Nuclear Energy & Environment

Science of Nuclear Energy & Radiation Course June 24 1998

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Topics

- Nuclear Fuel Waste Management: How to deal with the used fuel bundles that come out of CANDU reactors?
- The Role of Nuclear Energy in Climate Change : How can nuclear power contribute to reducing emissions of greenhouse gases?

Part 1: Nuclear Fuel Waste Management

A Technical and a Social Issue.

Resource: “Summary of the Environmental Impact Statement on the Concept for Disposal of Canada’s Nuclear Fuel Waste”, AECL-10721

Ethical Basis for Nuclear Fuel Waste Management

– " …from an ethical standpoint, including long-term safety considerations, our responsibilities to future generations are better discharged by a strategy of final disposal than by reliance on stores which require surveillance, bequeath long-term responsibilities of care, and may in due course be neglected by future societies whose structural stability should not be presumed…"

"The Environmental and Ethical Basis of Geologogical Waste Disposal"
Nuclear Energy Agency 1995

Technical Basis for Nuclear Fuel Waste Management

(Slides from AECL-10721)

Environmental Assessment

- AECL and nuclear utilities spend $500 M on R&D to develop geological disposal concept and produce Environmental Impact Statement (EIS).
- Independent Panel setup by government to review EIS in 1989.
- Extensive public consultation by panel over eight years as part of assessment process.

Panel Conclusions I

- *“Broad public support is necessary in Canada to ensure the acceptability of a concept for managing nuclear fuel wastes.”*
- *“Safety is a key part, but only one part, of acceptability. Safety must be viewed from two complementary perspectives: technical and social.”*

Resource: Canadian Environmental Assessment Agency Web site: www.ceaa.gc.ca

Panel Conclusions II

- *“From a technical perspective, safety of the proposed concept has been, on balance, adequately demonstrated for a conceptual stage of development, but from a social perspective it has not.”*

Panel Conclusions III

- *“As it stands, the AECL concept for deep geological disposal has not been demonstrated to have broad public support. The concept in its current form does not have the required level of acceptability to be adopted as Canada’s approach for managing nuclear fuel wastes.”*

Part 2: Greenhouse Gases

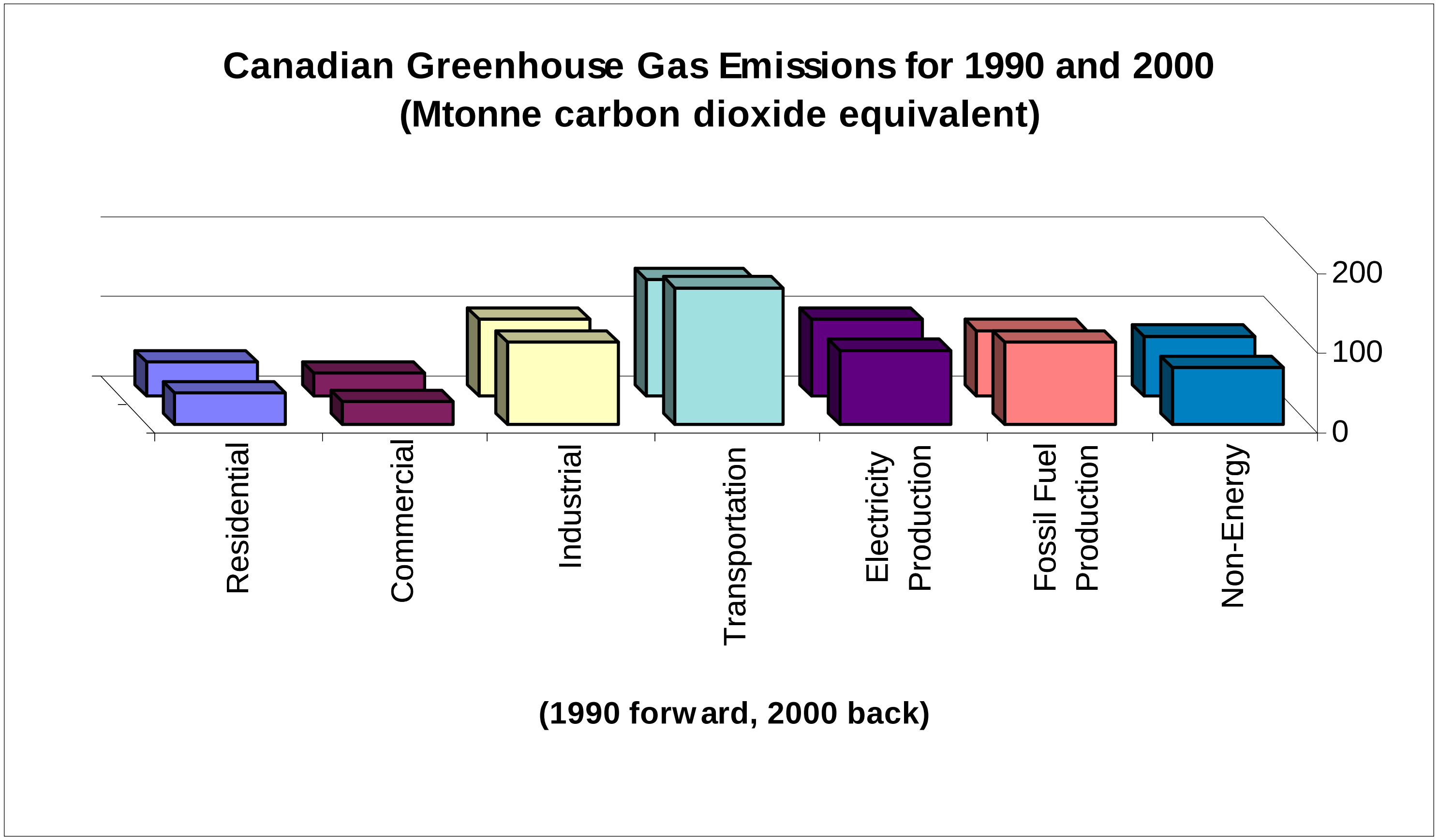
Some simple calculations with carbon reactions.

