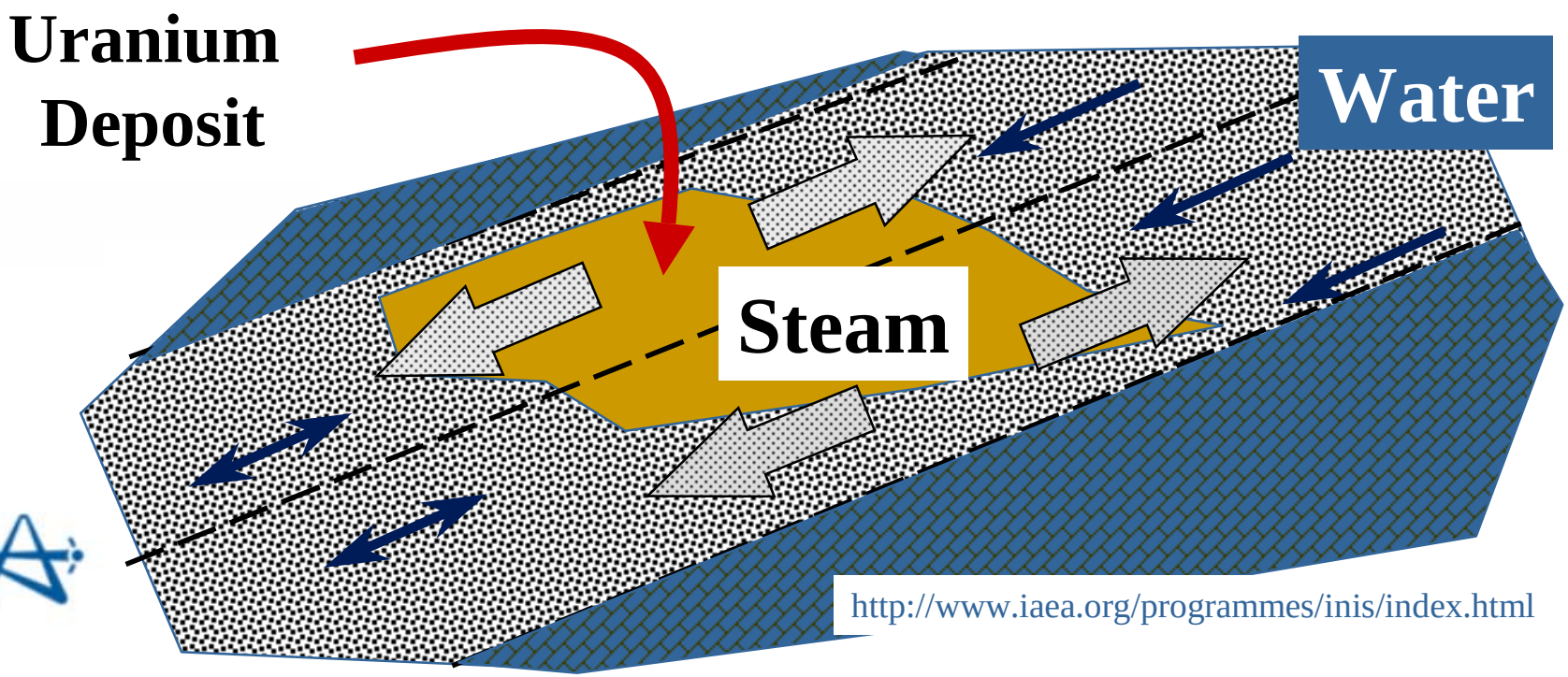
First Try – NRC Ottawa, 1941-42

Dr. G.C. Laurence was the first to assemble a reactor using uranium and carbon



Nature's Reactors

- Remains of at least six natural reactors were found in Oklo, Gabon, West Africa on June 2, 1972
- As oxygen built up in earth's atmosphere, uranium from a river in East Africa was dissolved and carried to the river delta
- Uranium precipitated at high concentration in the river silt and sand
- Some time later, the uranium-sand-silt mixture was soaked with water. Natural reactors were created. They worked for thousands of years.



http://www.iaea.org/programmes/inis/index.html

Uranium Through History

Heavy elements probably were produced in supernova explosions

Decay constants: U235 = 9.8×10^{-10} per year, U238 = 1.5×10^{-10} per year

TIME	-4 b.yr.	-2 b.yr.	0 (now)	+2 b.yr.
n_5	35.3	5.0	0.72	0.10
n_8	183.8	135.1	99.28	73.0
$n_5/(n_5+n_8)$ (uranium enrichment)	0.162	0.036	0.0072	0.0014
	Fast Reactor Possible	Thermal Reactor (LWR)	Thermal (Graphite or D2O)	Enrichment of Fuel Required

Bombs and Reactors

- The idea of fission energy production emerged just before World War II.
- US made their decision to develop nuclear weapons in ~1941.
- US, Soviet Union, UK, France, China developed weapon arsenals.
- Intense hostility (Cold War) maintained military emphasis until ~ 1990.

