Canadian Energy Systems 101

Part A. Fuel & Electricity Production and Use

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Your Energy Future

Calgary, Alberta
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UNIVERSITY OF CALGARY

About CESAR

CANADIAN ENERGY SYSTEMS ANALYSIS RESEARCH

CESAR develops and uses technology-based scenario modelling tools to inform policy and investment decisions on the transformation of Canada's anthropogenic energy and carbon flows to achieve sustainability.

With a focus on the anthropogenic energy and carbon flows of Canada, CESAR:

1. **BUILDS DATA RESOURCES & VISUALIZATION TOOLS**
2. **ANALYZES PAST ENERGY / CARBON SYSTEMS**
3. **MODELS FUTURE ENERGY / CARBON SYSTEMS**

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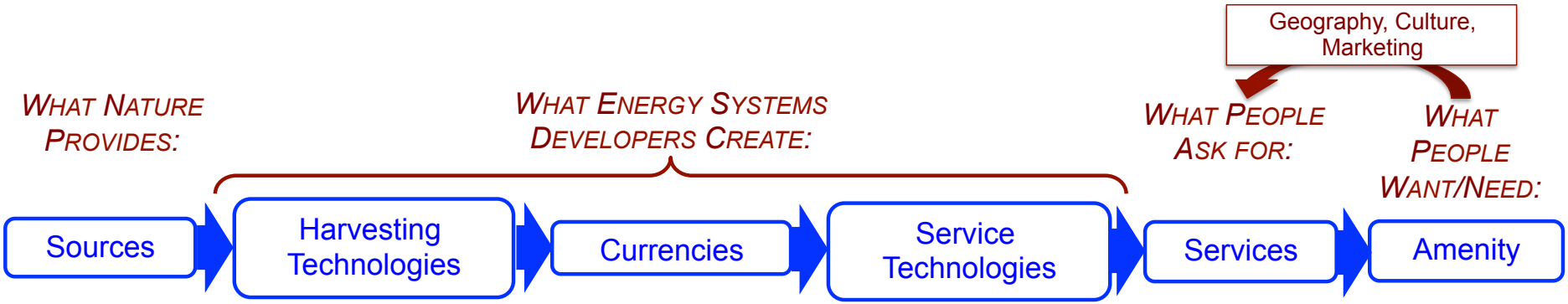
What are 'Energy Systems'?



- Coal
- Oil
- Natural gas
- Sunlight
- Wind
- Uranium
- Biomass
- Geothermal

…

- Oil Refinery
- SAGD facility
- Hydraulic fracturing
- Anaerobic digester
- Pipeline
- Nuclear power plant
- Coal power plant
- Gas turbine
- Solar panel
- Wind turbine

- Gasoline
- Diesel
- Electricity
- Methane
- Ethanol
- Hydrogen

…

- Automobile
- Telephone
- Light bulb
- Refrigerator
- X-ray machine
- Computer
- Furnace

…

- Comfortable, convenient, travel;
- Vacations;
- Large homes
- Food and drink;
- "Things"

…

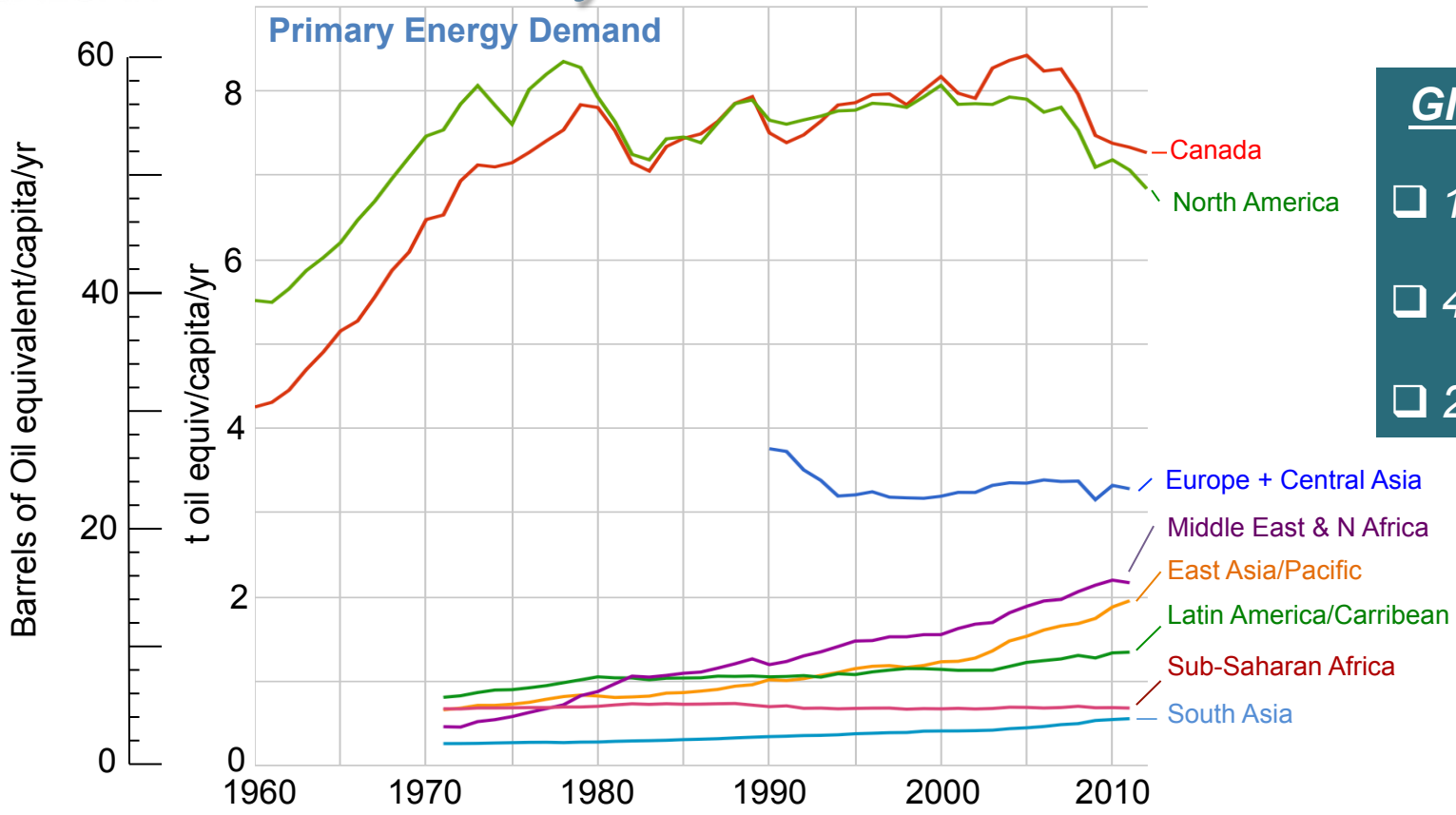
- Community
- Comfort
- Convenience
- Sustenance
- Illumination
- Healthy food
- Health care
- Clean water
- Status/value

…

Note: *'Energy Systems' only include anthropogenic flows of energy associated with the production and use of* ***Fuels and Electricity*** *(not Food or Fibre).*

Adapted from "Smelling Land" by David Sanborn Scott

Many others want the kind of energy systems we have…



Global Reality:

- *1.5B served;*
- *4B want more;*
- *2B unserved.*

From World Bank via Google Public data

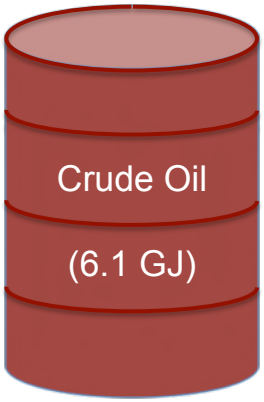
Joule: A SI* Unit of Work or Energy

** International System of Units*

One Joule (J):
the work required to produce one watt of power for one second.

kilo	kJ	10^3 J
Mega	MJ	10^6 J
Giga	GJ	10^9 J
Terra	TJ	10^{12} J
Peta	PJ	10^{15} J
Exa	EJ	10^{18} J

One GJ = 278 kWh:
Work energy to power 100 watt light bulb for almost 4 months.



Barrel of oil (159 L)
= ~6.1 GJ

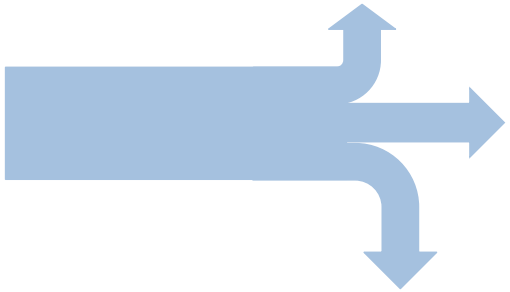
Also = Annual food consumption for a very muscular, hard working person.
(Couch potato: ~3.4 GJ/yr)

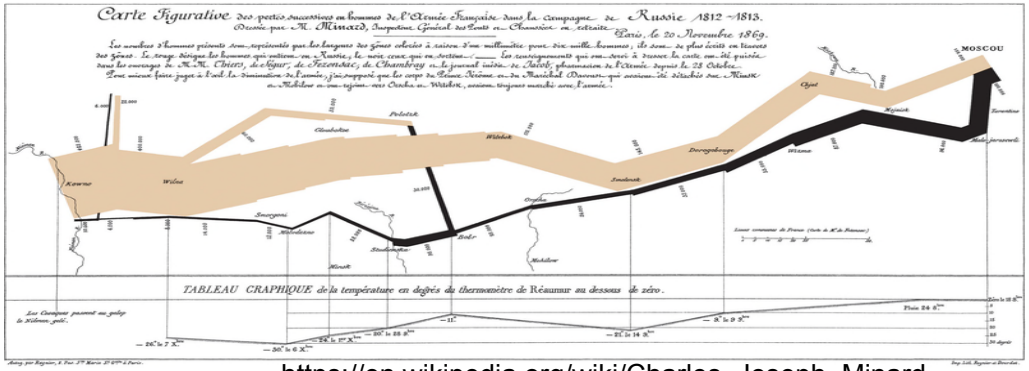
Food Energy Calculation

- ✓ 1 **C**alorie (food) = 1000 **c**alories (energy);
- ✓ Conversion Factor: 4180 J/Calorie;
- ✓ Assume person works 8 hr/day X 5 day/week X 52 wks /yr
- ✓ Food intake of 86 Cal/hr (360 kJ/hr) for time not in heavy labour (128 hr/wk)
- ✓ Food intake of 430 Cal/hr (1800 kJ/hr) for time doing heavy labour (40 hr/wk);

