Life Cycle Analysis (LCA) of Base Load Electricity in Ontario

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Motivation

- Some environmentalists argue that nuclear energy is bad for the environment because
  - uranium mining is emitting greenhouse gases
  - it is unsafe and releases radiation.

- CERI did an analysis comparing base load electricity generation technologies in terms of emissions, radiation and other criteria.

Motivation

- The Canadian Energy Research Institute (CERI) analyzed cradle-to-grave emissions (GHG emission, other air pollutants, water pollutants and radiation) for various types of baseload electricity generation in Ontario for 2005-2006

What are the baseload plants?

- Base load plants are the facilities:
  - They meet some or all of a region's continuous energy demand
  - They produce energy at a constant rate
  - Usually at a low cost relative to others
  - They typically run at all times through the year except in the case of repairs or scheduled maintenance (7/24)

What is included and what is not?

- Nuclear, Coal and Gas fired power plants and their fuel chain are included

- Renewable sources were not included because they do not meet the requirements of baseload power supply or they were not a major option for baseload electricity in Ontario

Structure of the Presentation

- Introduces the environmental Life Cycle Assessment (LCA) technique
- Describes application of the technique to base load electricity generation alternatives in Ontario: Nuclear, Natural Gas Coal fired
- Summarizes the results of the comparative evaluation

Environmental Life Cycle Assessment

- What is Environmental LCA?
- Why do we need Environmental LCA?

How air polluting is your car?

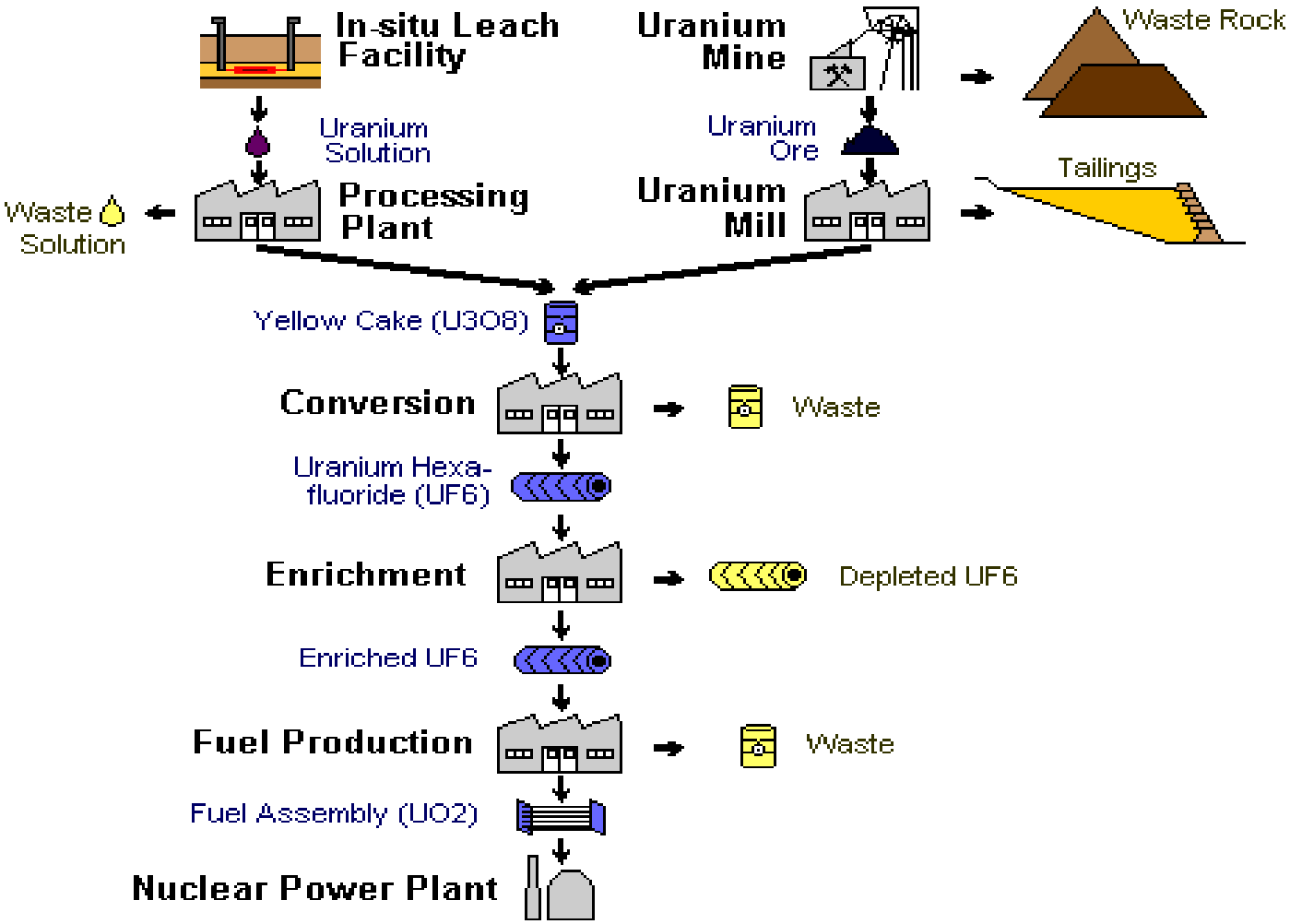
How air polluting is your electricity?

