



# EMERGING POSSIBILITIES FOR NUCLEAR ENERGY

*APEGM – 2008*

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*AECL – Whiteshell Laboratories*

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**UNRESTRICTED**

 **AECL EACL**



# OUTLINE

- **AECL**
- **CANDU Reactor**
- **Future Possibilities in Ontario**
- **Future Possibilities in Alberta – Oil Sands**
- **Future Possibilities – Hydrogen Generation**
- **Other – Desalination, Manitoba, . . .**
- **Conclusions**



# ATOMIC ENERGY OF CANADA LIMITED

- **AECL – a Canadian Crown Corp. was established in 1952 to develop the peaceful uses of nuclear energy for the benefit of Canadians**
- **AECL designs, markets and manages construction of CANDU power reactors and MAPLE research reactors globally**
- **Radioisotope production [Canada produces about 50% of global supply of medical isotopes]**
- **Performs nuclear-related R&D for the Canadian Govt [‘national lab’ role]**
- **Supplies reactor maintenance services, refurbishments**
- **Supplies waste management and decommissioning services**
- **Three main offices: (Total of approx 4800 employees)**
  - *Mississauga, ON [reactor design, sales, maint – 2050 employees],*
  - *Chalk River, ON [R&D, radioisotope production – 2500 employees],*
  - *Pinawa, MB [Formerly R&D – 250 – 300 employees]*



# AECL Whiteshell Laboratories





# **AECL Whiteshell Laboratories - Background -**

- ◆ **AECL Whiteshell Laboratories has operated since 1964 [Max employees approx 1100 (1985)]**
  - **Organic Cooled Reactor Program (WR-1)**
  - **Shielded Facilities (Hot Cells), Radiochemical Laboratories**
  - **Environmental Research**
  - **Canadian Nuclear Fuel Waste Management Program**
  - **Small Reactor Development**
  - **CANDU Research & Development**
    - **Reactor Safety**
    - **Chemistry and Material Science**