6.1=((8X5X52X1800)+(16X5X52X360)+(24X2X52X360))/1e6

Sankey Diagrams:
Used to Depict Flows

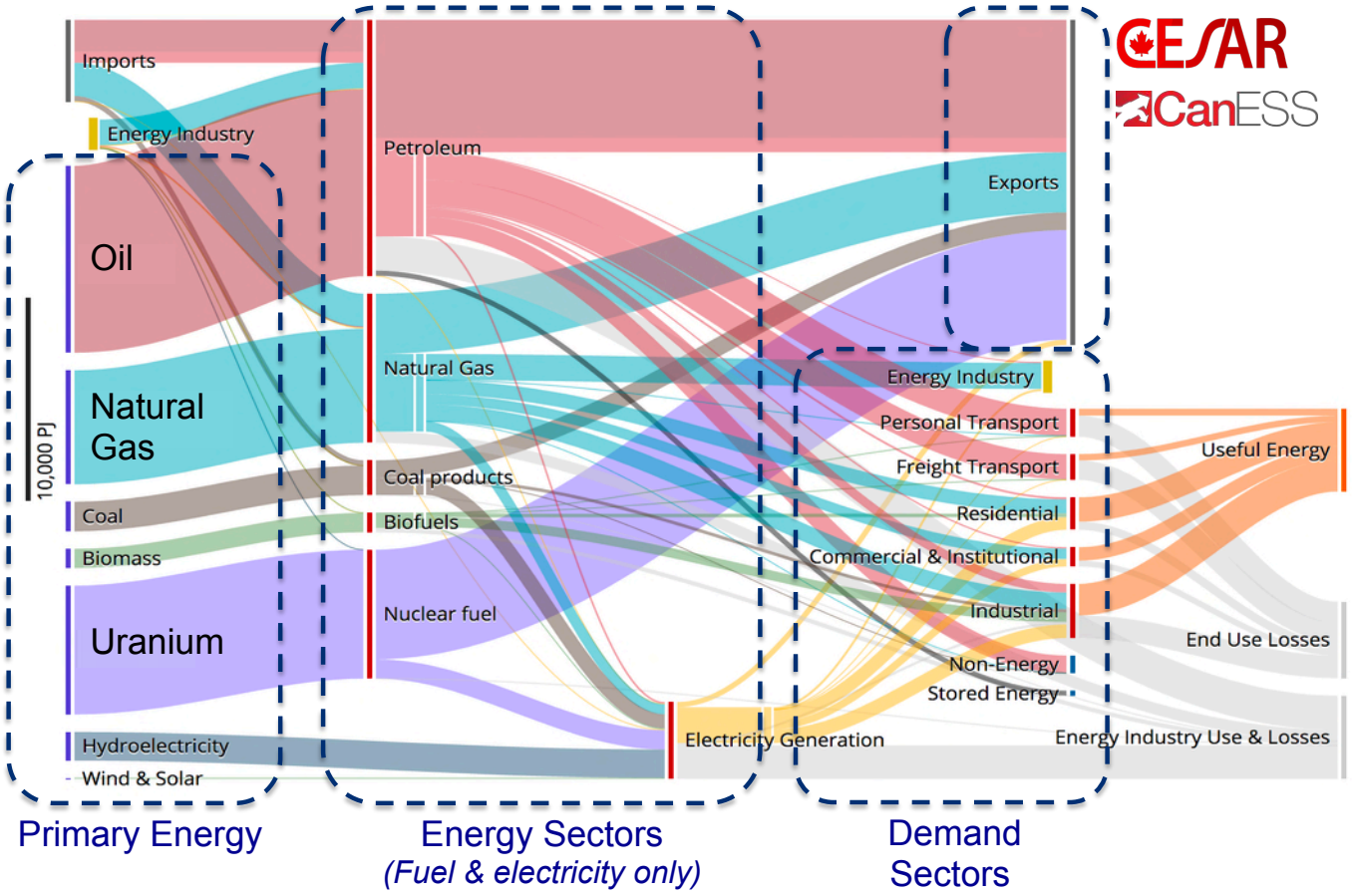




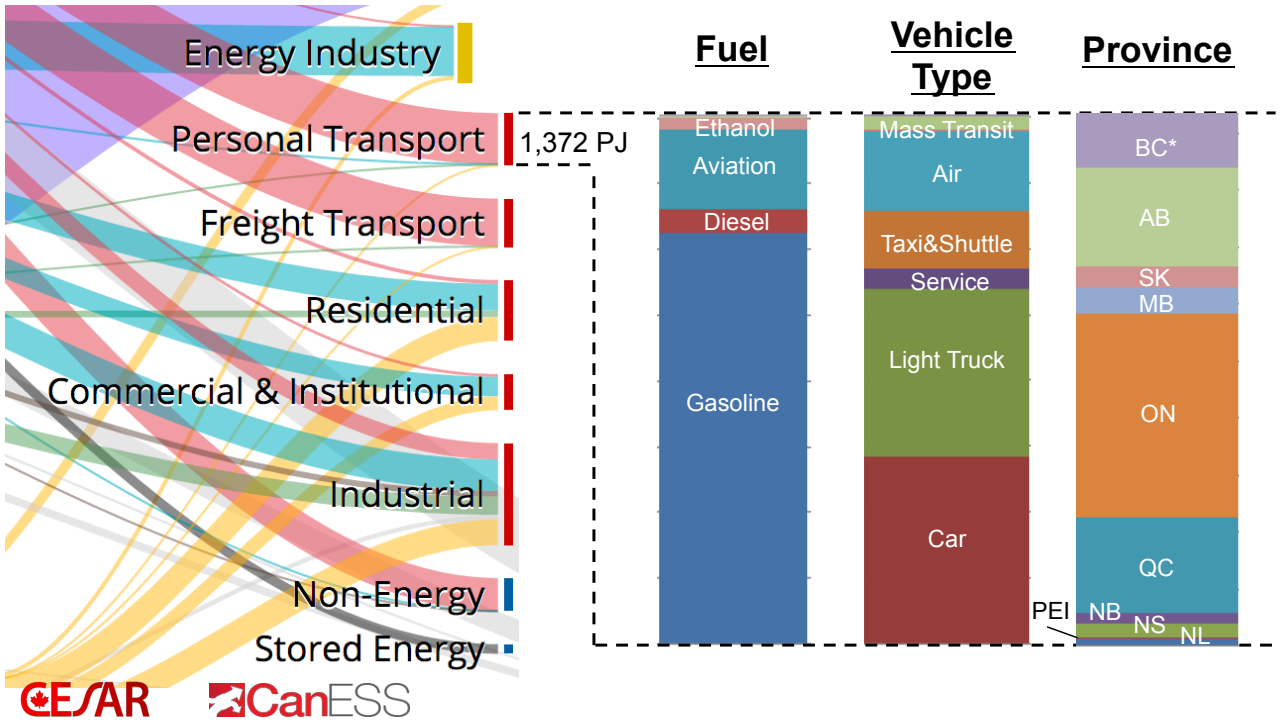
https://en.wikipedia.org/wiki/Charles_Joseph_Minard

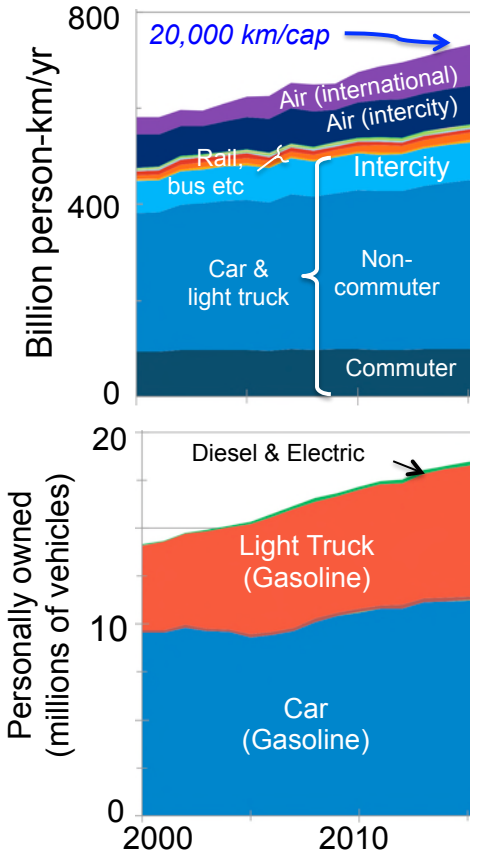
- Width of arrows drawn in proportion to the flow
- **1869: Charles Minard** drew a diagram of Napolean's Russian Campaign of 1812, depicting declining troop numbers across E Europe;
- **1898: Mathew Sankey** drew diagram depicting energy efficiency of steam engine.
- Widely used to show flow through energy systems

Canada's Fuel & Electricity Systems (2013)

