UNIVERSITY OF CALGARY

Institute for Sustainable ENERGY, ENVIRONMENT AND ECONOMY

Transportation Fuels & the Next Energy System Transformation

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THE VAN HORNE INSTITUTE

The Calgary Region as a Transportation Hub
Calgary – December 2, 2010

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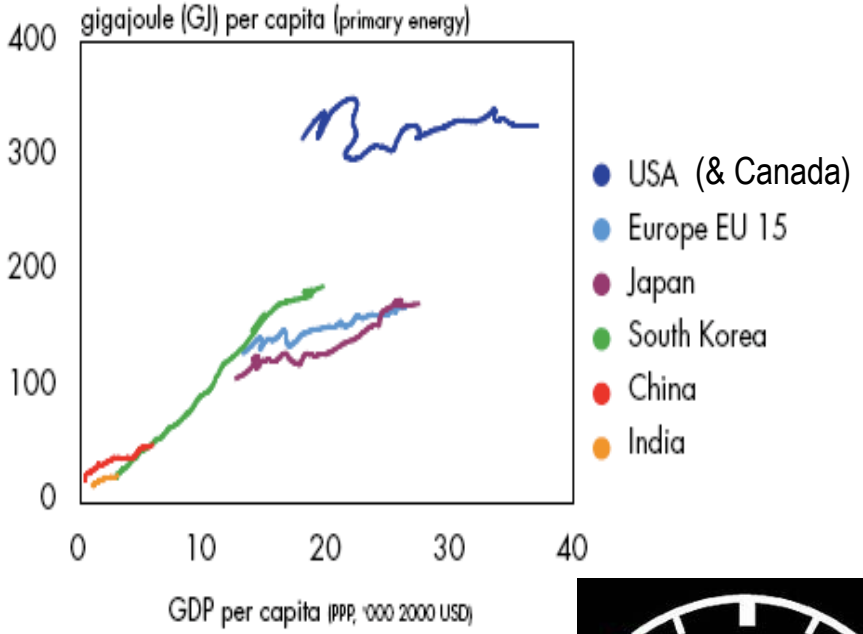
Why Transform Energy Systems?

1. Energy Security



DEMAND

- ✓Global Population Growth;
  - Esp. developing countries;
- ✓Economic Development
  - Esp. in China & India
- ✓Expect double energy demand by 2050

SUPPLY

- ✓Declining conventional
- ✓More unconventional
  - Typically higher cost
  - More environmental footprint
- ✓Military & political concerns

Bottom Line: Higher prices (esp. oil); US Policies to reduce oil dependence

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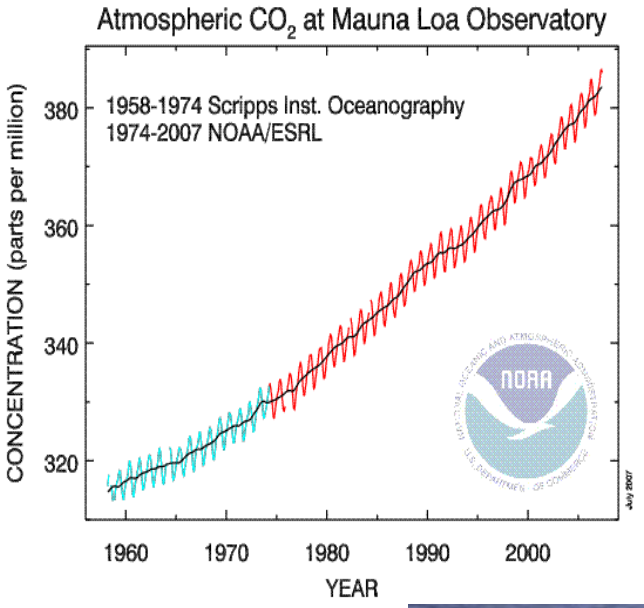
Why Transform Energy Systems?