How air polluting is your pencil?

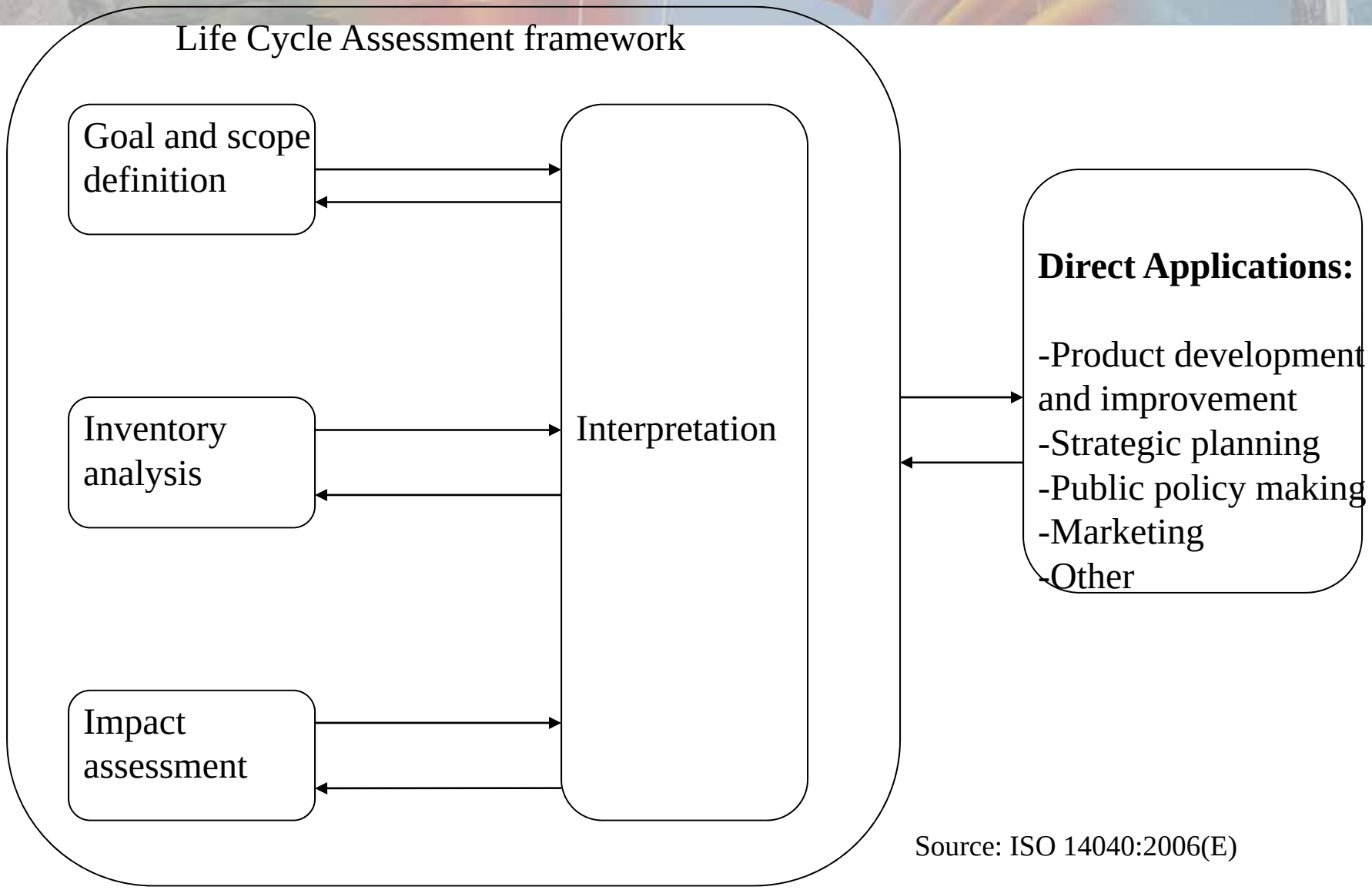
LCA

- ISO 14040: “LCA addresses the environmental aspects and potential environmental impacts throughout a product’s life cycle from cradle to grave.”
  - Raw material acquisition
  - Production
  - Use
  - End of life treatment
  - Recycling
  - Final disposal

Nuclear electricity chain – Generic Form



Four Phases of LCA



Source: ISO 14040:2006(E)