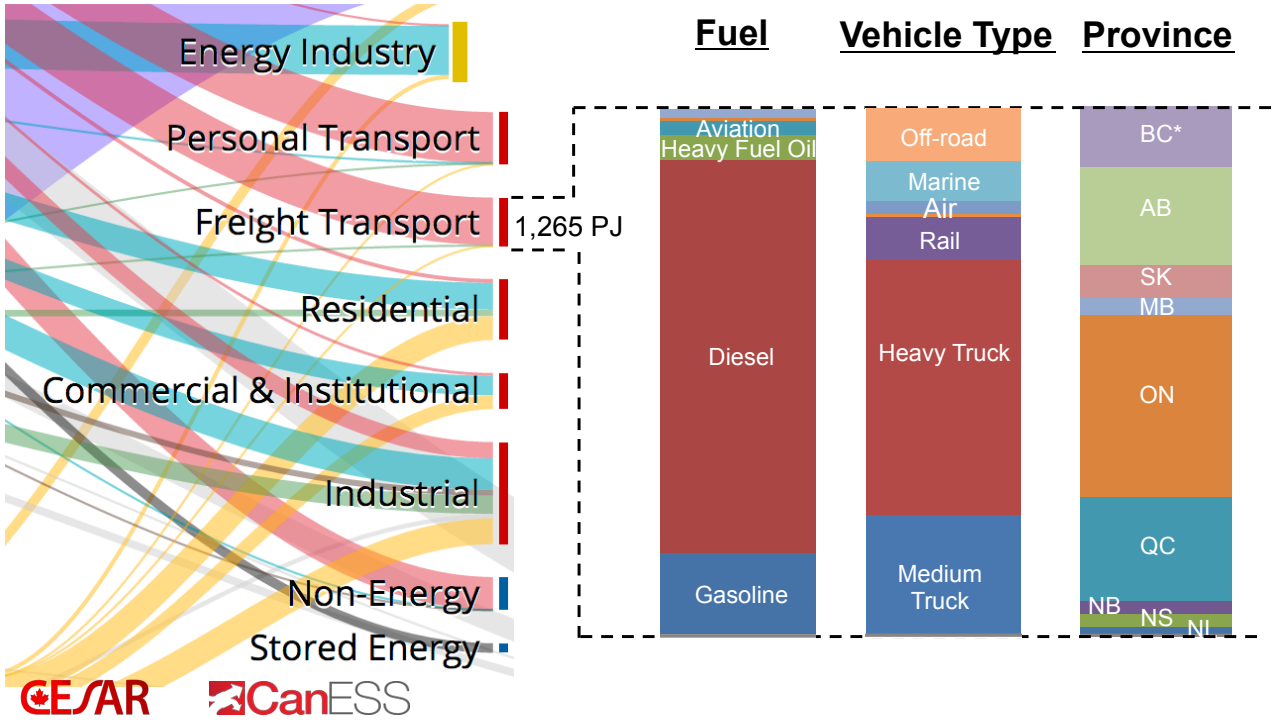


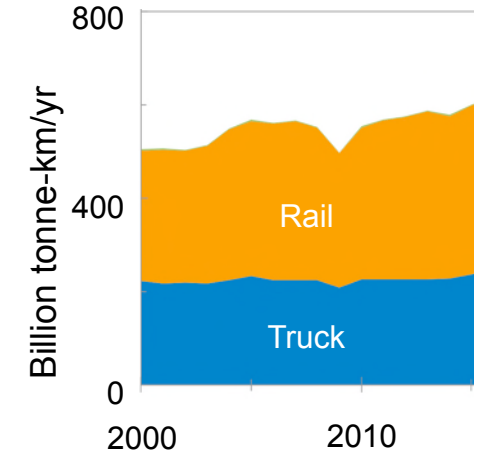
Personal Transportation in 2013

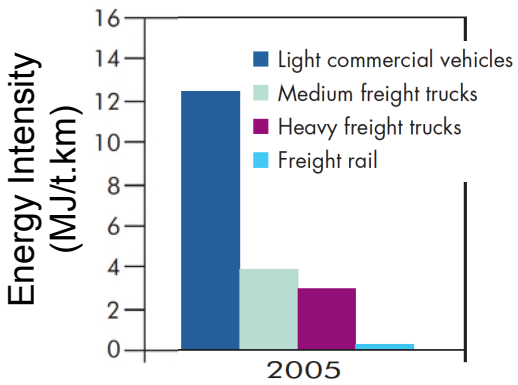




Freight Transportation in 2013

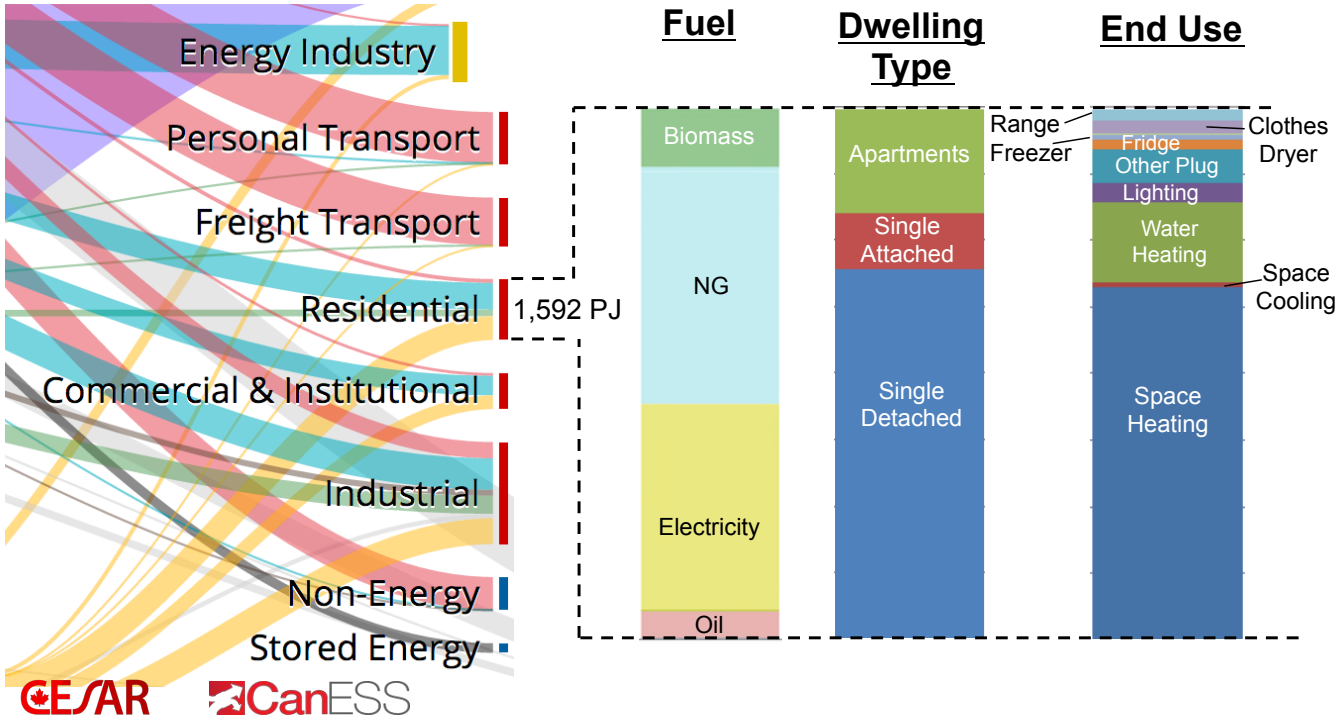


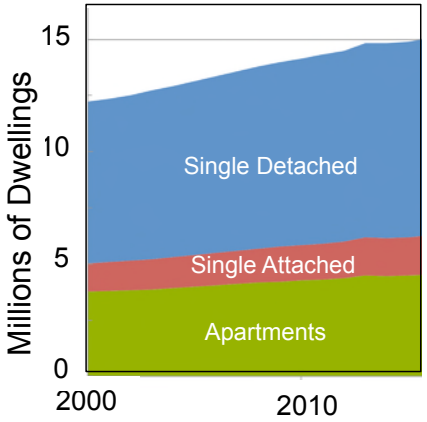




* Energy intensity Data from Fig 6.5. IEA 2009. https://www.iea.org/publications/freepublications/publication/transport2009.pdf

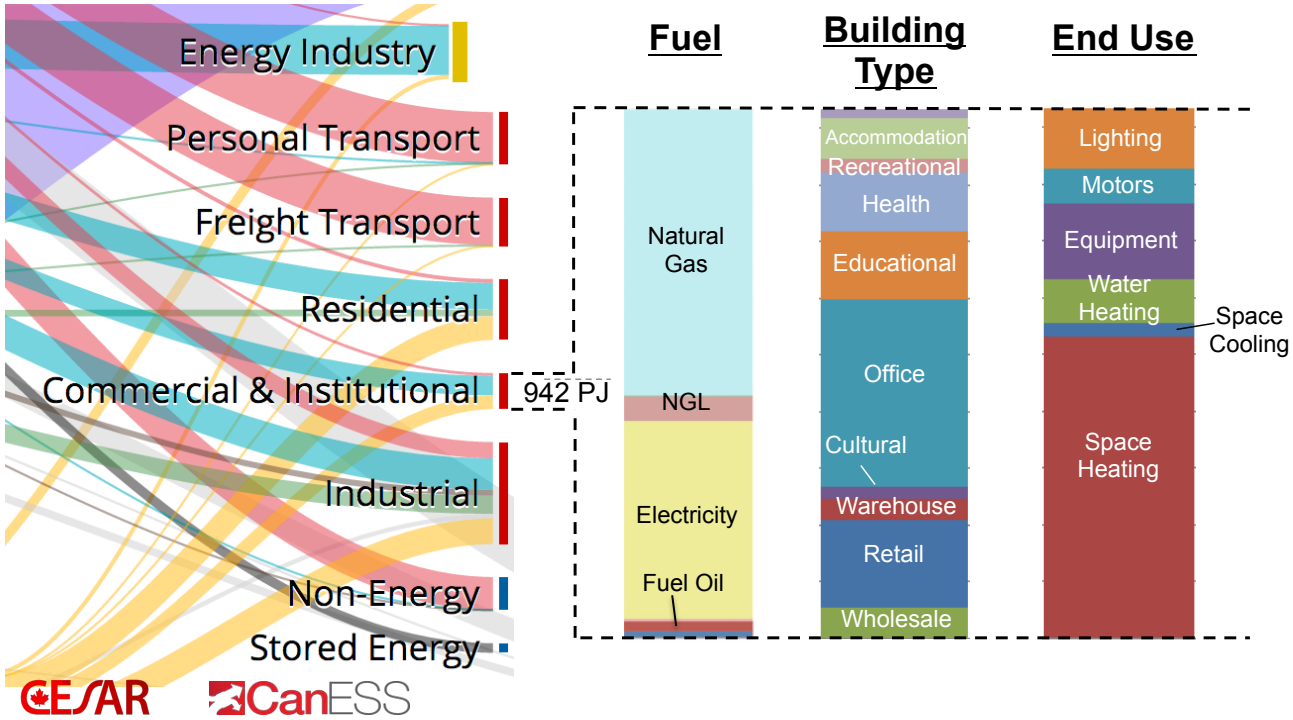
Residential Buildings (2013)