2. Climate Change



- ~80% of greenhouse gas (GHG) emissions are coupled to fossil energy use:
- ~84% of global energy comes from fossil fuels

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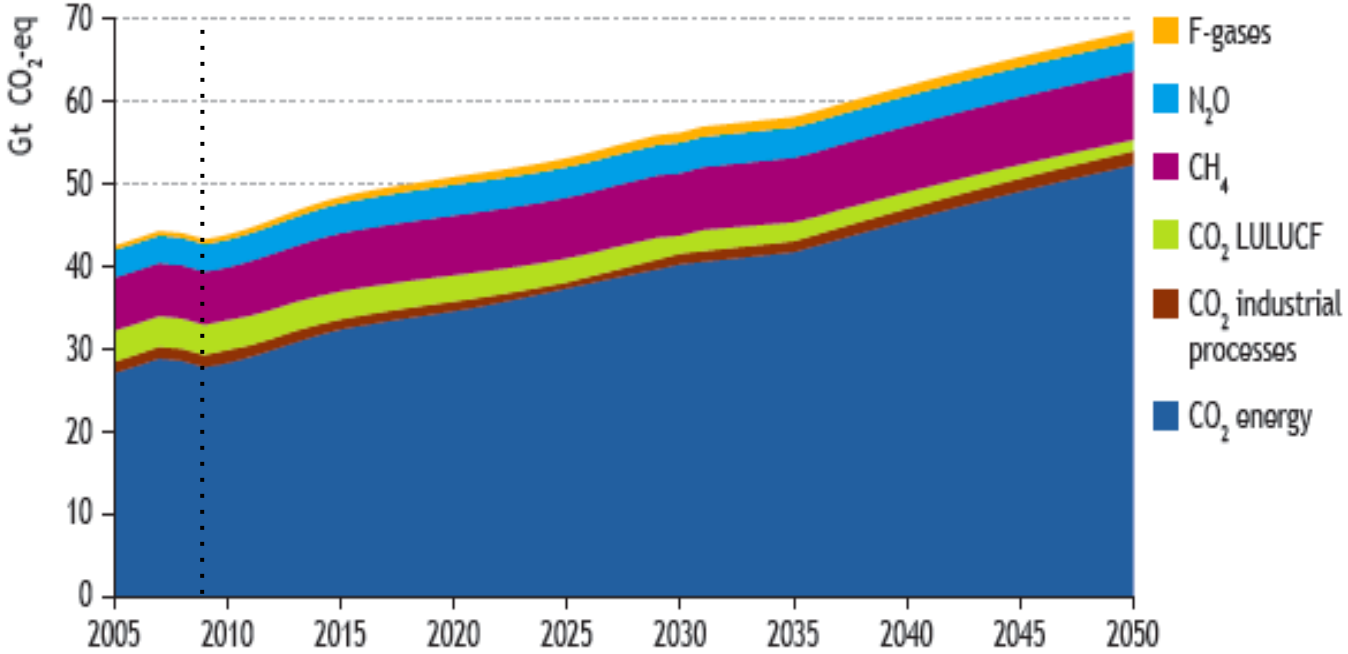
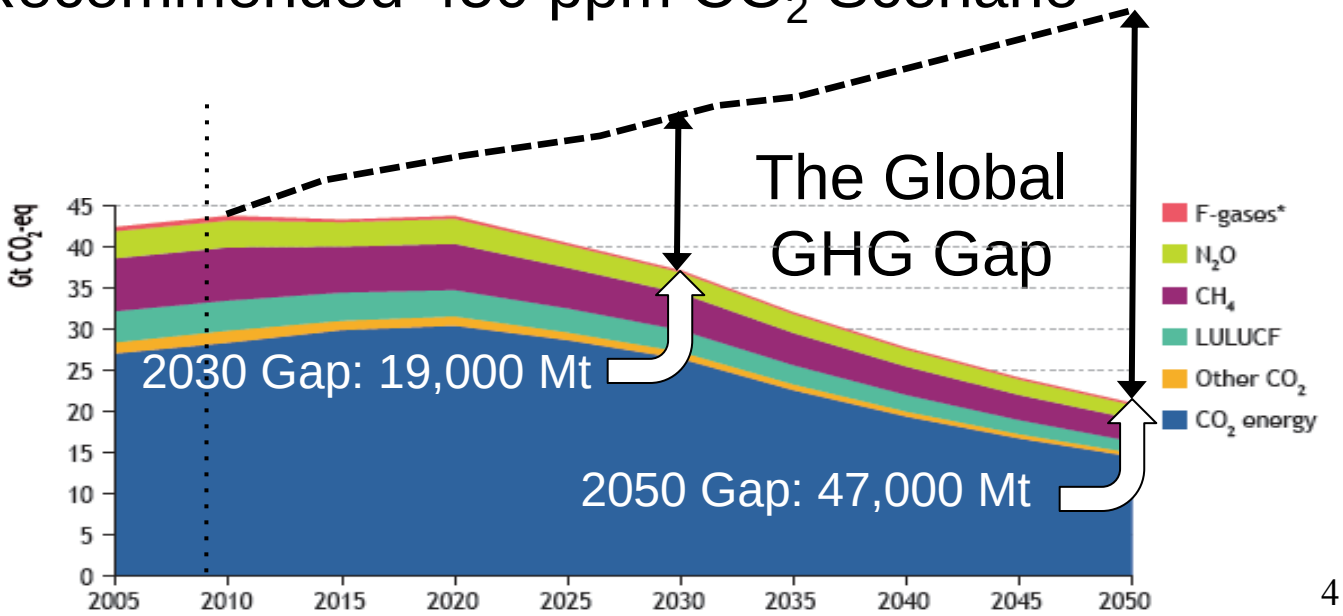
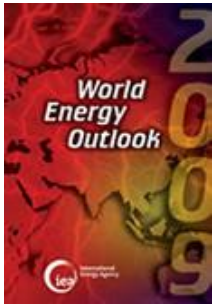
Magnitude of the Challenge for Global GHG Emission Reductions