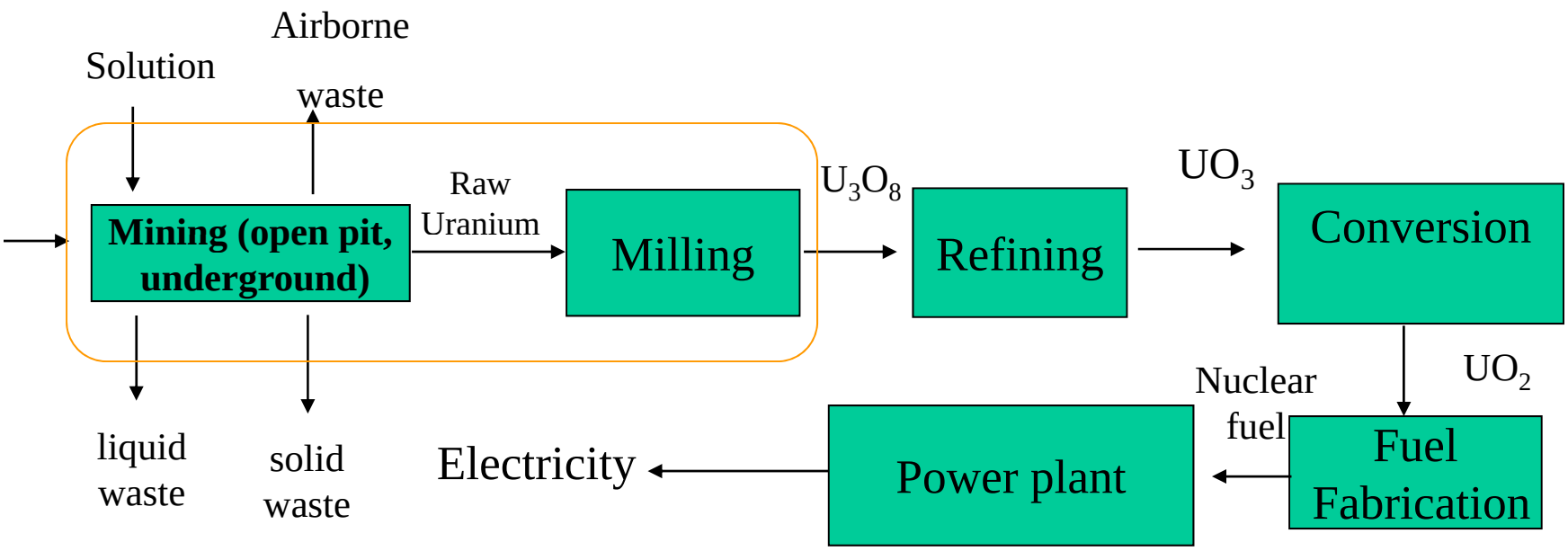
LCA – Phase 1:
Goal and Scope (System Boundaries)

- Fuel chains of Nuclear, Natural Gas and Coal fired power plants in Ontario are investigated facility by facility.

- This approach is called "Process LCA", this is an accounting approach and very data intensive.

LCA – Phase1:
Goal and Scope (system boundaries)

Nuclear electricity generation chain:



LCA – Phase2:
Data requirement for LCI - Nuclear

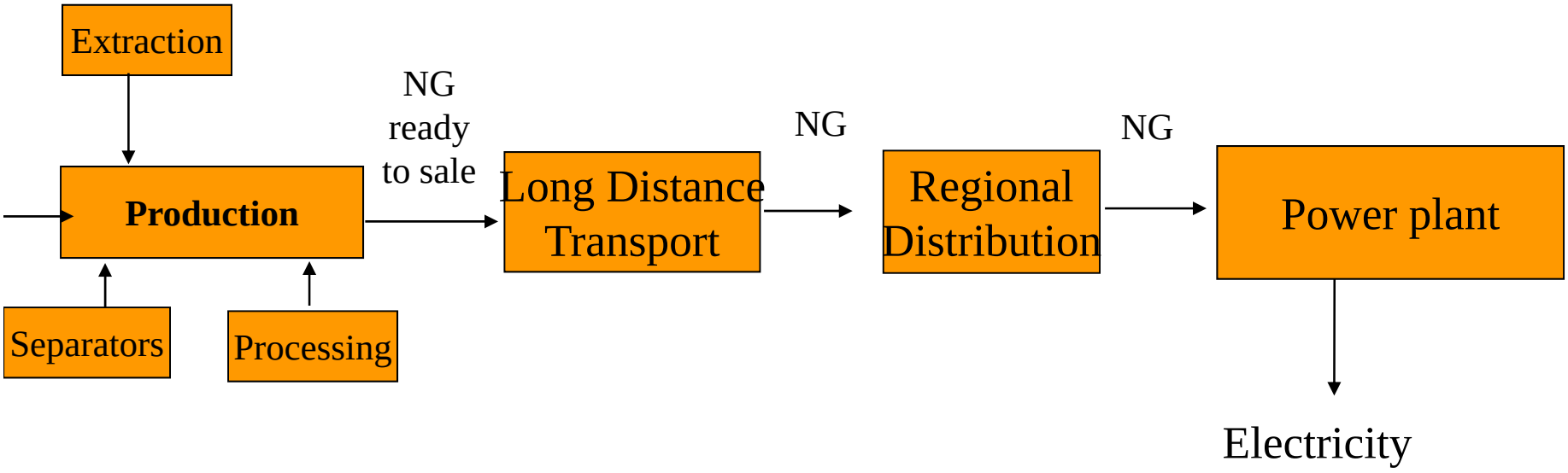
- The following facilities are identified and included:
  - Mining & Milling: Key Lake, McArthur River, Rabbit Lake and McClean Lake
  - Refinery: Blind River