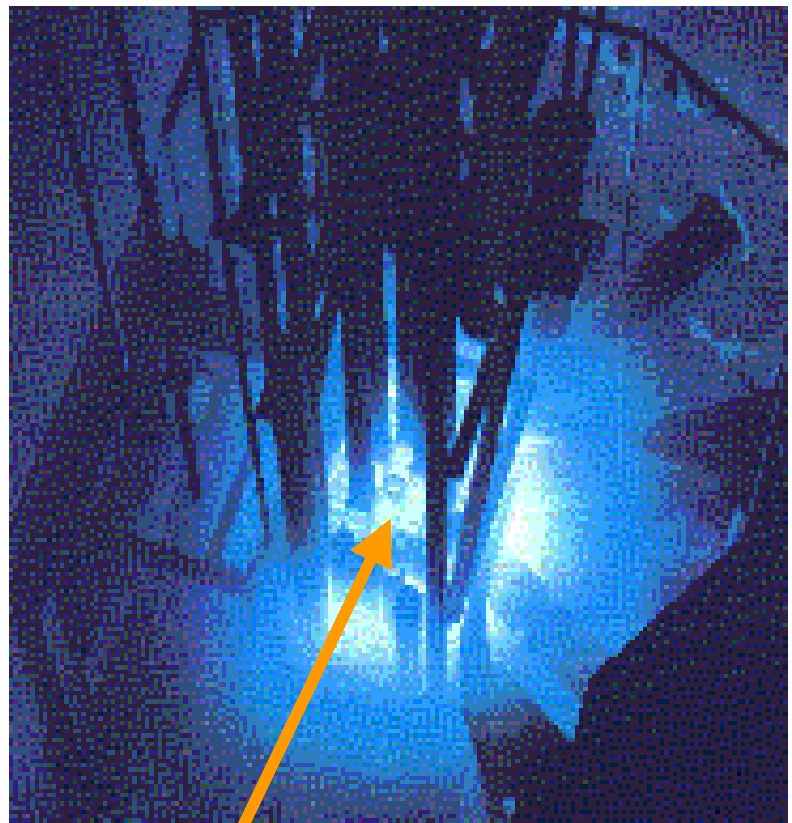
- The “Atoms for Peace” idea offered peaceful nuclear technology in return for a promise not to make weapons.
- The future is, as always, uncertain. Many nuclear weapons now are obsolete – replaced by even more effective, non-nuclear offensive weapons.

- In early 1944, Canada was assigned task of building a high-power heavy water reactor (NRX) for production of Pu239 and U233 for weapons.

- Canada retired the Bomarc and Genie nuclear-tipped missile systems in ~1972

A Quick Peek

The McMaster Nuclear Reactor



Reactor Core

A Modern Nuclear Power Plant

- Darlington NGS, East of Oshawa. Four units, total power output of 3524 megawatts