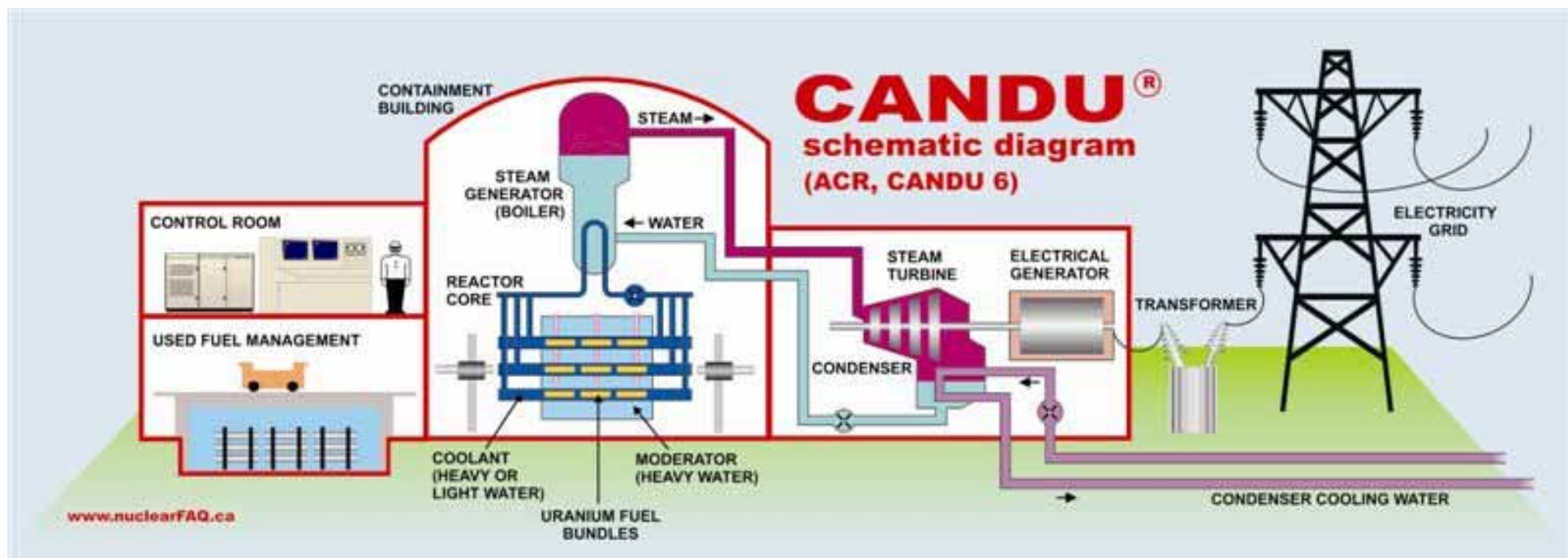


## **WL - Background (2)**

- **AECL Whiteshell Laboratories is now being decommissioned.**
- **An Environmental Assessment at the Comprehensive Study level has been completed and approved for WL Decommissioning**
- **A 6 year Decommissioning License was issued commencing 2003 January by Canadian Nuclear Safety Commission**
- **Safety Management, Quality Assurance and Regulatory Compliance Programs are in place and Whiteshell Decommissioning is underway.**



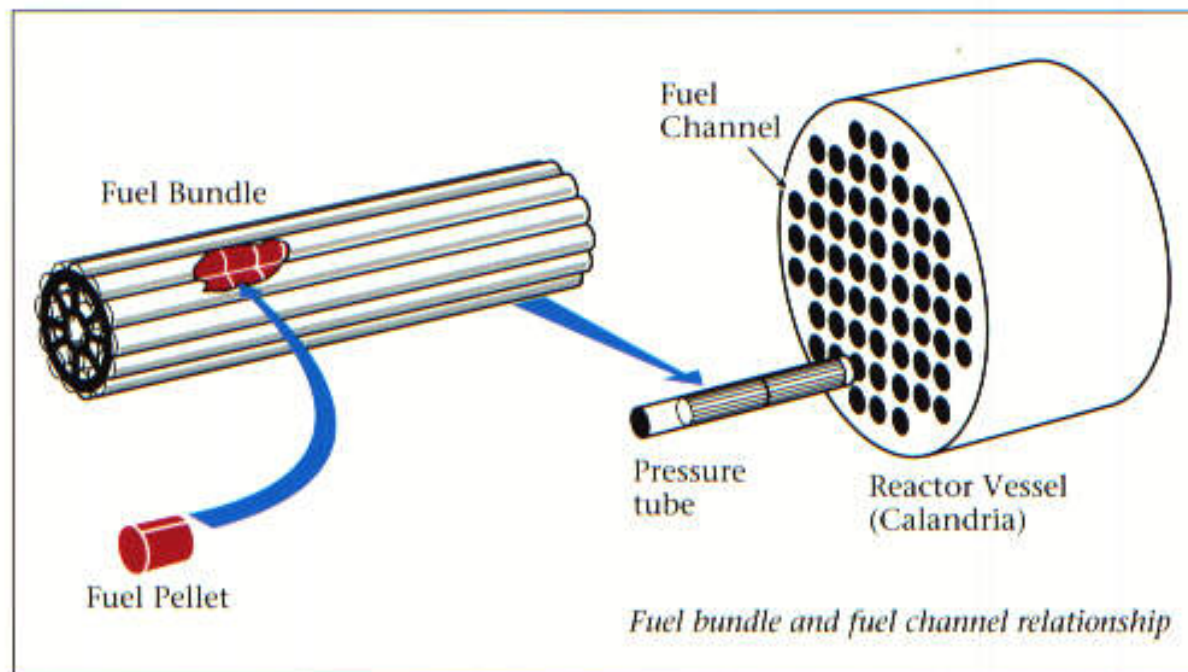
# CANDU



- On-Power Refuelling



# CANDU



- 8 pellets (approx 1 cm dia, 1.5 cm long) could power one 2000 sq ft house for one year
- Fuel bundle is fireplace log size (approx 10 cm dia, 50 cm long)