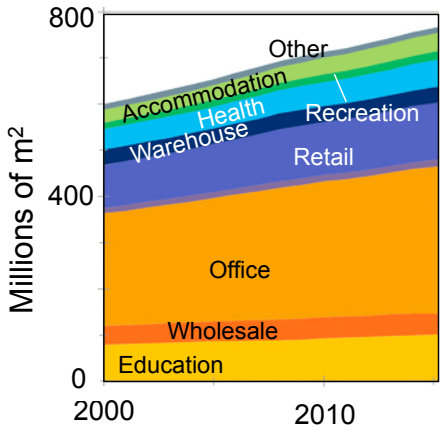




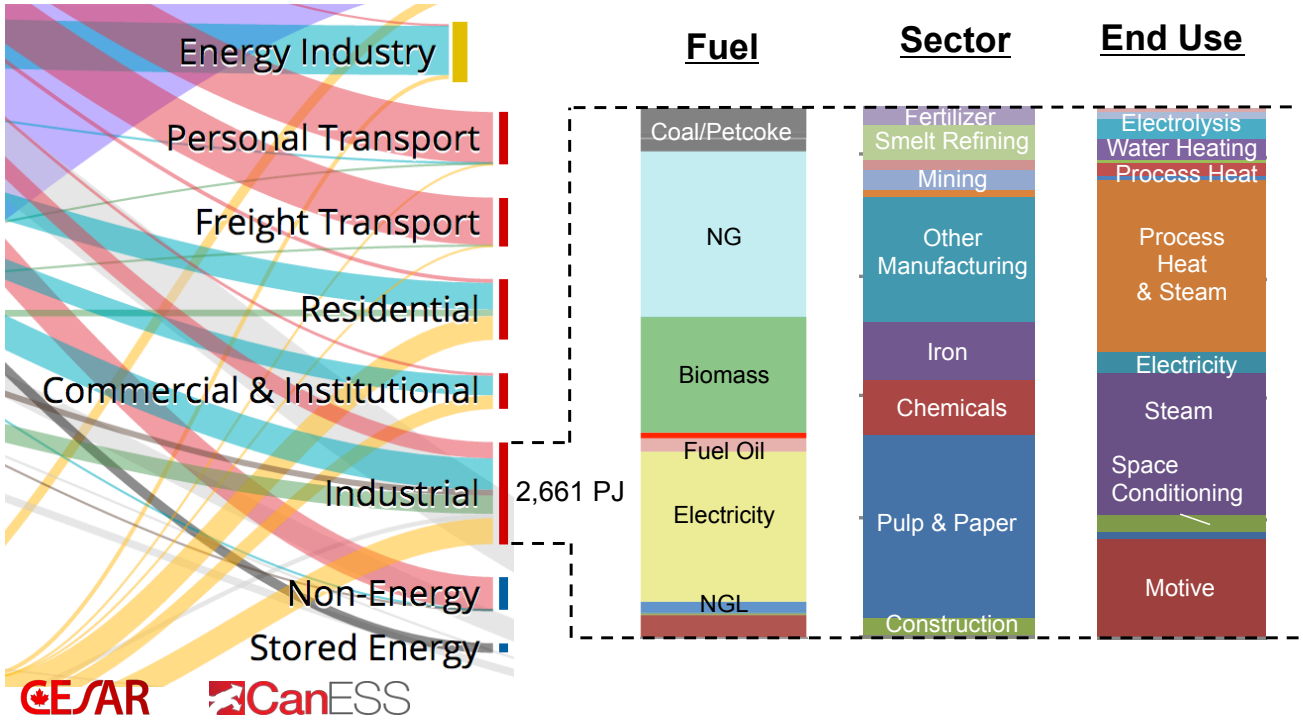
Average house size data from http://shrinkthatfootprint.com/how-big-is-a-house

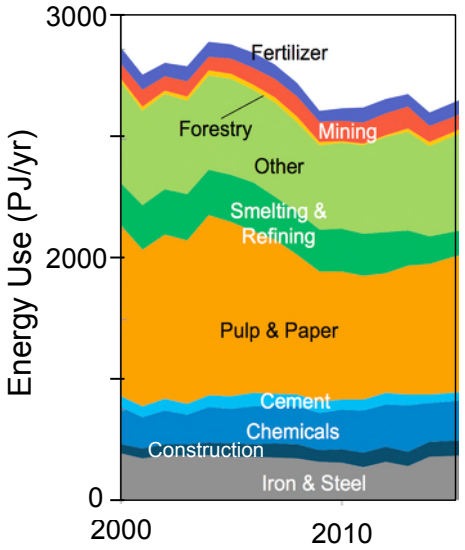
Commercial & Institutional Buildings (2013)





Energy using Industries (2013)





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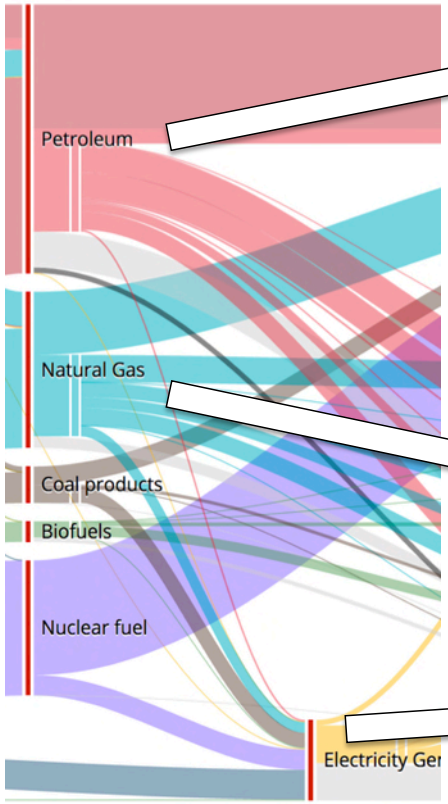
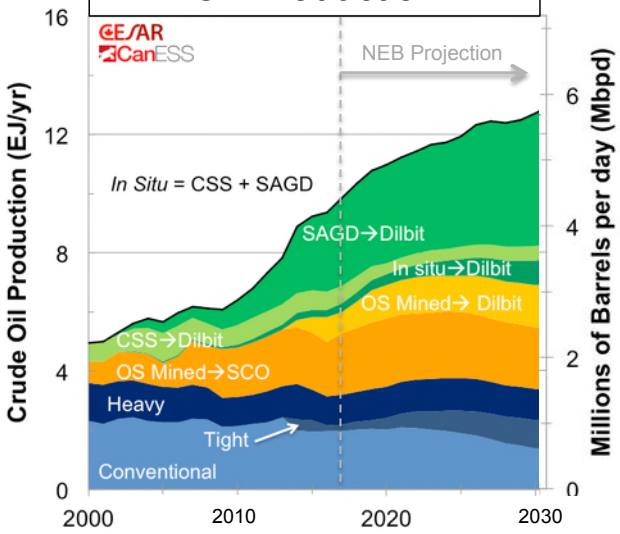
Energy Sectors

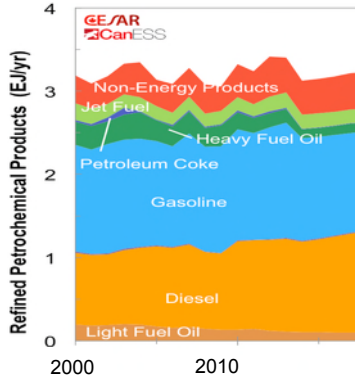
CANADIAN ENERGY SYSTEMS ANALYSIS RESEARCH