Reactor Types: Prototypes and Successes

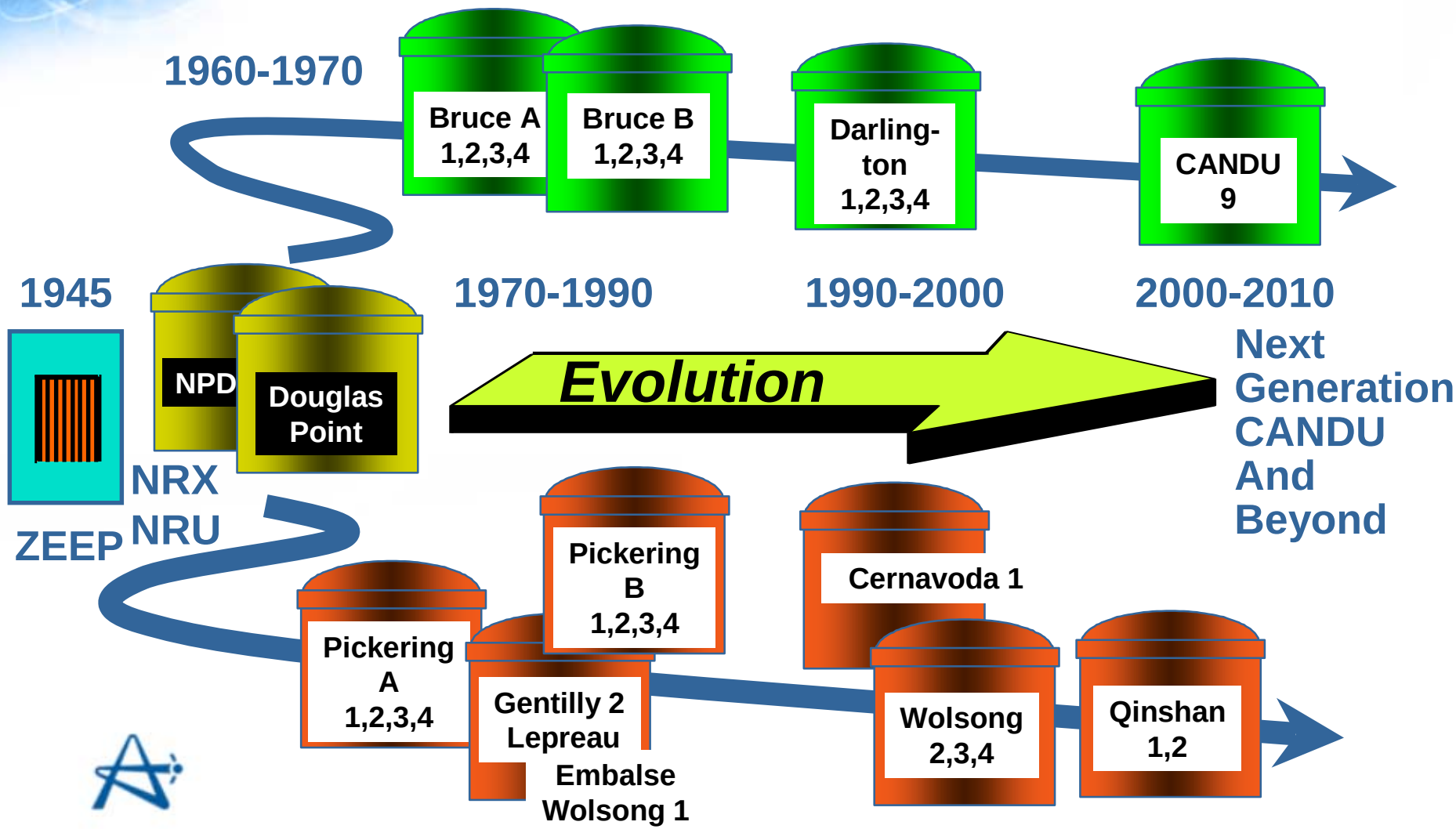
THERMAL											FAST	CLASS
GRAPHITE					WATER		HEAVY WATER				NONE	MODERATOR
Molten Salt	Na	CO_2	H_2O	He	H_2O	H_2O	H_2O	D_2O	Organic	CO_2	Na/NaK	COOLANT
		MAG-NOX					BLW	CANDU	OCR			Natural U
	Hallam	AGR	RBMK	HTGR PBMR	PWR	BWR	SGHW	Atucha CVTR		KKN, EL4		Enriched U
MSBR				THTR	LWBR							Thorium - U
							ATR				FBR	Plutonium-U

FUEL

Success is Not Permanent

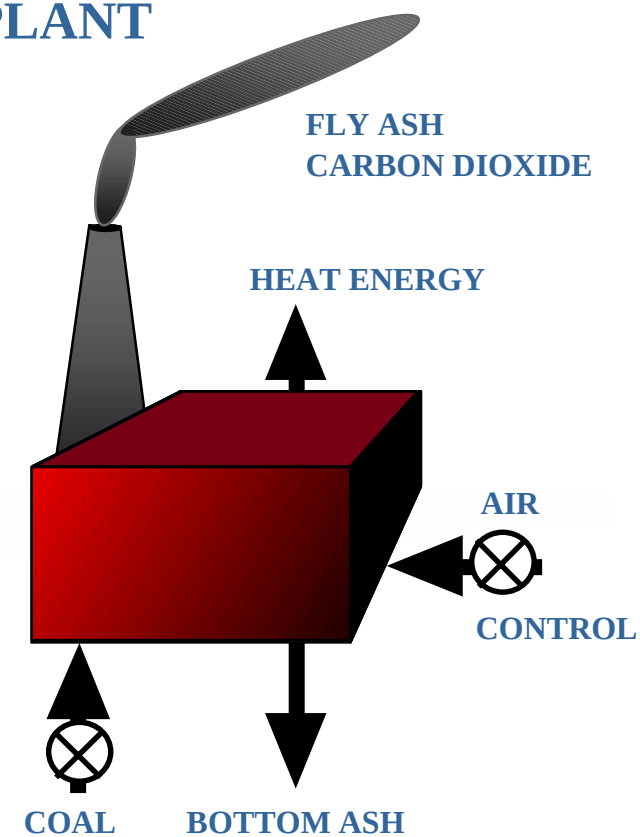
- Three Mile Island Unit 2 (a modern US pressurized water reactor)
  - Errors committed by operators, designers, and regulators
  - Zero environmental or health effects, but large losses (>5 b$)
  - “Unjustified self-confidence” can be seen as the root cause
- Darlington station (designed, built by experienced companies)
  - Delays during construction – OH senior management and government
  - Errors in generator design – Swiss design organization
  - Error in heat transport system design - designers
- Chernobyl (USSR built several plants, and some of them operated well for years)
  - Errors were committed by government, designers, regulators, managers, operators
  - About 40 people were killed (operators, firemen, rescue workers)
  - Huge cost (>10 b$)
- Ontario Hydro Operational Breakdown
  - Errors committed by management, directors, government, unions
  - Staff reduced drastically by management, without proper care
  - Maintenance neglected, units understaffed, so 7 units were forced to shut down
  - Pickering A (then Bruce) units will be extensively refurbished