# CANDU REACTORS

- ◆ **22 CANDUs built in Canada [20 – Ont, 1-Que, 1-NB]**
  - 18 operating, 2 being refurbished, 2 shutdown
  - 542 – 935 MW each
- ◆ **9 CANDUs built globally [1 – Argentina, 2-Romania, 4-South Korea, 2 - China]**
- ◆ **In 2006, 54% of Ontario Electricity, 15.5% of Canadian electricity, 16% globally was nuclear generated**
- ◆ **One 700 MW(e) nuclear power plant [NPP] avoids 5,000,000 tonnes of CO<sub>2</sub>, compared to a coal-burning plant**
- ◆ **From 1971 to 1999, Ontario NPP avoided:**
  - ◆ 11,000,000 tonnes SO<sub>2</sub>
  - ◆ 2,500,000 tonnes NO<sub>x</sub>
  - ◆ 1,200,000,000 tonnes CO<sub>2</sub>
- ◆ **45 years of Canadian nuclear waste would fill 5 hockey rinks to the top of the boards**



# Ontario – Darlington Four-Unit Nuclear Power Plant [NPP]





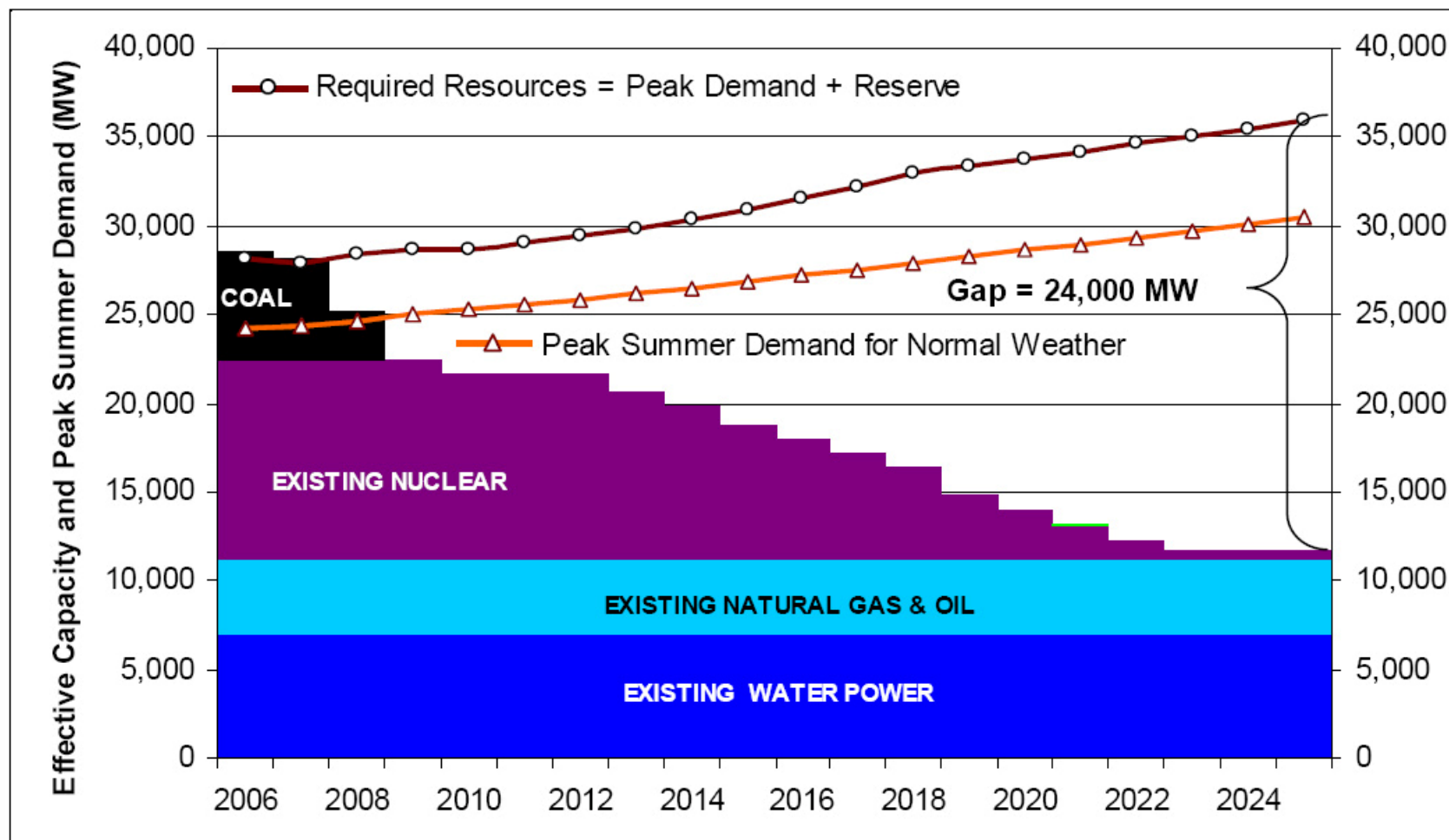
## ADVANCED CANDU REACTOR (ACR)