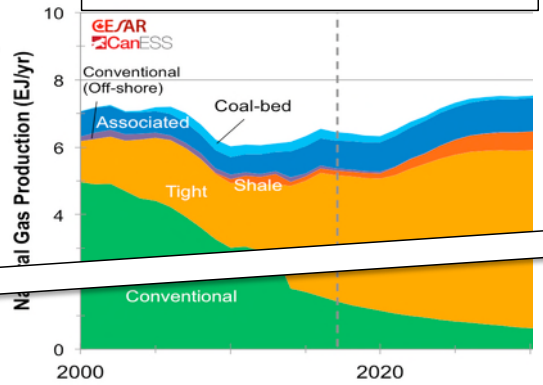
Oil Production



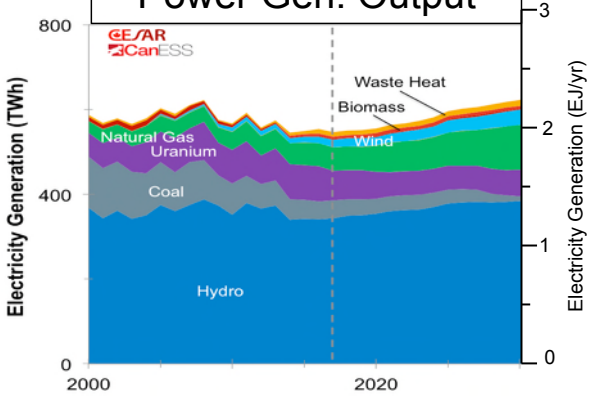
Refined Petroleum Products



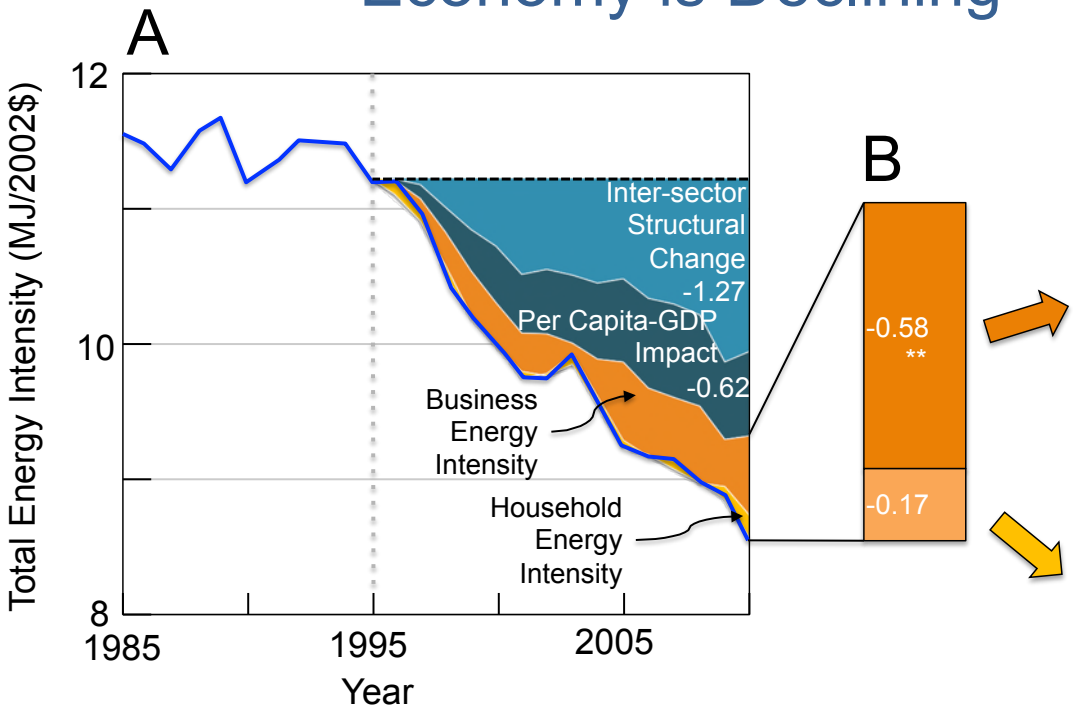
Natural Gas Production

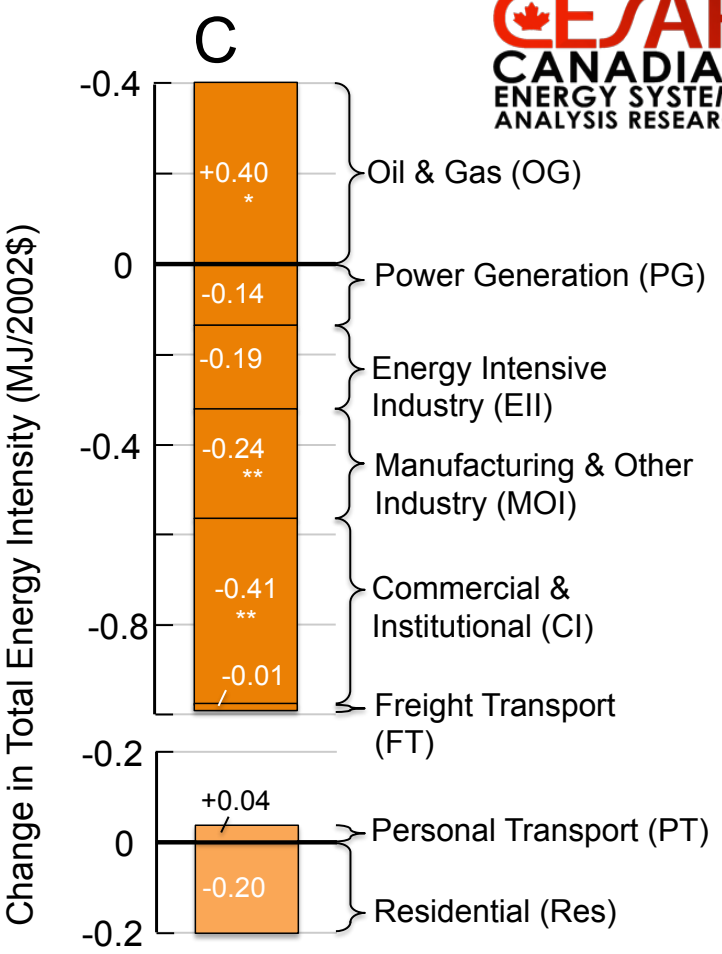


Power Gen. Output



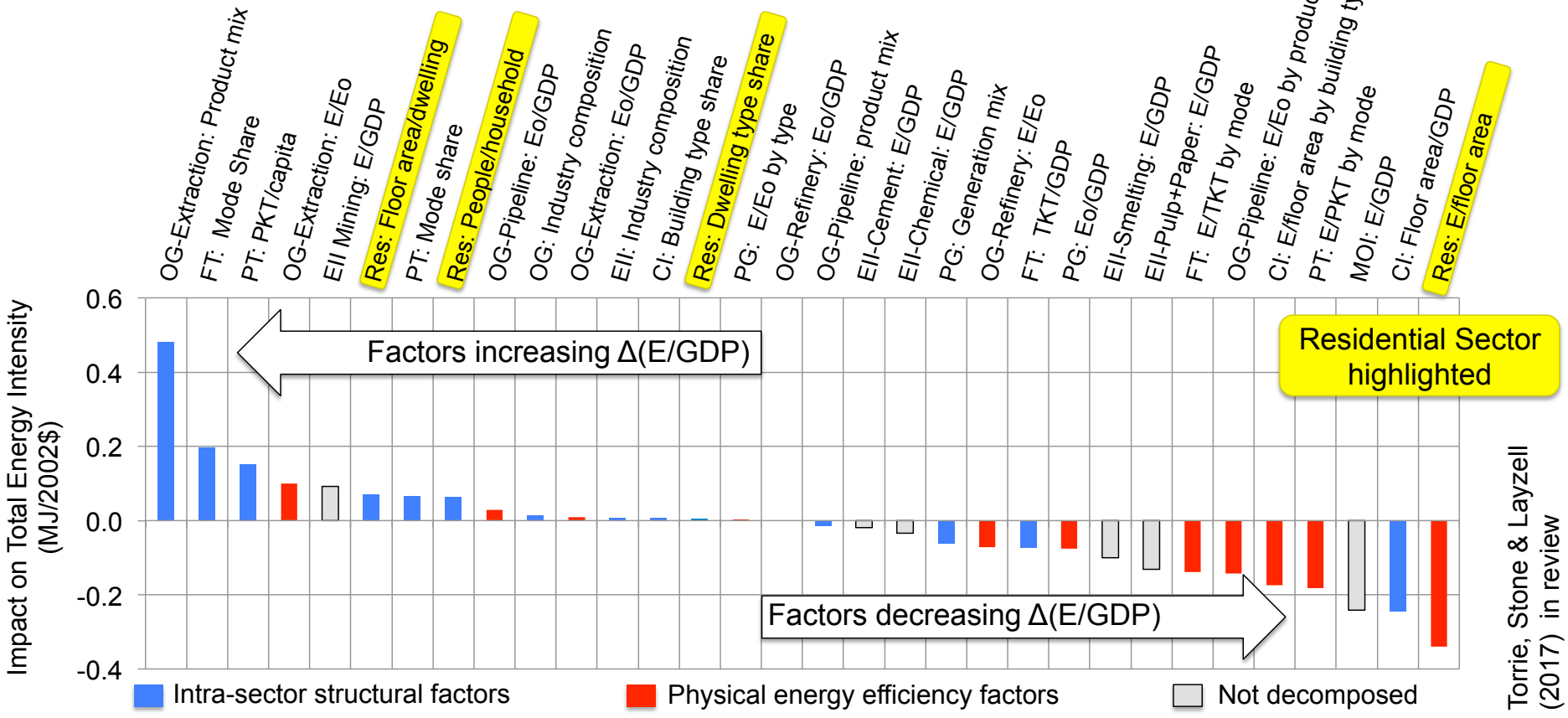
The Energy Intensity (MJ/$GDP) of the Canadian Economy is Declining





Torrie, Stone & Layzell (2016) Energy Economics 56: 101-106

Within Each Sector, there are often Counteracting Forces



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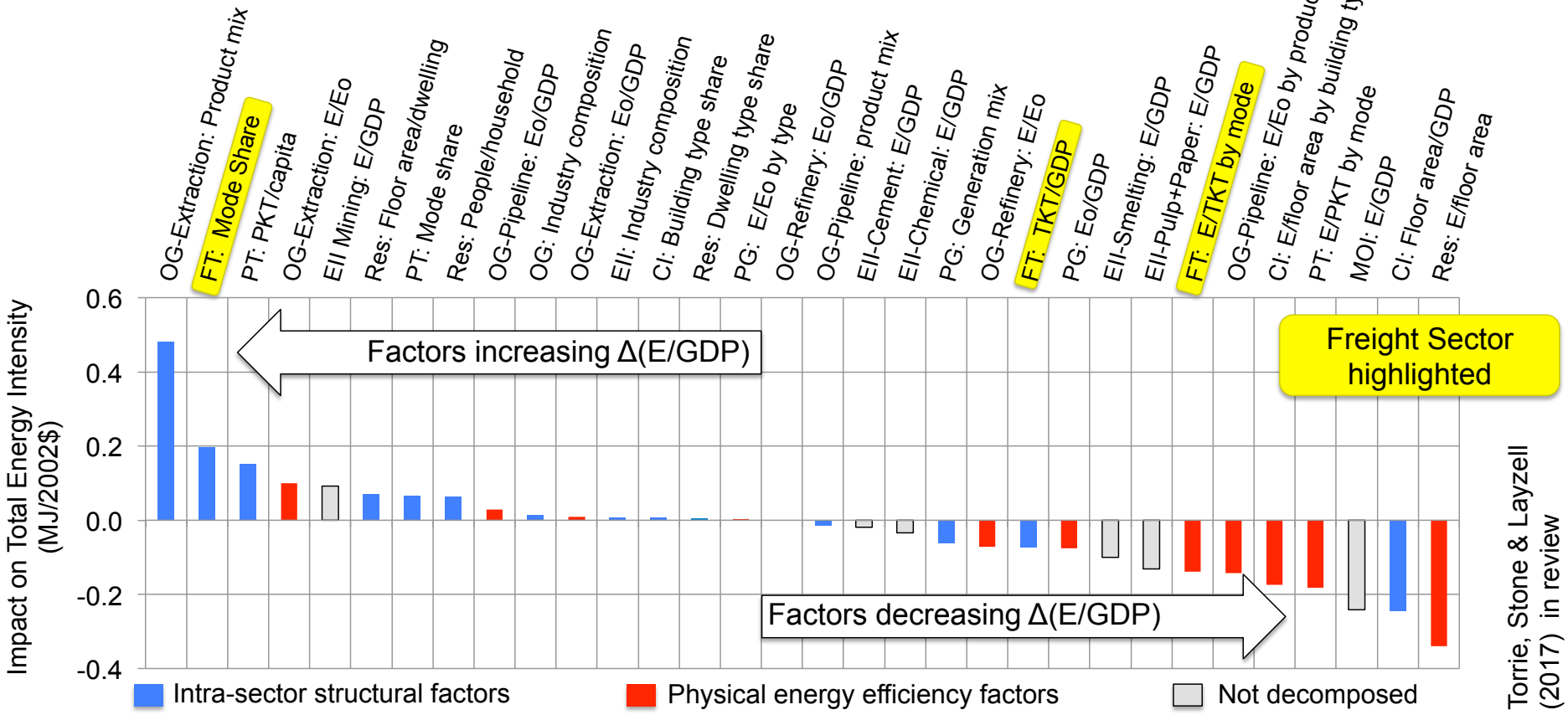