Reference (Business as usual) Scenario



Recommended 450 ppm CO_2 Scenario





International Energy Agency World Energy Outlook (Nov 2009)
http://www.iea.org/

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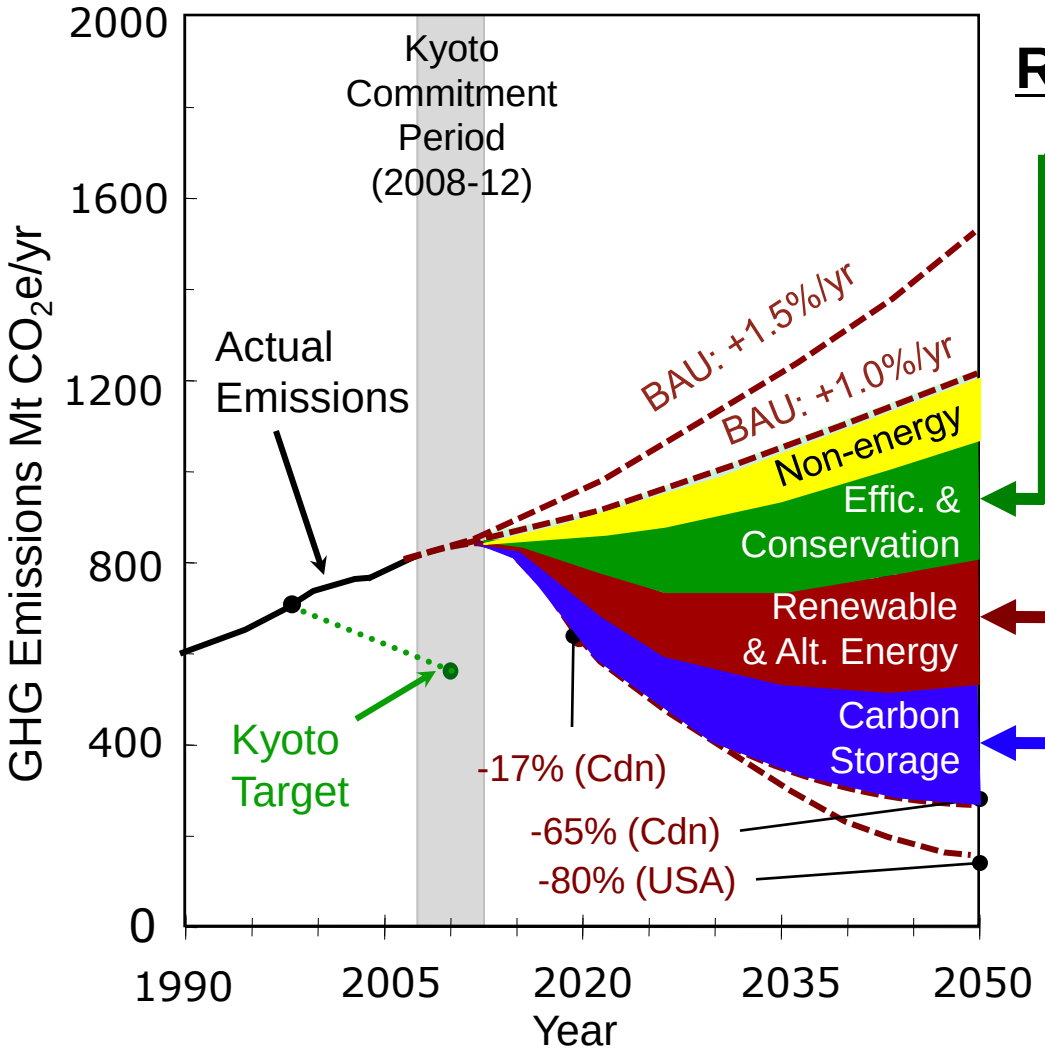
Canada's Climate Change Challenge