Resource: Environment Canada's climate change web page
http://www.ec.gc.ca/climate

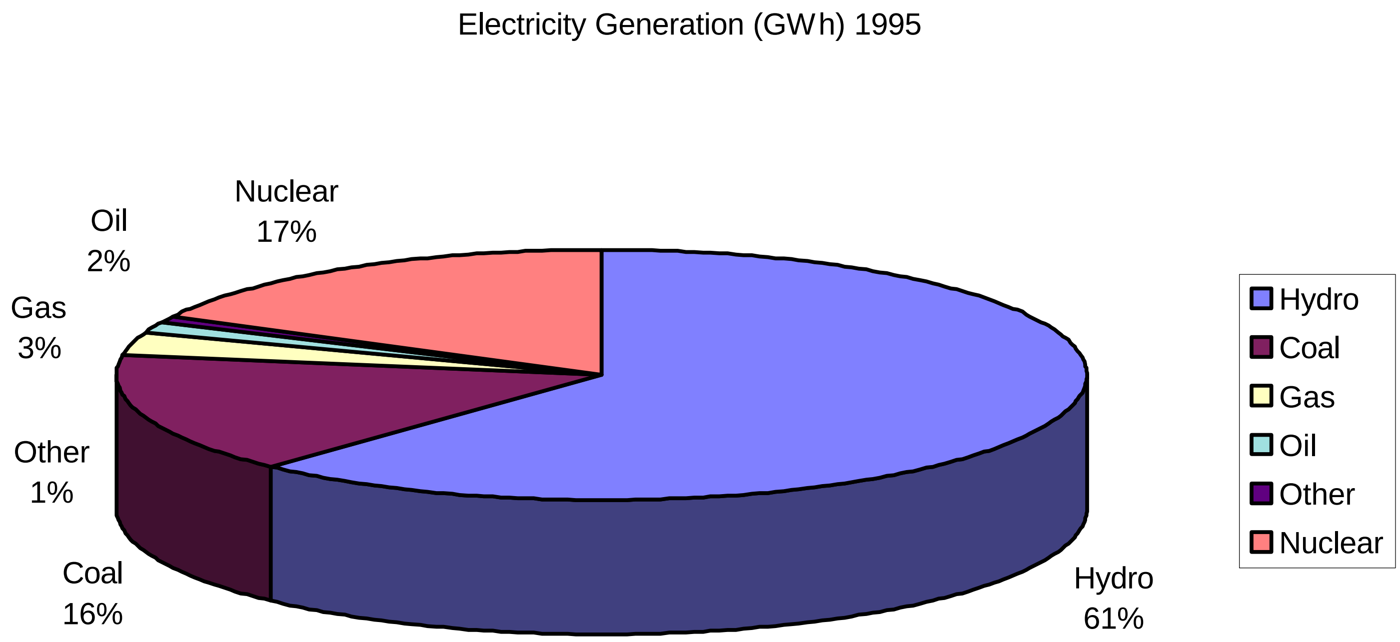
Kyoto Protocol

- In Kyoto, Canada and 160 other countries, agreed to a Protocol that called for reductions in greenhouse gas emissions over the next 15 years.
- Canada's reduction target is 6 percent below 1990 levels for the period spanning 2008 to 2012.
- 6 % of 1990 CO_2 ~ 0.06 x 564 Mt = 34 Mt