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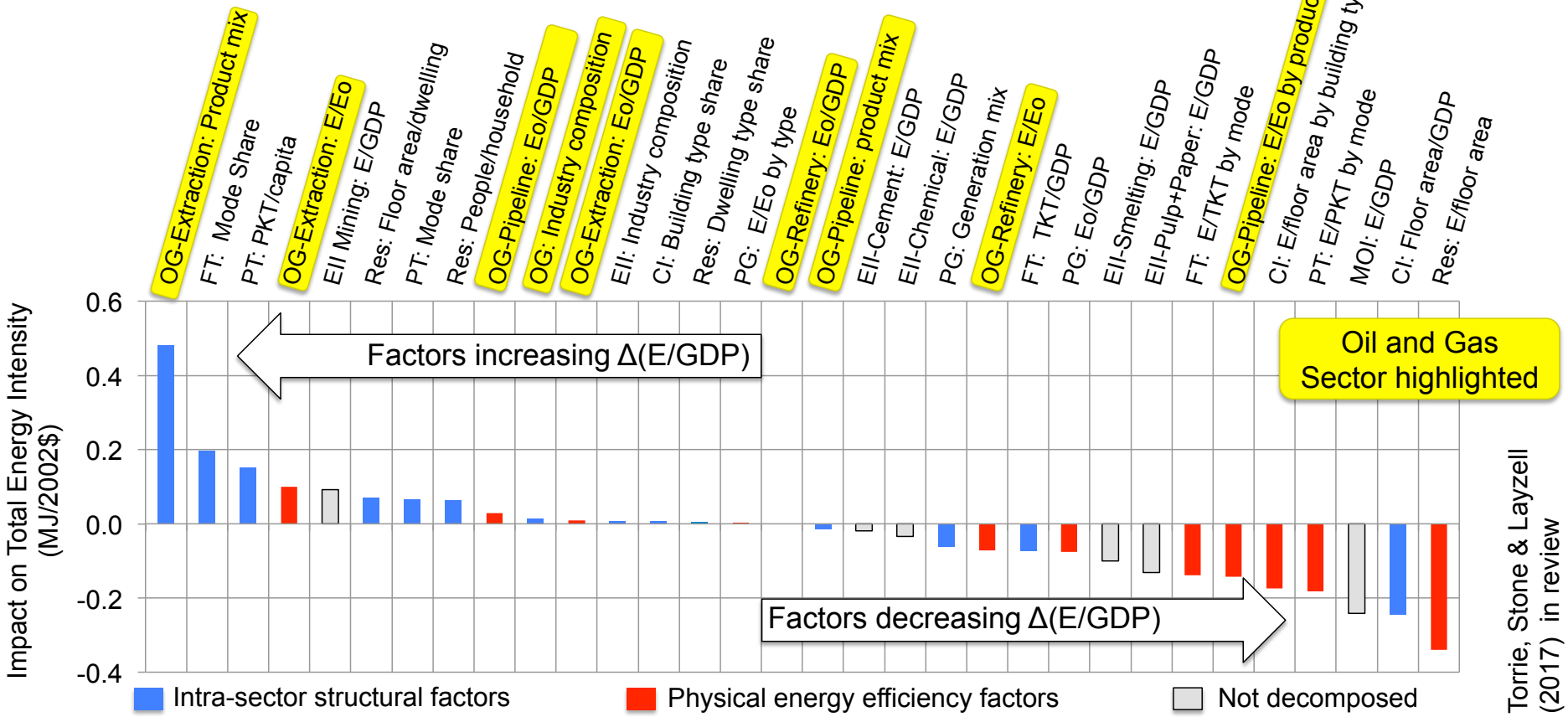
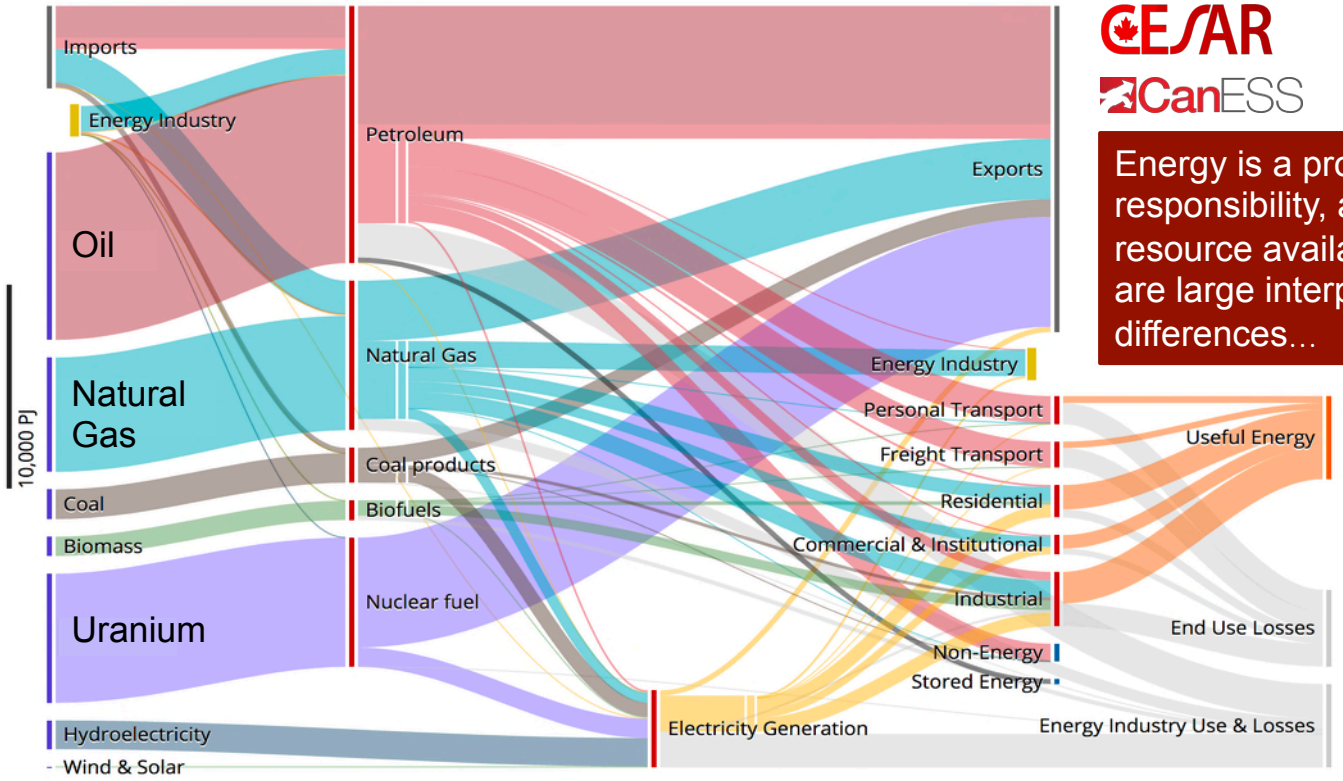


Canada's Fuel & Electricity Systems (2013)

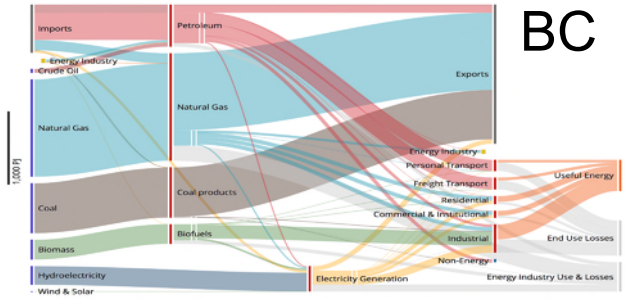


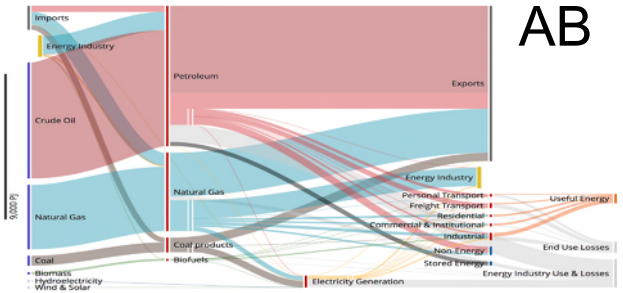
Energy is a provincial responsibility, and given resource availability, there are large interprovincial differences…

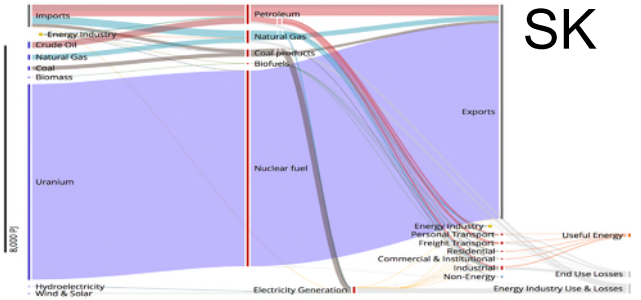
CESAR CanESS

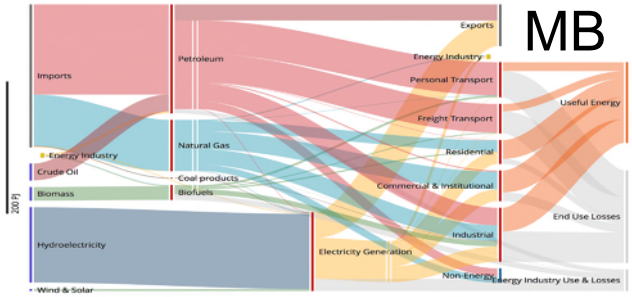
(www.cesarnet.ca)