Reducing Energy Emissions:

- Energy efficiency and conservation; *(transportation & building systems, co-generation, coal > NG, societal & behavioural changes…)*
- Increase market share for renewable & nuclear energy;
- Keep fossil carbon out of the atmosphere. *(C capture and (geological) storage; Forest and agricultural sinks [e.g. biochar])*

What do we know about past energy system transformations?

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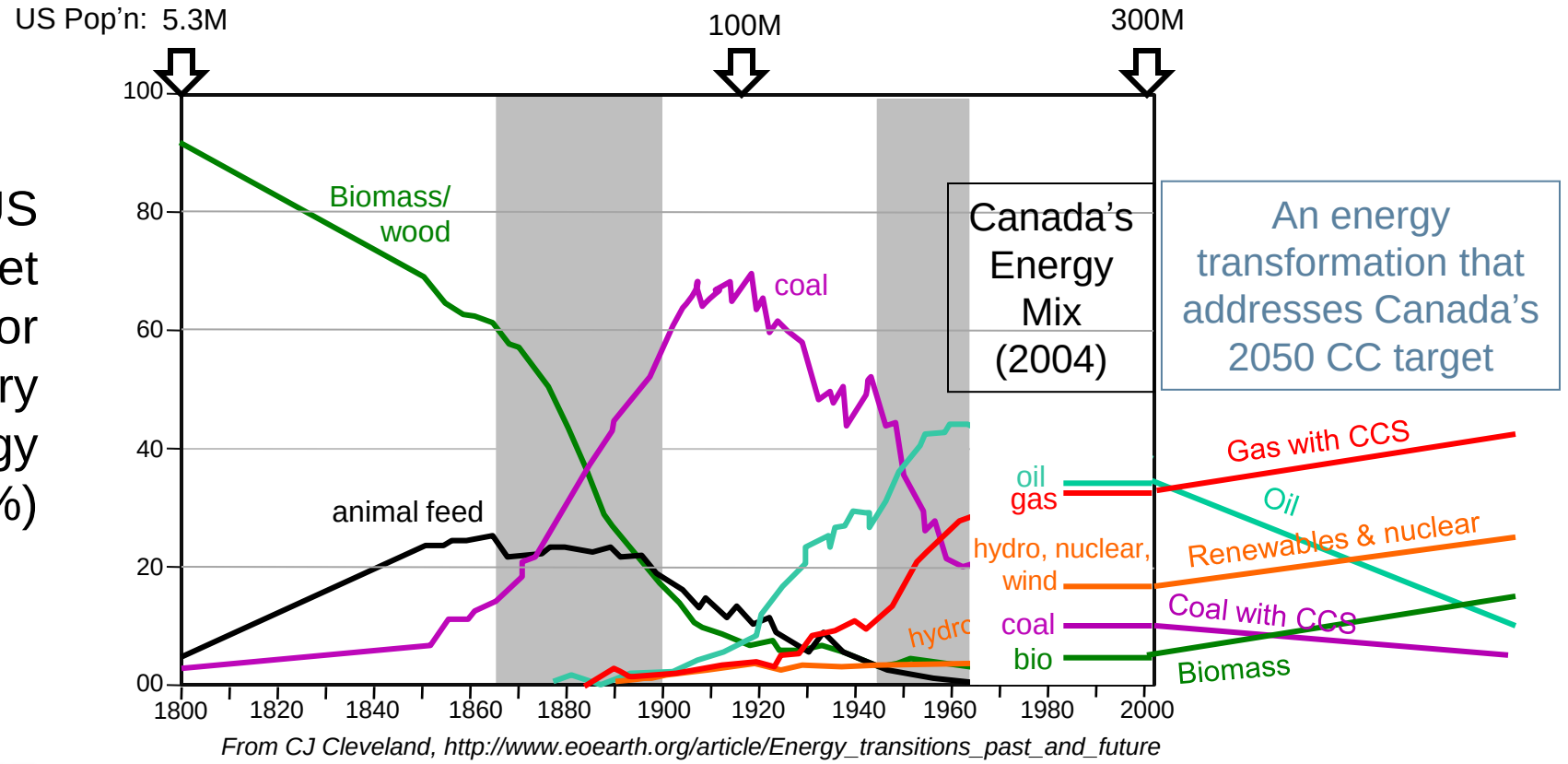
Energy System Transformations