LCA – Phase2:
Data requirements for LCI - Nuclear

- Conversion: Port Hope
- Fuel Fabrication: Zircatec Port Hope, GEC Toronto and GEC Peterborough
- Power Plants: Pickering (A&B), Bruce (A&B) and Darlington

LCA – Phase1:
Goal and Scope (system boundaries)

NG electricity generation chain:



LCA – Phase2:
Data requirement for LCI – Natural Gas

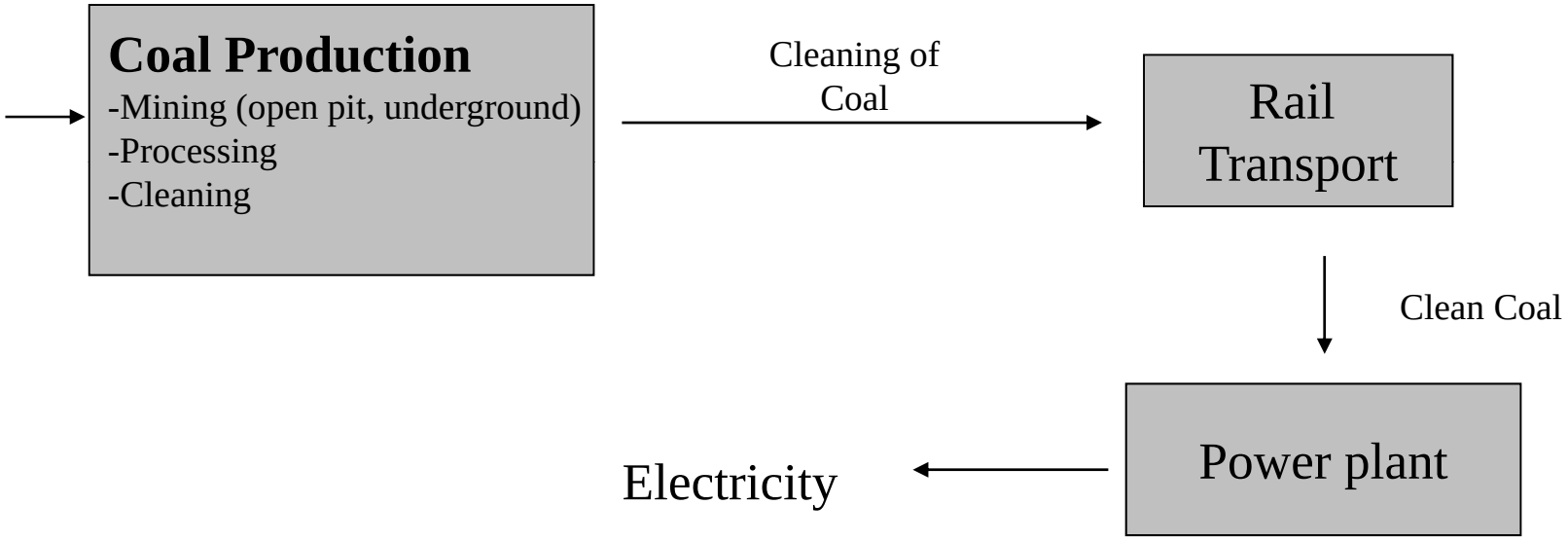
- The following main sources /facilities are identified:
  - Production: For Alberta, provincial production and share of Ontario's utilities are determined. Also Liquefied Natural Gas (LNG) will be addressed
  - Long Distance transport: For Canada, a city gate as a representative point

LCA – Phase2:
Data requirement for LCI – Natural Gas

- Power Plants (26): AES Kingston, ALGOMA Steel, Bayer-Sarnia, Bowater-Thunder Bay, Cardinal Power, Dow Chemical-Sarnia, Ford Motor-Windsor, General Chemical- Amherst burg, Hiram-Walkerville, Iroquois Falls, Kirkland Lake, Lake Superior-Sault, Redpath-Toronto, Spruce-Kapuskasing, Terra-Bickford, Transalta-Mississauga, Transalta-Ottawa, TransCanada-Nipigon, TransCanada-Kaupsasing, TransCanada-NorthBay, TransCanada-Tunis, Trigen-London, UWO-London, West Windsor, Fort Frances, York University (use of disaggregated emission data and aggregated generation data)