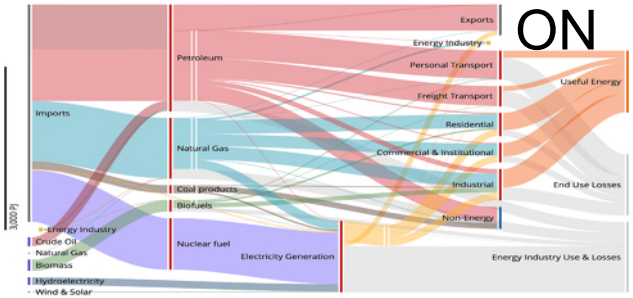
Provincial Energy Systems (2013)

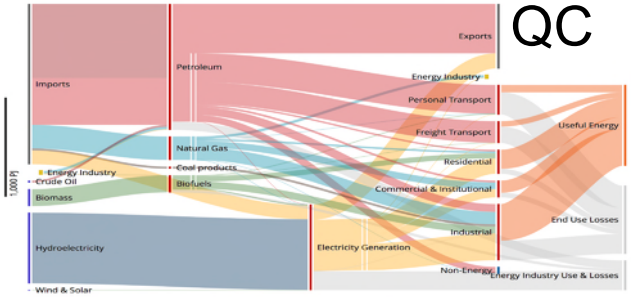


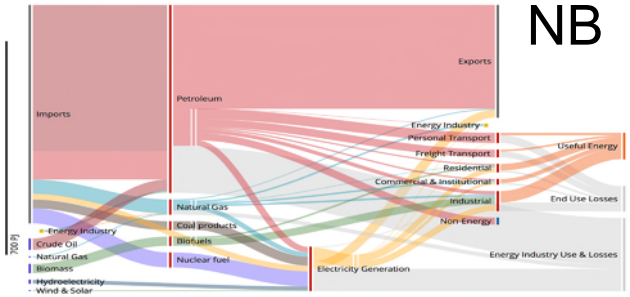


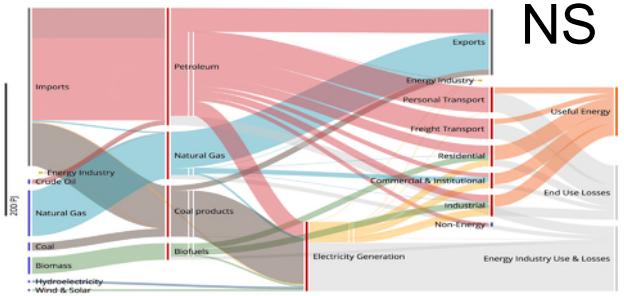


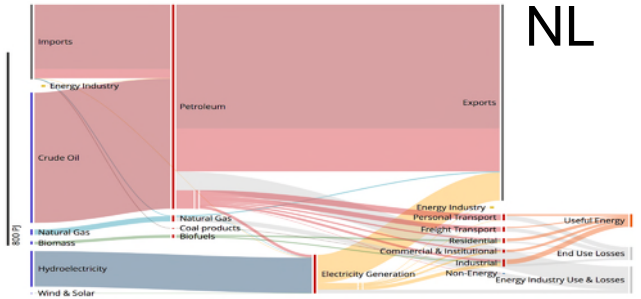












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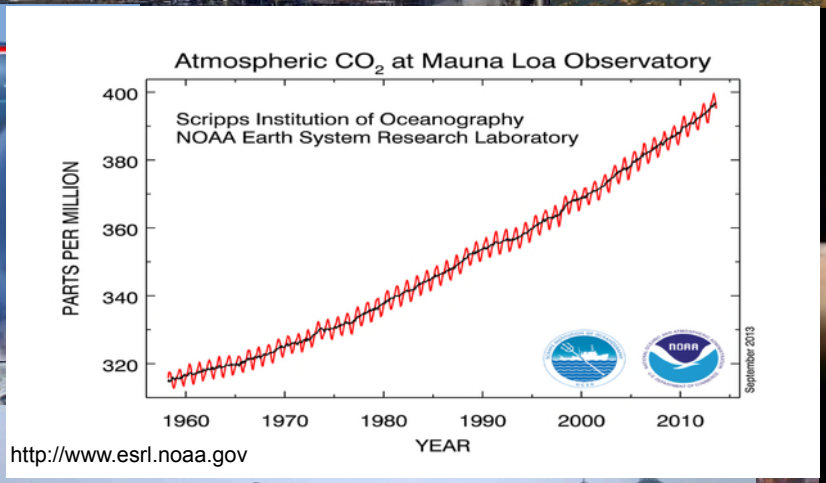
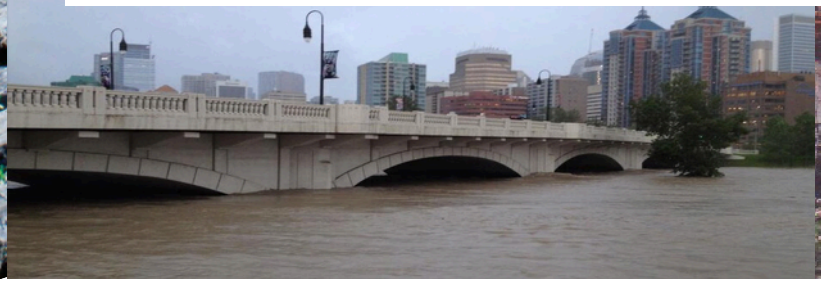
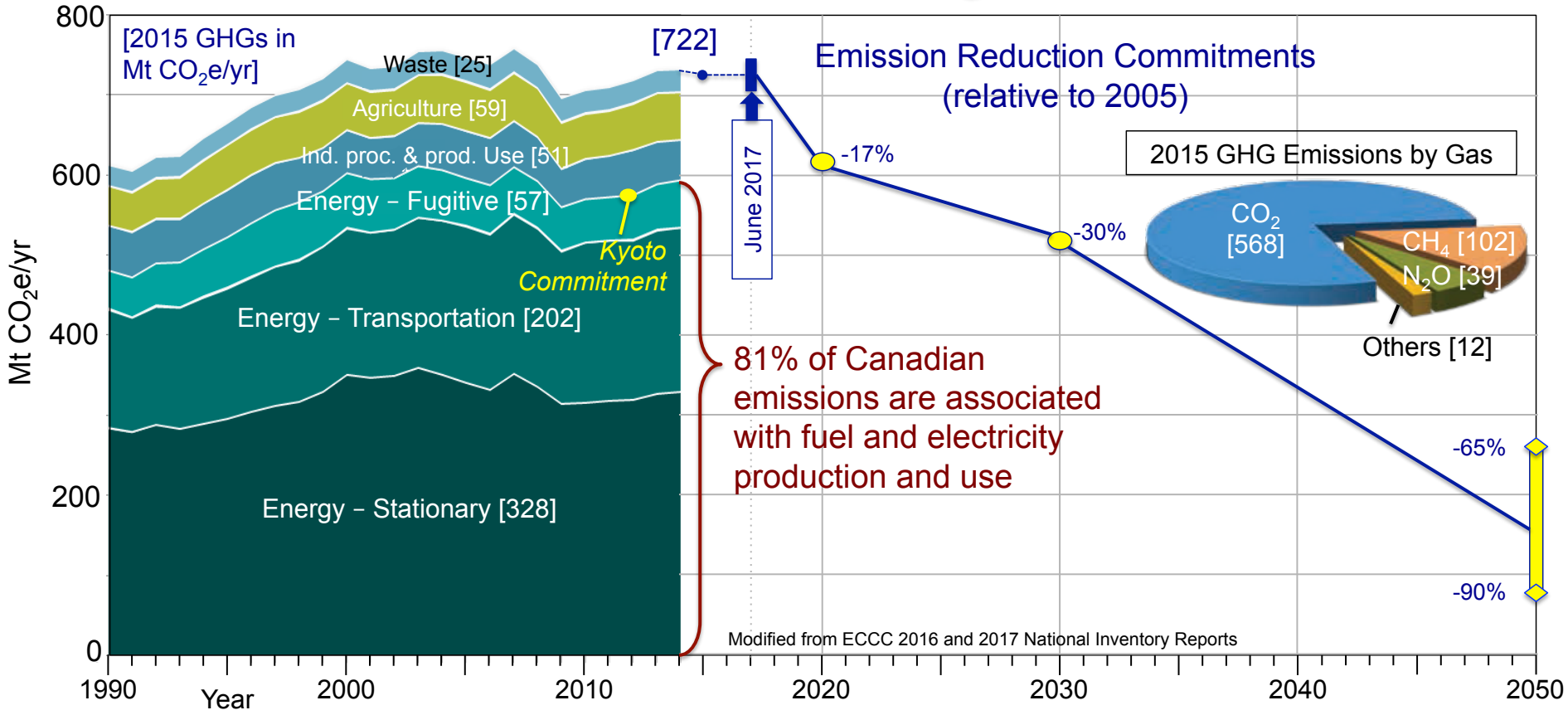
Energy Systems and the Climate Change Challenge

Unintended Consequences of Canada's Energy Systems





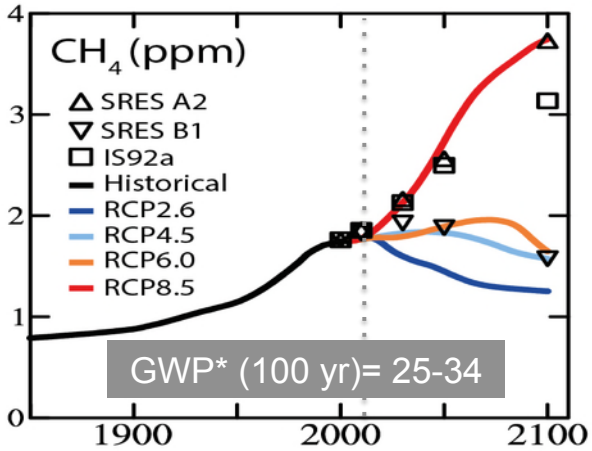
Canada's Greenhouse Gas (GHG) Emissions & Targets



Anthropogenic Greenhouse Gases (GHGs)

Percent [and ppm] increase since 1850

CH_4:
100% [0.9 ppm]