US Market Share for Primary Energy (%)



From CJ Cleveland, http://www.eoearth.org/article/Energy_transitions_past_and_future

NOTE:

1. *Relative stability in market share (MS) over past 40 yrs;*
2. *Long 'incubation period' (~40 yrs) for MS to increase from 1%→10%;*
3. *Maximum rate of MS change was 1-2% per year*

…to address climate change, we need 2% MS/yr X 40yrs

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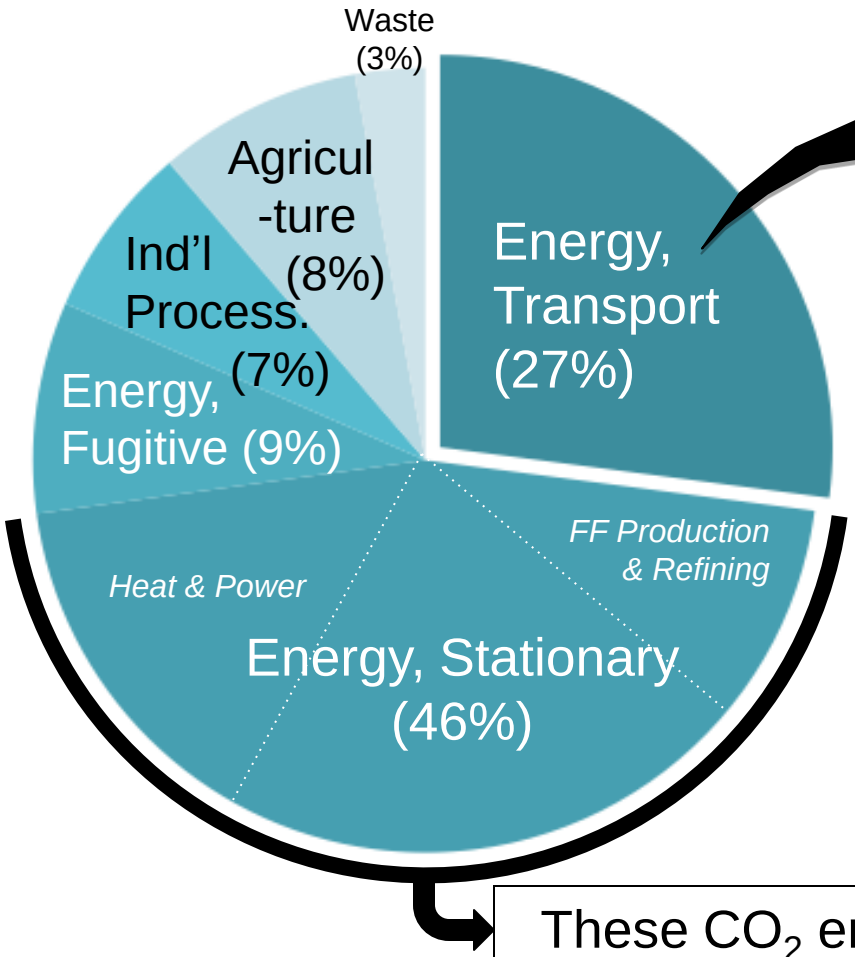
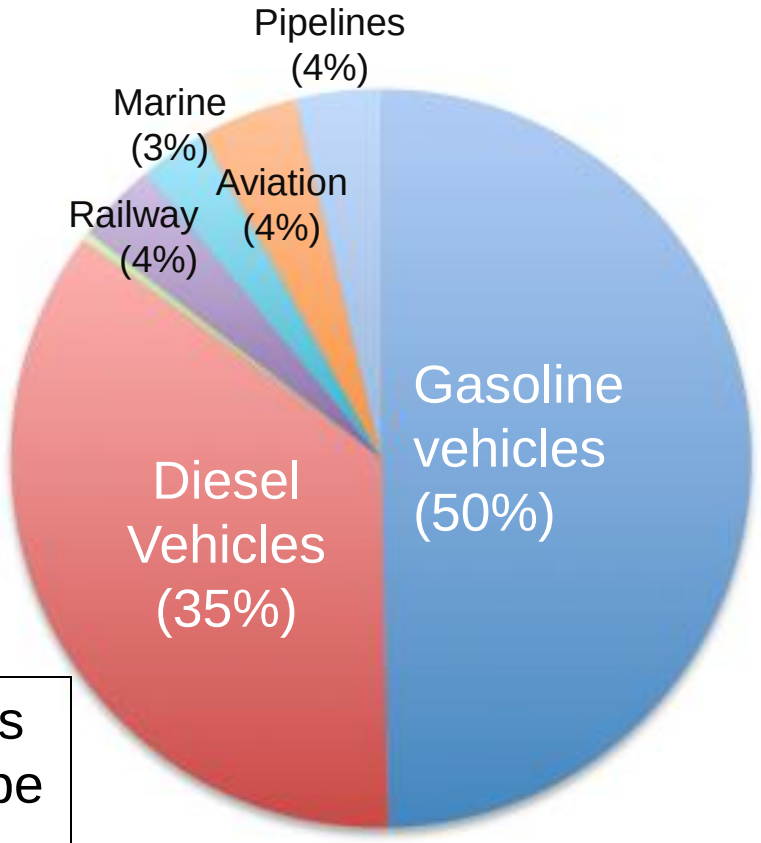
Canada's GHG Emissions (2008)