Sources of Greenhouse Gases



1995 Electricity Generation (534,869 GWh)



Combustion of Carbon

- The combustion of carbon reaction is: $C + O_2 \longrightarrow CO_2 + 94{,}050$ cal/mole
- In gram-moles: 12g + 32g → 44g and thus, the combustion of 1 g of C yields 44/12 = 3.67 g of CO_2 .
- Energy produced is 94,050 cal x 4.184 J/cal = $3.94*10^5$ J per gram-mole of carbon or $3.94*10^5$ /12 = $3.28*10^4$ J per g of carbon.

Coal

- If coal were 100 % carbon then expect 1 kg to produce $3.28*10^4$ x 1000 = 32.8 MJ when burned
- However, coal contains moisture and mineral impurities in addition to carbon, main types:
  - Bituminous ~ 24 MJ/kg (NS,BC)
  - Lignite ~ 9 MJ/kg (Sask)
  - Sub-bituminous ~ 15 MJ/kg (Al)

Carbon Dioxide from Coal I

- 1 GWh = 10^9 x 60 x 60 = $3.6*10^{12}$ J
- To calculate the amount of carbon that must be burned to generate a given quantity electricity in a thermal power plant need to assume an efficiency factor, “ f ”.
- f = electrical energy/thermal energy
- f = 0.4 is a reasonable assumption for modern coal plants

Carbon Dioxide from Coal II

- 32.8 MJ thermal energy obtained from combustion of 1 kg carbon
- To obtain 1 GWh of electricity need to burn $3.6 * 10^6$ MJ/ 32.8 MJ/kg = $1.1*10^5$ kg C at ideal power plant efficiency f =1.0
- For realistic power plant efficiency f = 0.4, 1 GWh requires $1.1*10^5$ /0.4 = $2.7*10^5$ kg of carbon to be burned

Carbon Dioxide from Coal III

- CO_2 generated when $2.7*10^5$ kg of carbon is burned = $2.7*10^5$ x 44/12 = $1.0*10^6$ kg, assuming f = 0.4
- Therefore, electricity generation from coal (83,358 GWh in 1995) produces about $1.0*10^6$ (kg) x 83,358 = 84 Mtonne CO_2
- Canadian production of CO_2 from electricity generation is 90-95 Mtonne from coal, gas and oil.

CO_2 from Natural Gas I

- Natural Gas is mixture of methane (85%), ethane (9%), propane (3%), butane (0.1%) and nitrogen and other gases (~2.9%)
- Assuming gas all methane, can approximate by reaction: $CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$ which yields 212,800 cal ($8.9*10^5$ J) per gram-mole of CH_4 (22.4 liters at STP)
- $4.0*10^4$ J/L ~ 1066 Btu/ft^3 (1031 quoted)

CO_2 from Natural Gas II

- Burning 1 g of CH_4 yields $8.9*10^5$ /16 = $5.6*10^4$ J, and 44/16 = 2.75 g CO_2
- 1 GWh ($3.6*10^{12}$ J) means burning $3.6*10^{12}$ / ($5.6*10^4$ x f) = $1.6*10^{-4}$ Mt CH_4 giving $4.4*10^{-4}$ Mt CO_2 ,with f = 0.4
- In 1995, Canada generated 16,697 GWh of electricity from gas giving 7.4 Mt CO_2
- Same GWh from coal gives 16.8 Mt CO_2

Displacement of CO_2 by Nuclear

- In 1995, 92,306 GWh electricity was generated by nuclear reactors in Canada, if this electricity had been generated by coal then $1.0*10^6$ x 92,306 = 92 Mt CO_2 would have been produced (16 % of the 1990 CO_2 level) .
- For bituminous coal (24 MJ/kg), mass of coal burned = 34 Mt (~1.1 tonne /sec)

Projection to 2010

- At current growth rate CO_2 produced by Canada will be 669 Mt by 2010 compared to 564 Mt in 1990.
- Therefore reduction to 531 Mt required to fulfill Kyoto - 138 Mt
- Projected fossil fuel electricity generation in 2010 will produce ~ 150 Mt CO_2
- offset: tripling(?) domestic nuclear capacity