<b>Feature</b>	<b>CANDU 6</b>	<b>ACR</b>
<b>No. of Fuel Channels</b>	<b>380</b>	<b>520</b>
<b>Reactor Core Diameter (m)</b>	<b>7.6</b>	<b>7.5</b>
<b>Lattice Pitch (mm)</b>	<b>286</b>	<b>240</b>
<b>Power (MWe)</b>	<b>666</b>	<b>1085</b>
<b>Total D2O (m3)</b>	<b>460</b>	<b>250</b>



# Ontario Electricity Capacity/Demand

[MB Capacity 5,400 MW, potential of 5,000 MW additional hydro]



Source: OPA



## Ontario Electricity Capacity/Demand Notes

- ◆ **In 2006, Wind Generation in Ontario was approx 395 MW, and Biomass 70 MW**
- ◆ **2025 projection for wind generation in Ontario is 5,000 MW**
- ◆ **The 24,000 MW projected gap in 2025 is approximately 25 – 35 CANDUs (including refurbished and new reactors) or 12,000 – 24,000 windmills (100% capacity factor)**



# Alberta Oil Sands





# Alberta Oil Sands

- ◆ **174 Billion barrels of recoverable oil (less than 10% of total reserve) over 141,000 sq km.**
- ◆ **Two methods of recovery:**
  1. **Surface mining – open-pit**
  2. **Below 200 m deep – In-situ recovery using high pressure steam injection – Steam Assisted Gravity Drainage (SAGD) - 60% recovery or more possible**
- ◆ **High plant construction and operating costs, zero exploration cost, politically stable region, relatively close to markets**
- ◆ **By 2010, projected 2,000,000 barrels/day – 67% of Canadian production**



## **Alberta Oil Sands (cont'd.)**

- ◆ **National Energy Board estimates 1,200 cubic ft natural gas required to make steam to recover 1 barrel of AOS oil (equivalent to 6,000 cu ft natural gas)**
- ◆ **High ratio (energy in/energy out), also using shrinking, portable resource to produce other portable resource (could also burn part of recovered AOS oil, but ...)**
- ◆ **Per barrel of AOS oil, 80 kg Green House Gas (GHG) released, and 2 – 4 barrels of waste water**
- ◆ **Present plants are licensed to divert 359,000,000 m<sup>3</sup> of water from Athabasca River [per year]**
- ◆ **[Twice City of Calgary needs]**



## Alberta Oil Sands (cont'd.)

- ◆ **Presently 3 producing plants, many more planned or under construction !**
- ◆ **Use a Reactor [CANDU] to make steam:**
  - Save natural gas for better uses
  - Save GHG
  - Same cost [AT WORST]
- ◆ **One 450 MWe reactor → 30,000 barrels AOS Oil/day [10,000,000 barrels/yr], while avoiding 1,000,000 tonnes CO<sub>2</sub> released**
- ◆ **Further, AOS (heavy) oil is usually upgraded [add hydrogen relative to carbon content] – presently use hydrogen from natural gas**