Transportation



These CO_2 emissions have the potential to be captured and stored.

From: http://www.ec.gc.ca/ges-ghg/0590640B-87F7-449A-AA8F-D5674A7BAC57/2010%20Annual%20Summary%20of%20Trends.pdf

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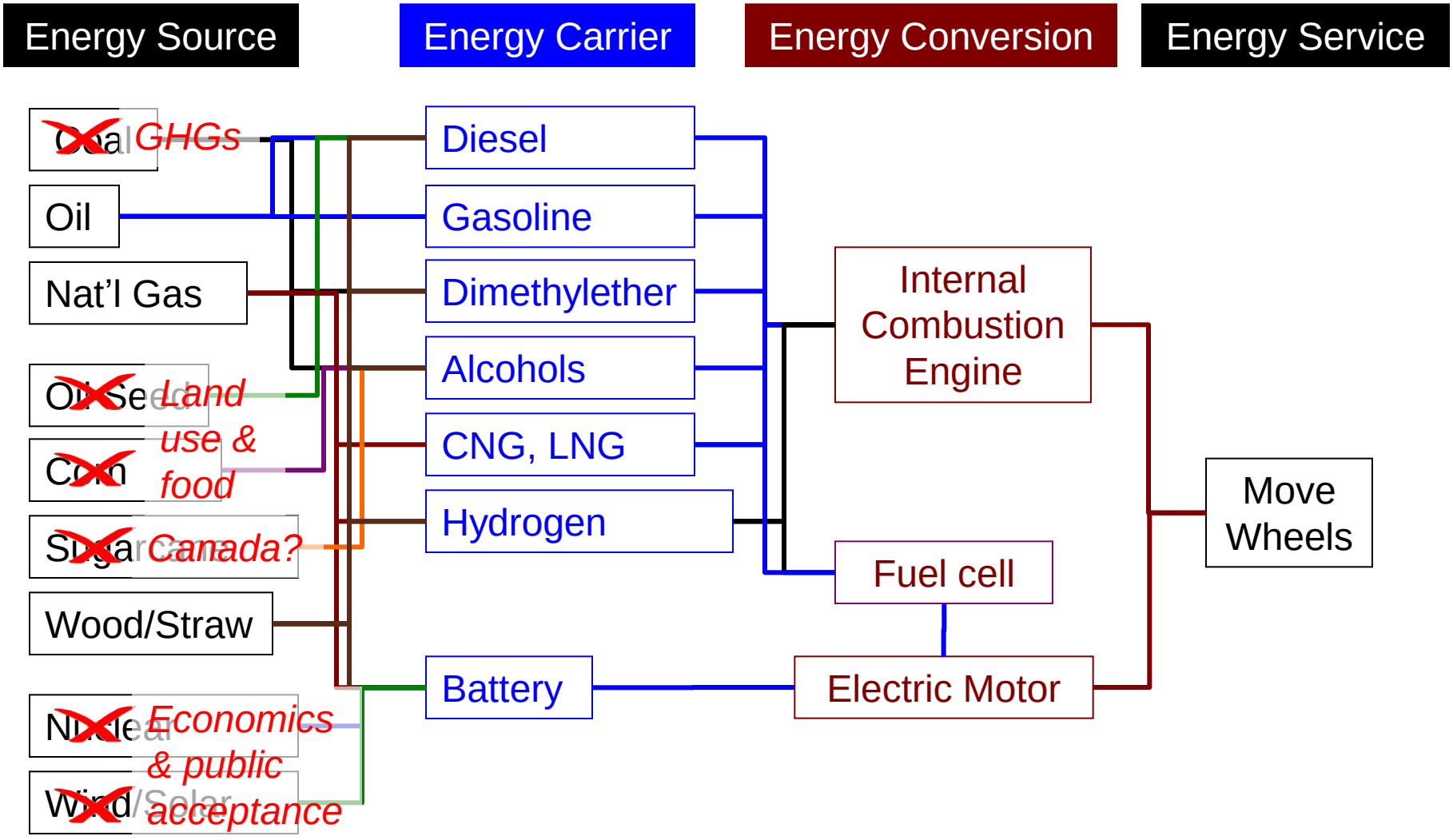
The Energy System Chain for Transportation