Genealogy of CANDU Power Plants

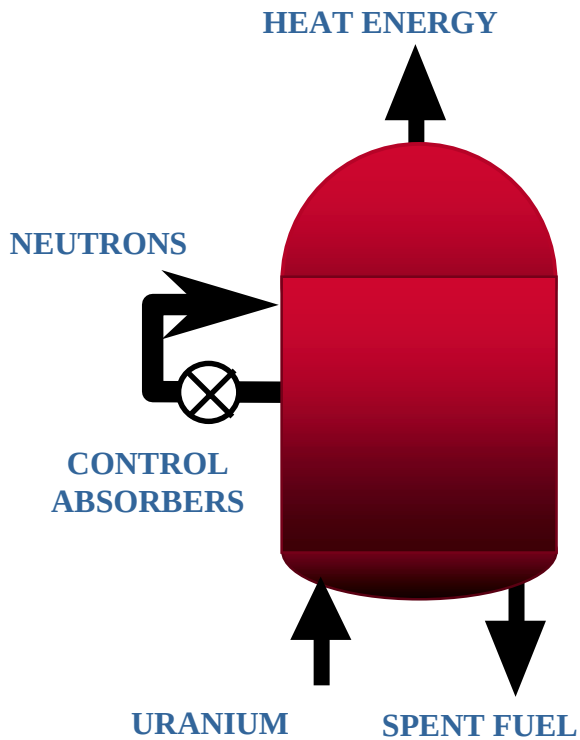


Fundamentals of Power Generation

COAL-FIRED POWER PLANT PLANT



URANIUM-FIRED POWER



Offshore Adventures

- India
  - AECL exported two units in early 1970's; Indian nuclear explosion led to isolation
  - Indian industry is now operating 10-12 small units, two larger units under construction
  - Fully mature industry, good performance
- Pakistan
  - One small unit operating (KANUPP, designed by Canadian General Electric)
- Korea
  - First CANDU6 unit started in 1983. Four units now operating. Two being considered
  - Fully mature industry. Both PWR and CANDU types
  - CANDU performance is excellent – several times at the top of world charts
- Argentina
  - Mature industry
  - One CANDU 6 unit started in 1983. An above-average performer
- Romania
  - One CANDU 6 unit started in 1986 – excellent performance. Second unit to be completed
- China
  - Growing industry – 2 operating, 8 under construction
  - Two CANDU 6 units under construction, for startup in 2002
- Turkey
  - Project cancelled by Turkish national government in 2000

Today's Viewpoint

- World Market Status
  - Continued fierce opposition from much of the green movement
    - Some interesting recent exceptions – e.g. Sweden, Switzerland
  - Low rate of ordering for new nuclear plants
    - Difficult to sustain experienced design and research staff
    - Low intake of new, young staff
  - Improving performance of, and reliance on, existing plants
    - Especially US and India
    - Service business is good – older plants are being refurbished
  - Extreme competition from remaining international competitors
    - UK, US, Russia, France, Germany
- Main Short-term Issues
  - Public acceptance
    - Governments follow; people lead
    - Recovery from a bad reputation takes time
  - Economics
    - High capital cost – a barrier
    - The "eternal supply of fossil fuel at low price" myth
  - Confusion in the electricity supply industry
    - Deregulation, privatization, mismanagement – most rates are rising
    - Instability of fossil fuel prices

Questions For Our Grandchildren

- Big Systems
  - How many people?
  - How much wealth do you need?
  - How much wealth do you want?
  - What wealth can be sustained?
  - Do you care about the welfare of foreign people?

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