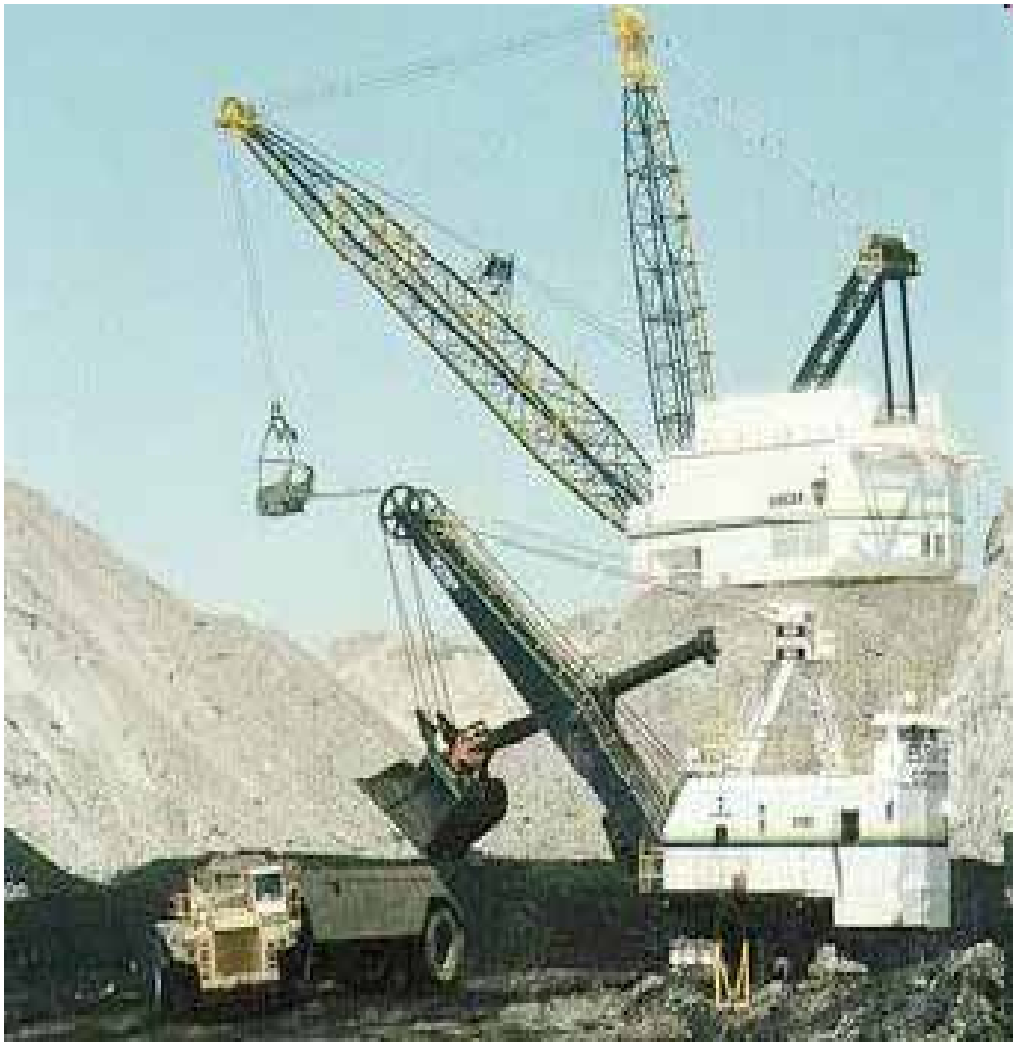
LCA – Phase1:
Goal and Scope (system boundaries)

Coal electricity generation chain:



LCA – Phase2:
Data requirement for LCI – Coal

- The following main sources/facilities are identified:
  - Production: Saskatchewan (lignite) and USA (Bituminous)
  - Transport: Saskatchewan and USA



LCA – Phase2:
Data requirement for LCI – Coal

- Power Plants: Atikokan (lignite), Lambton (bituminous), Nanticoke (bituminous), Thunder Bay (lignite, sub- bituminous)

LCA – Phase2:
Life Cycle Inventory Analysis (LCI)

Collecting Data

- The qualitative and quantitative data for the inventory analysis are collected for each unit process within the system boundary for 2005 and 2006.

- In addition to the collected data, the data set includes a mixture of measured, calculated or estimated data for some processes (e.g. production of NG, Coal,...)

LCA – Phase2:
Life Cycle Inventory Analysis (LCI)

Collecting Data

- We have also used some information available through *GHGenius*

- The *GHGenius* model has been developed for *Natural Resources Canada* to identify the amount of greenhouse gases generated by a variety of fuels and technologies through their life cycles.