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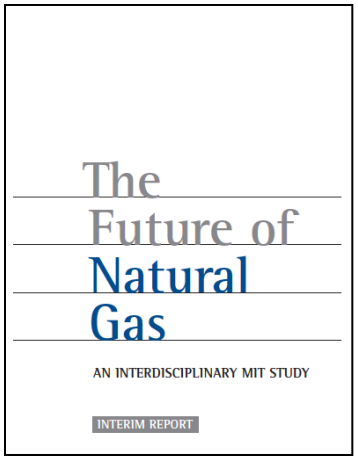
Natural gas is likely to take market share from oil for transportation



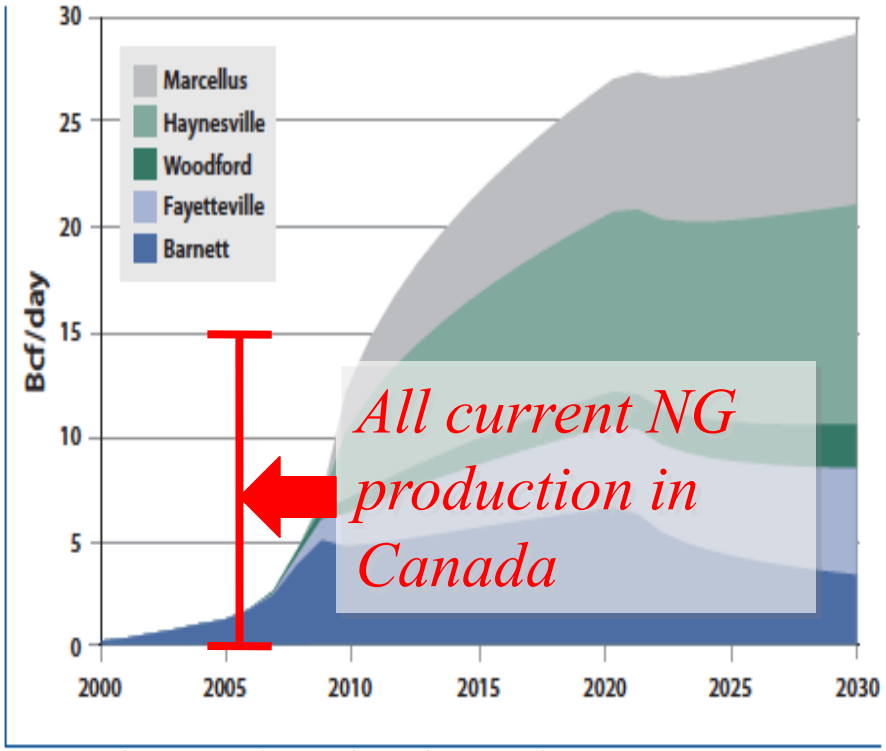
"Natural gas will assume an increasing share of the U.S. energy mix over the next several decades, with the large unconventional resource playing a key role."