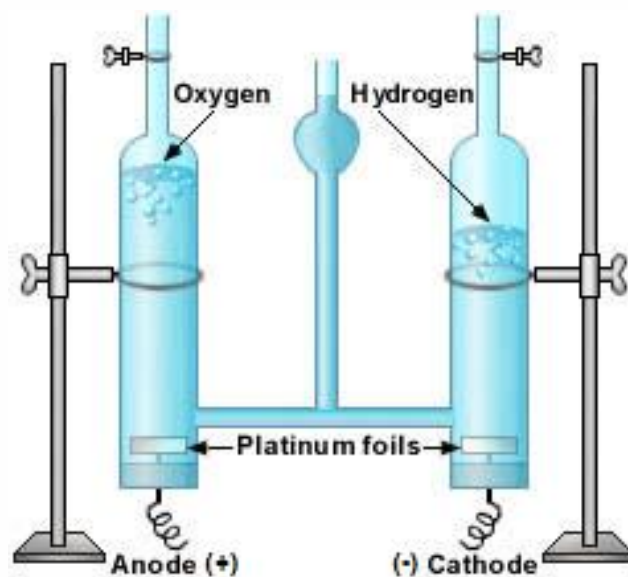
## **Alberta Oil Sands (cont'd.)**

- ◆ **Energy Alberta Corp. (bought out by Bruce Power) has applied to the CNSC for a construction license for a two unit CANDU station in Northern Alberta.**



# Hydrogen Generation - Hydrolysis

- **Cathode:**  $2 H_2O + 2 e^- \rightarrow H_2 + 2 OH^-$
- **Anode:**  $2 H_2O \rightarrow O_2 + 4H^+ + 4e^-$
- **Overall:**  $2 H_2O \rightarrow 2 H_2 + O_2$





## Hydrogen Generation – Hydrolysis (Cont'd.)

- ◆ **Need to add electrolyte to water to increase conductivity**
- ◆ **Energy balance poor at STP**
- ◆ **Works much better at high Temps (100 C to 850 C) → Reactor**
- ◆ **AOS Reactor – could produce electricity (for plant and/or grid), steam (for recovery – SAGD) and/or hydrogen (for upgrading/transport)**
- ◆ **CANDU – 1 part in 7000 of hydrogen component in H<sub>2</sub>O is deuterium; by-product is more D<sub>2</sub>O [1 tonne D<sub>2</sub>O per 1,000 tonnes H<sub>2</sub>]**



## **Hydrogen Generation – Hydrolysis (Cont'd.)**

- ◆ **Transportation (35% of Canadian Energy is used for Transportation)**
- ◆ **Reactor could be used to produce hydrogen (hydrogen is not a fuel, but an energy carrier - !)**
- ◆ **Could make electricity by day/peak times, hydrogen at night**
- ◆ **Could make hydrogen at a reactor and distribute that, OR**
- ◆ **Could distribute electricity and generate hydrogen regionally**



# OTHER POSSIBILITIES

- ◆ **Desalination of Ocean Water (Isreal: \$0.53/m<sup>3</sup>)**
- ◆ **Manitoba Electricity**
- ◆ **Have stated previously that 5,000 MW of additional hydro power is available, but**
  - **Remote, expensive**
  - **Added transmission line construction costs and losses**
- ◆ **Refurbishment of Pointe du Bois**
  - **\$800 M, 120 MW → \$6.50M/MW**
- ◆ **Construction of Wuskwatim**
  - **\$1,300 M, 200 MW → \$6.50M/MW**
- ◆ **CANDU at Pinawa [Winnipeg River, transmission corridor, licensed nuclear site]**
  - **\$1,400M, 700 MWe → \$2.00M/MW**



# CONCLUSIONS

- ◆ **NOT trying to sell reactors (!!)**
- ◆ **Planting seeds/food for thought**
- ◆ **Global energy needs are increasing**
- ◆ **Non (AOS) hydrocarbons scarce, and their use adds to GHG problem**
- ◆ **Nuclear Energy Renaissance starting**

**‘Nuclear energy is the largest, proven, non-carbon energy source available.’**