LCA – Phase2:
Data requirement for LCI – Emission

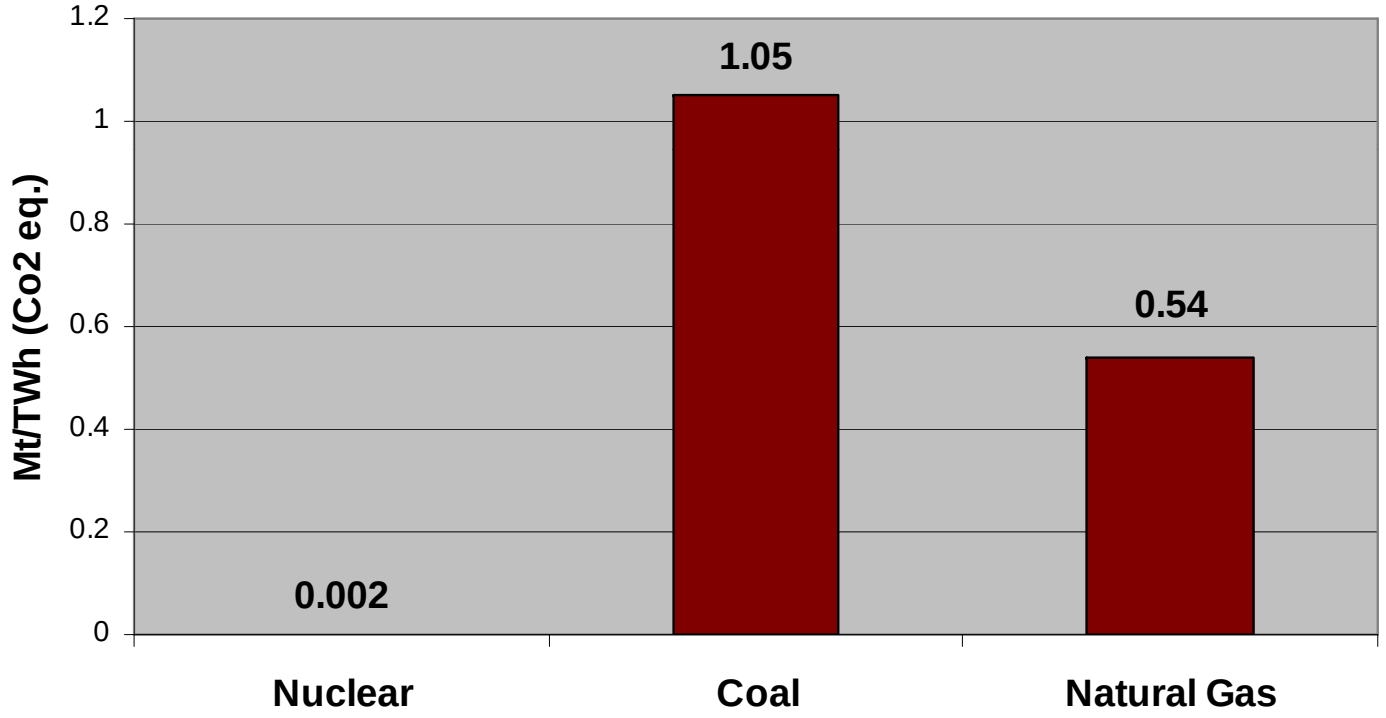
- The following emissions are of major interest, however we collected all available data:
  - Emission to Air: GHG,CAC, Lead, Arsenic, Mercury and Uranium
  - Emission to Water: Lead, Arsenic, Mercury and Uranium
  - Other Releases: Radiation (Tritium, Radon)
- GHG: CO_2, CH_4, N_2O
- CAC: SO_2, CO, NO_X, VOCs, Particulates

Findings-GHG Emissions

- This study concludes that life cycle GHG emissions resulting from the generation of one TWh of nuclear electricity are so small, that they are simply not comparable to the other types of baseload electricity generation.