The Future of Natural Gas (2010) MIT study

CH_4 → *Transportation (esp. diesel)*
→ *Power generation (esp. coal)*

US Shale Gas Production Potential

(based on mean resource estimates & current drilling rates)



From: The Future of Natural Gas (MIT 2010)
& http://www.nrcan.gc.ca/eneene/sources/natnat/2010/janjan-eng.php

Possible sources of methane:

- Conventional NG
- Tight & shale gas
- Biogas
- Arctic gas
- Methane hydrates
- Bio-synthetic NG

GHG savings of about 22% relative to gasoline or diesel.
Plus lower fuel costs.

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What is the Optimal Use of Biological Resources for Transportation?

Campbell et al 2009. Science 324: 1055 (22 May 2009)
Values for Small SUV, highway driving

CO_2

Hydrolysis & Fermentation

Ethanol

CO_2 Heat

Internal Combustion Vehicle (ICV)

CO_2 Inputs

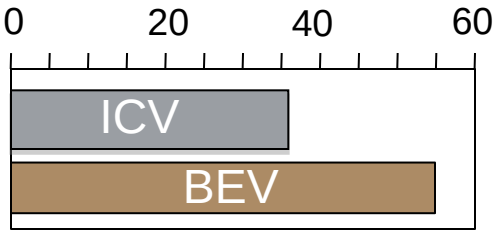
Forestry or Agric-ulture

1 Hectare Land

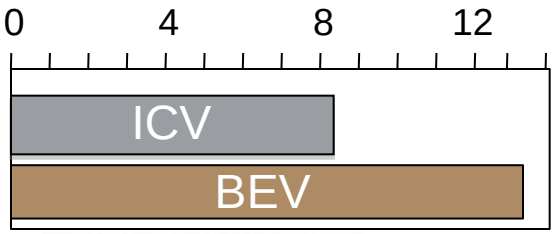
Ligno-cellulosic biomass

(wood & straw)

Distance (10^3 km/ha/yr)



CO_2 Offset Generated (t CO_2e/ha/yr)



Combustion or Gasification

Electricity

Battery Electric Vehicle (BEV)

CCS CO_2

Heat CHP

BEV Vehicles are more efficient than ICV in converting land area into km travelled or GHG emission reductions. They would be even better if CCS and CHP were used.

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Conclusions

1. Energy Security and Climate Change Concerns are likely to drive an energy system transformation in the next 10+ yrs.
2. In the near future, natural gas may offer an interim solution for fleet and vehicles and large trucks, trains, ships.
   - *~22% GHG reduction and poss. lower fuel costs;*
   - *How to achieve 65%+ emission reductions?*
3. Use of biological systems (Forestry and Agriculture) to provide wood/straw for transportation could help meet climate change targets.
   - *But technologies not yet ready for prime time*

Renewable Chemical Commodity Feedstocks from Integrated Catalytic Processing of Pyrolysis Oils

Tushar P. Vispute,[1] Huiyan Zhang,[1,2] Aimaro Sanna,[1,3] Rui Xiao,[2] George W. Huber[1]

Science 330:1222 (26 Nov. 2010)