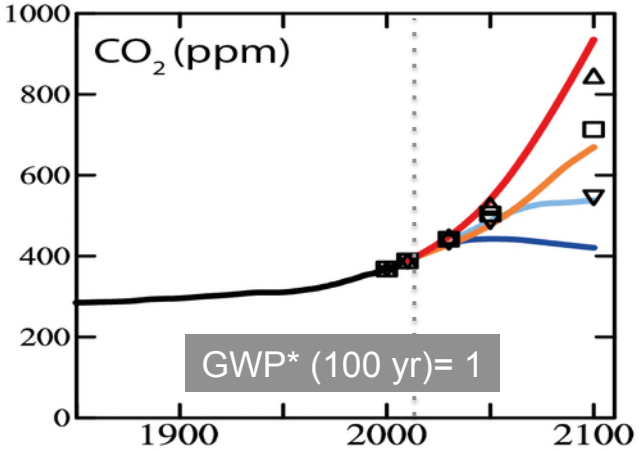


Energy system sources:
- Natural gas leaks

Bio-Sources:
- Anaerobic Metabolism

Bio-Sinks:
- Methane oxidation

CO_2:
43% [120 ppm]

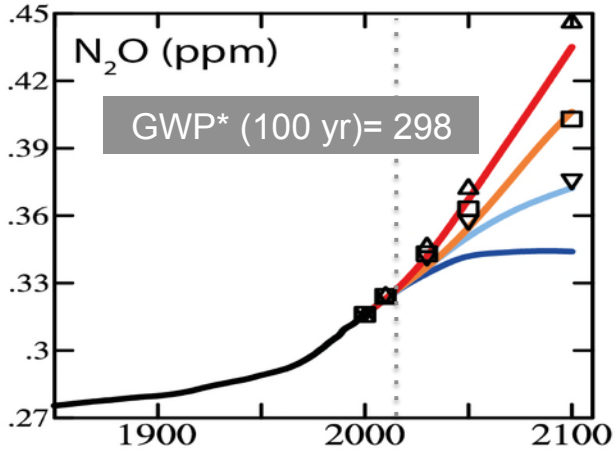


Energy system sources:
- Fossil fuel combustion

Bio-Sources:
- Respiration
- Biomass combustion

Bio-Sinks:
- Photosynthesis

N_2O:
18% [0.05 ppm]



Industrial sources:
- Nylon production

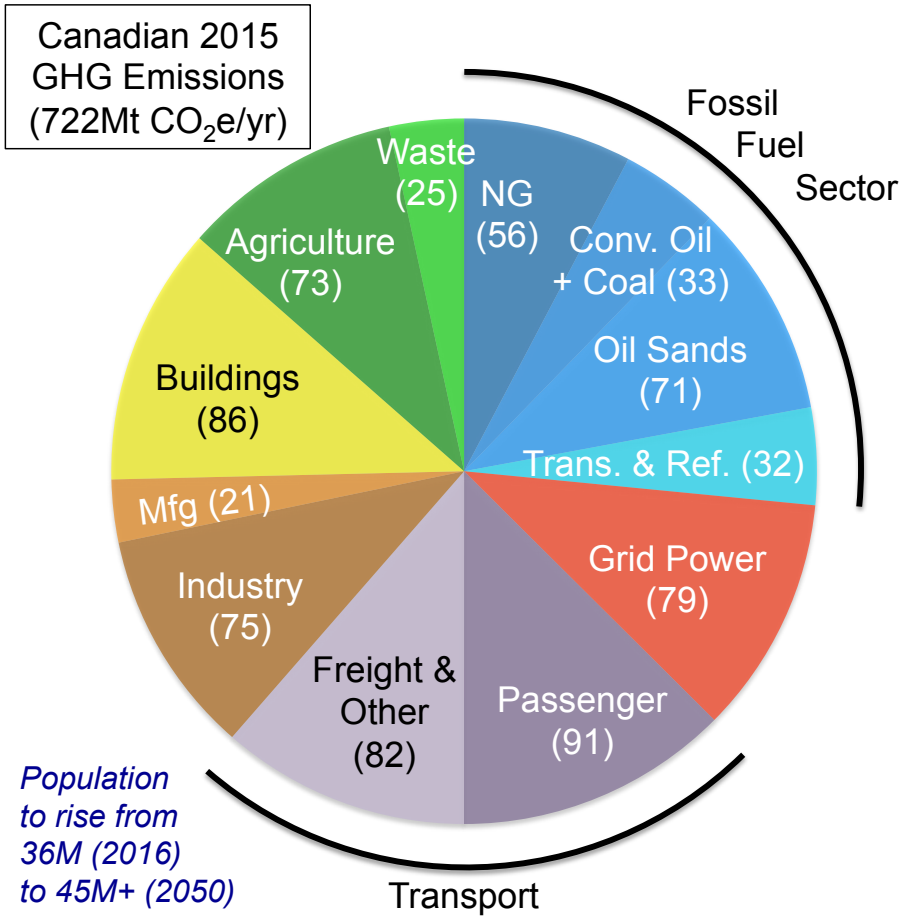
Bio-Sources:
- Nitrification
- Denitrification

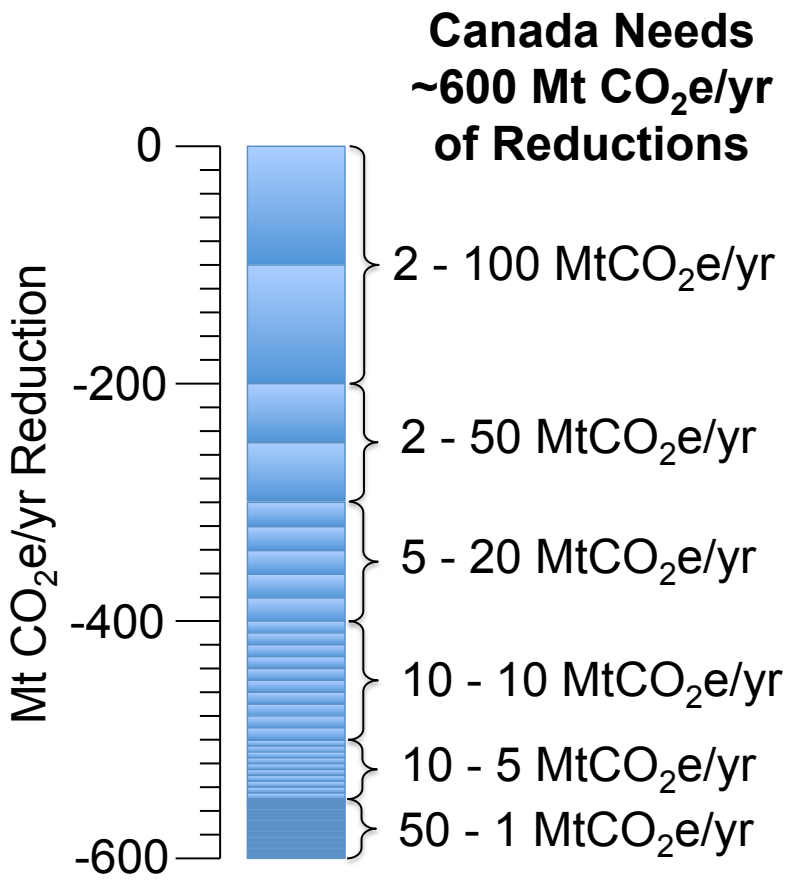
Bio-Sinks:
- N_20 reduction

*Global Warming Potential (rel. to CO_2)

From **Climate Change 2013: The Physical Science Basis,** International Panel on Climate Change (IPCC) http://www.ipcc.ch/report/graphics/index.php?t=Assessment%20Reports&r=AR5%20-%20WG1&f=Chapter%2008

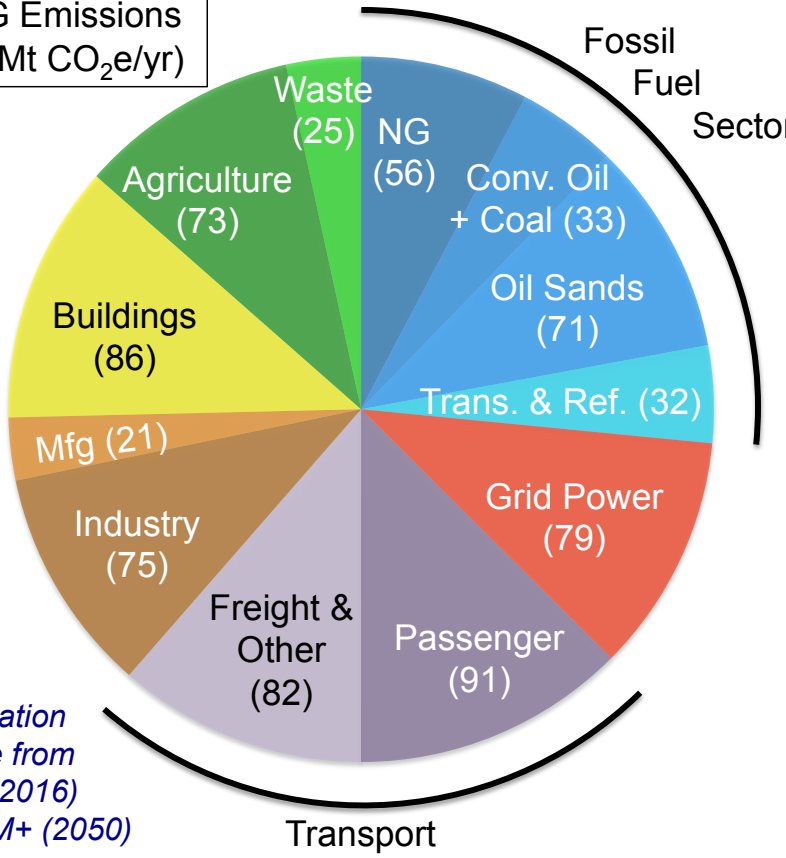
The Climate Change Challenge





Climate Change Solutions

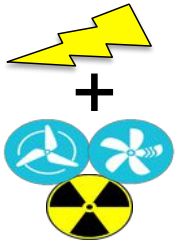
Canadian 2015 GHG Emissions (722Mt CO_2e/yr)



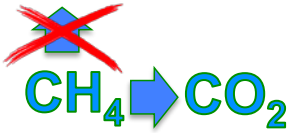
Population to rise from 36M (2016) to 45M+ (2050)

Energy Efficiency & Conservation *(incl. technology & behavioural change)*

Biofuels *(to displace fossil fuels)*



Electrification *(to displace C based fuels) with* Low/Zero C power generation



Prevent CH_4 or N_2O from entering atmosphere

CO_2 removal & storage (Geological or Biological)