Findings-GHG Emissions

Comparative Life-Cycle GHG Emissions
for Ontario Electricity Generation Sector

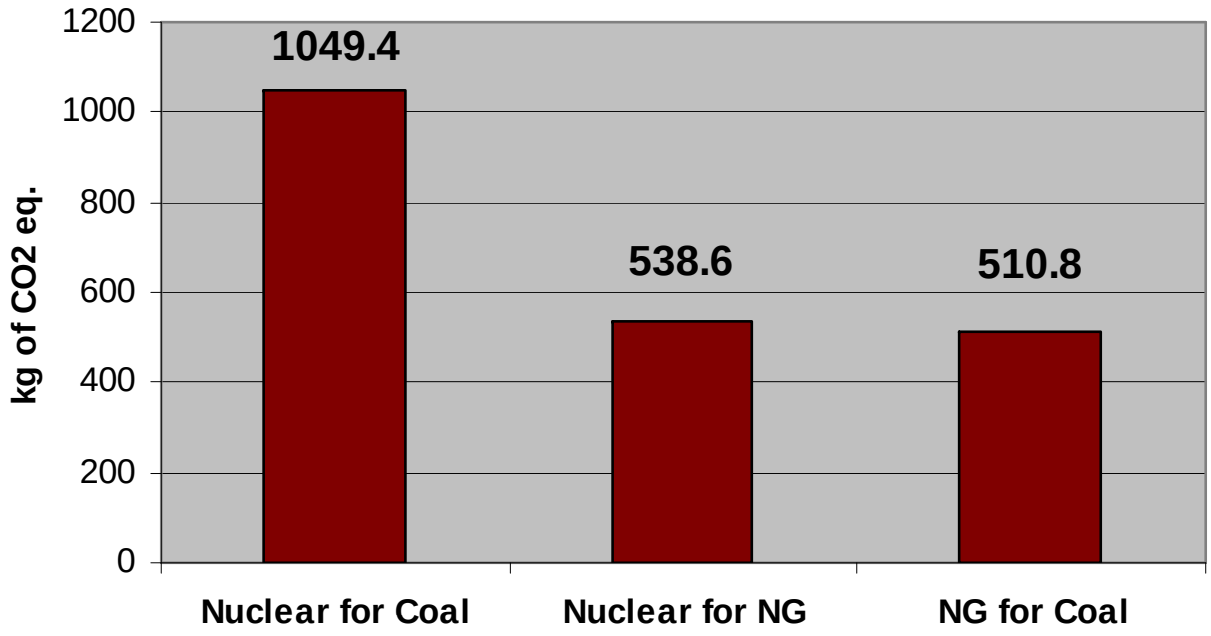


Findings-GHG Emissions

- If a MWh of coal-fired or natural gas-fired electricity capacity is replaced by a MWh of nuclear electricity, Ontario could have avoided 1049 kg, 539 kg of GHG emissions relatively.

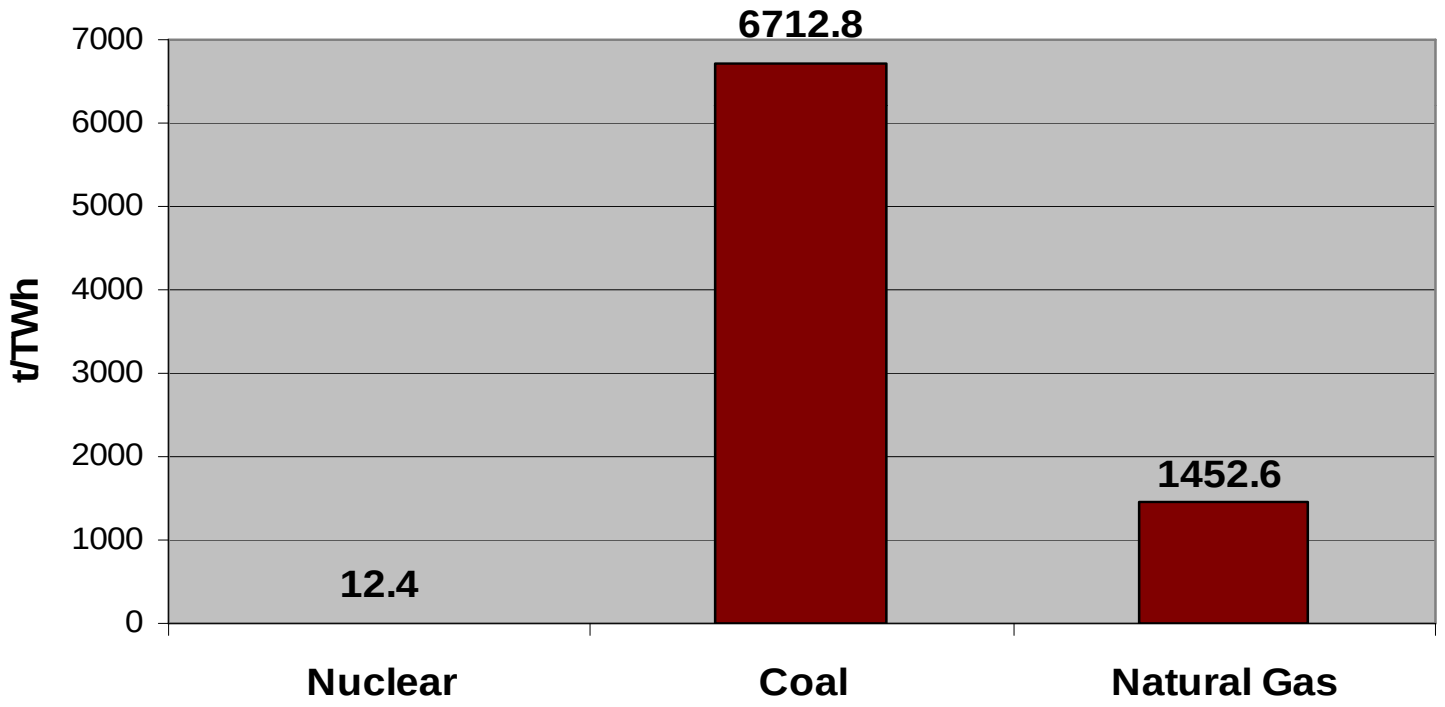
Findings-GHG Emissions

GHG Emissions Avoided by Replacing One MWh by Switching Fuels



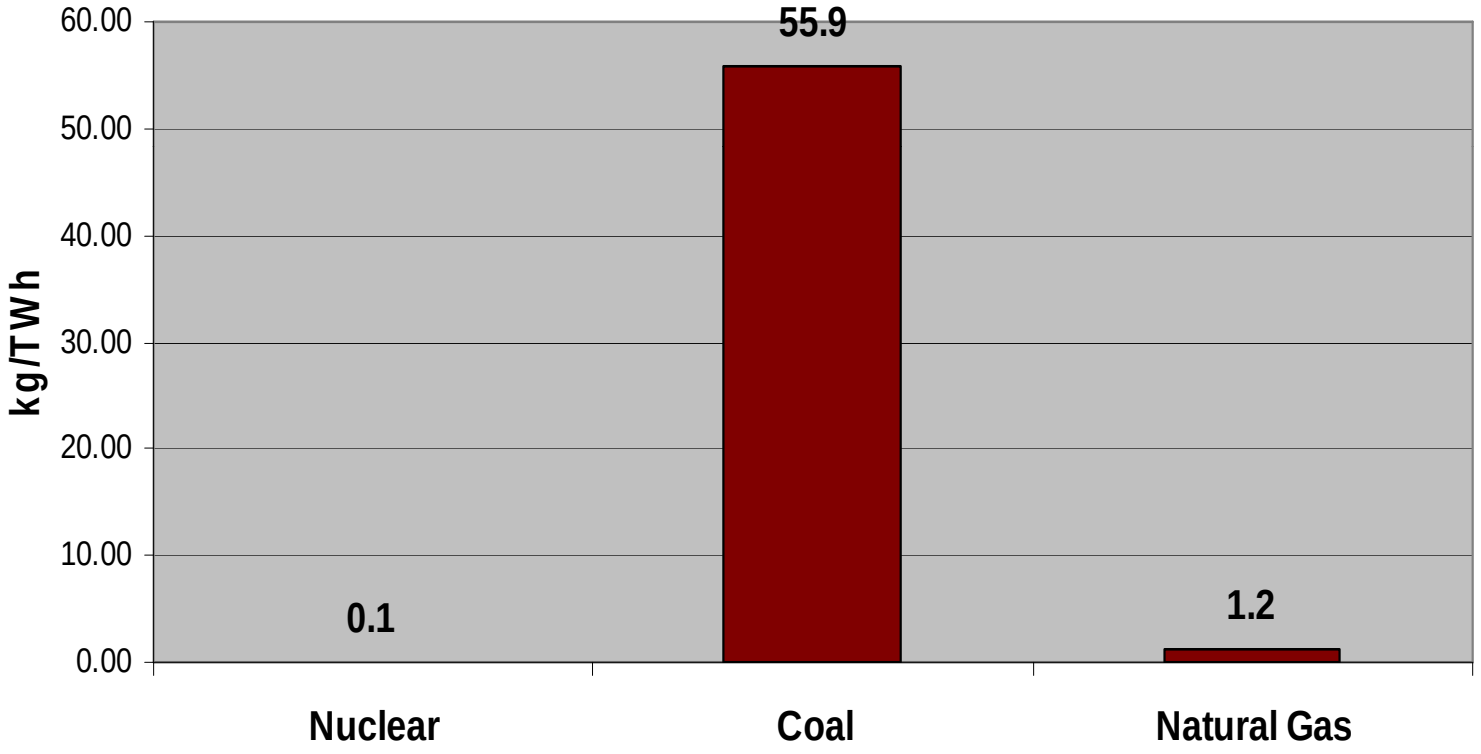
Findings-CAC Emissions

Comparative Life-Cycle CAC Emissions



Findings-Heavy Metal Emissions

Comparative Life-Cycle Heavy Metal Emissions



Findings-Radionuclide Emissions

While the initial release is highest for Nuclear:

- Half-life of the nuclides are much shorter for nuclear power than for coal
- End result is that cumulative radiation (collective dose) over 10,000 years for nuclear is lower than coal by an order of magnitude (ten times)

Findings-Energy related Disaster by Type

- While the Chernobyl plant in Ukraine, is not representative of the nuclear industry approach to safety, either structurally or operationally, and was totally preventable; immediate fatalities were 79.

- The largest energy related facilities are listed below:

Findings-Energy related Disaster by Type

Energy-related Disaster by Type: Largest Number of Facilities

Type of Disaster	Location	Number Killed	Year
Hydro-electric dam failure	Machhu II, India	2,500	1979
Hydro-electric dam failure	Hirakud, India	1,000	1980
LPG pipeline leak and fire	Asha-ufa, Siberia	600	1989
Fuel depot hit by lightning	Durunkha, Egypt	580	1994
Oil fire	Cubatao, Brazil	508	1984
Oil pipeline leak and fire	Warri, Nigeria	500+	1998
Oil fire	Seoul, South Korea	500	1994
LPG explosion	Mexico City, Mexico	498	1984
LPG explosion	Nile River, Egypt	317	1983
Coal mine (methane explosion)	Kozlu, Turkey	272	1992
Gas well blowout with H_2S	Gaoqiao, China	234	2003
Coal mine (methane explosion)	Sunjiawan, Liaoning, China	215	2005

THANK YOU