From each according to his ability; to each according to his needs

Karl Marx's dictum as applied to energy supply and consumption in a North American context

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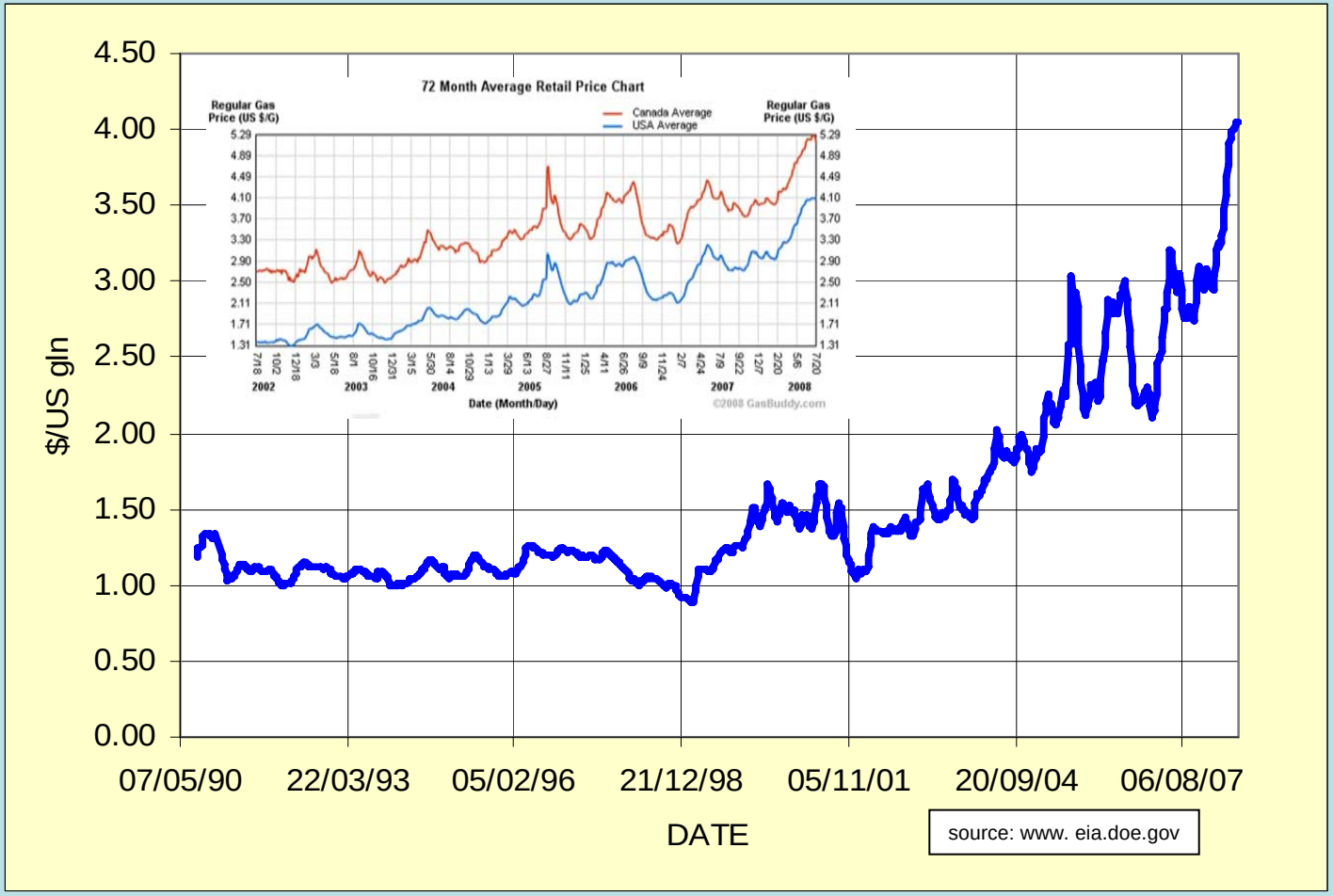
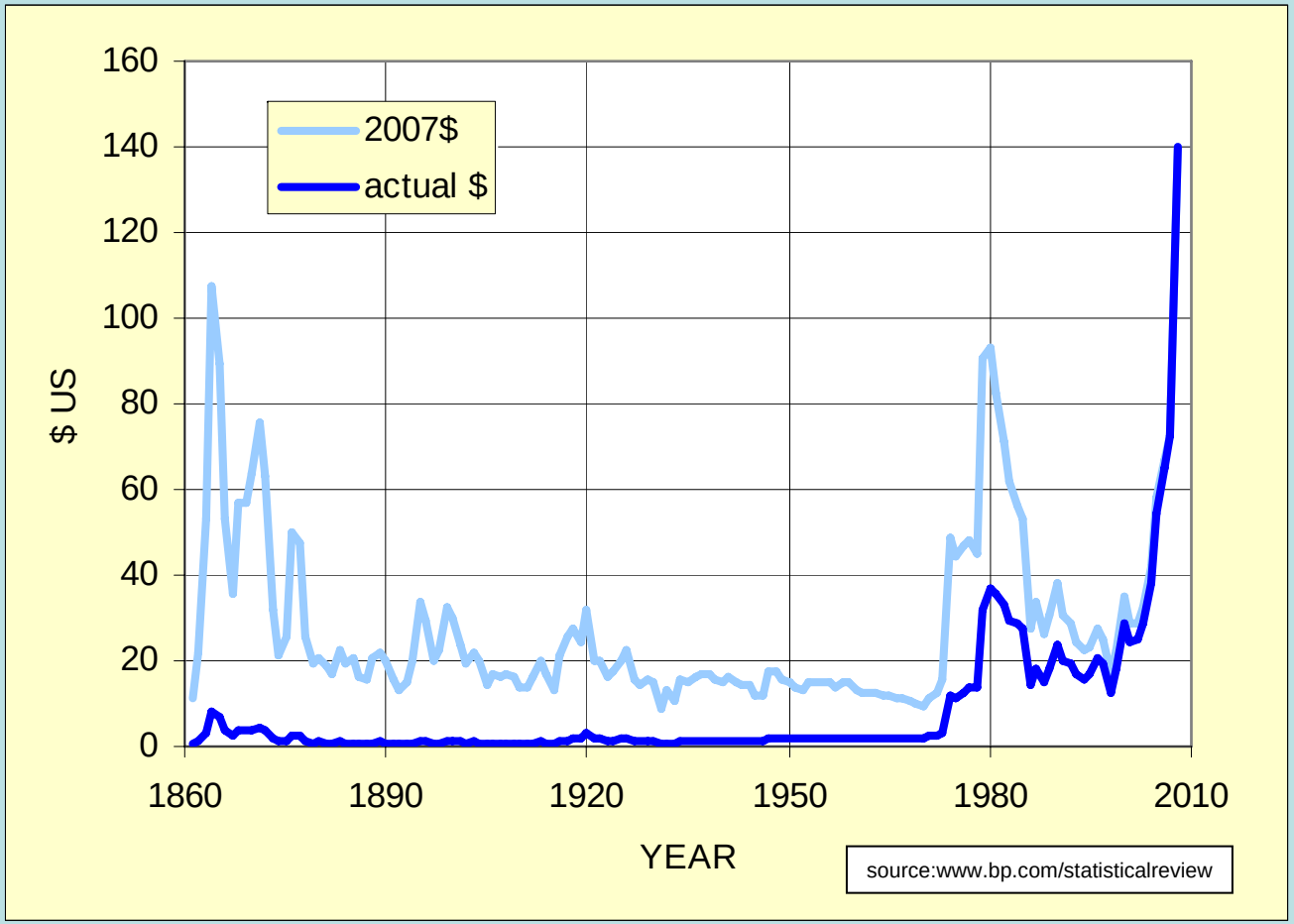
PROVIDENCE
ESTABLISHED 1925
COLLEGE & SEMINARY

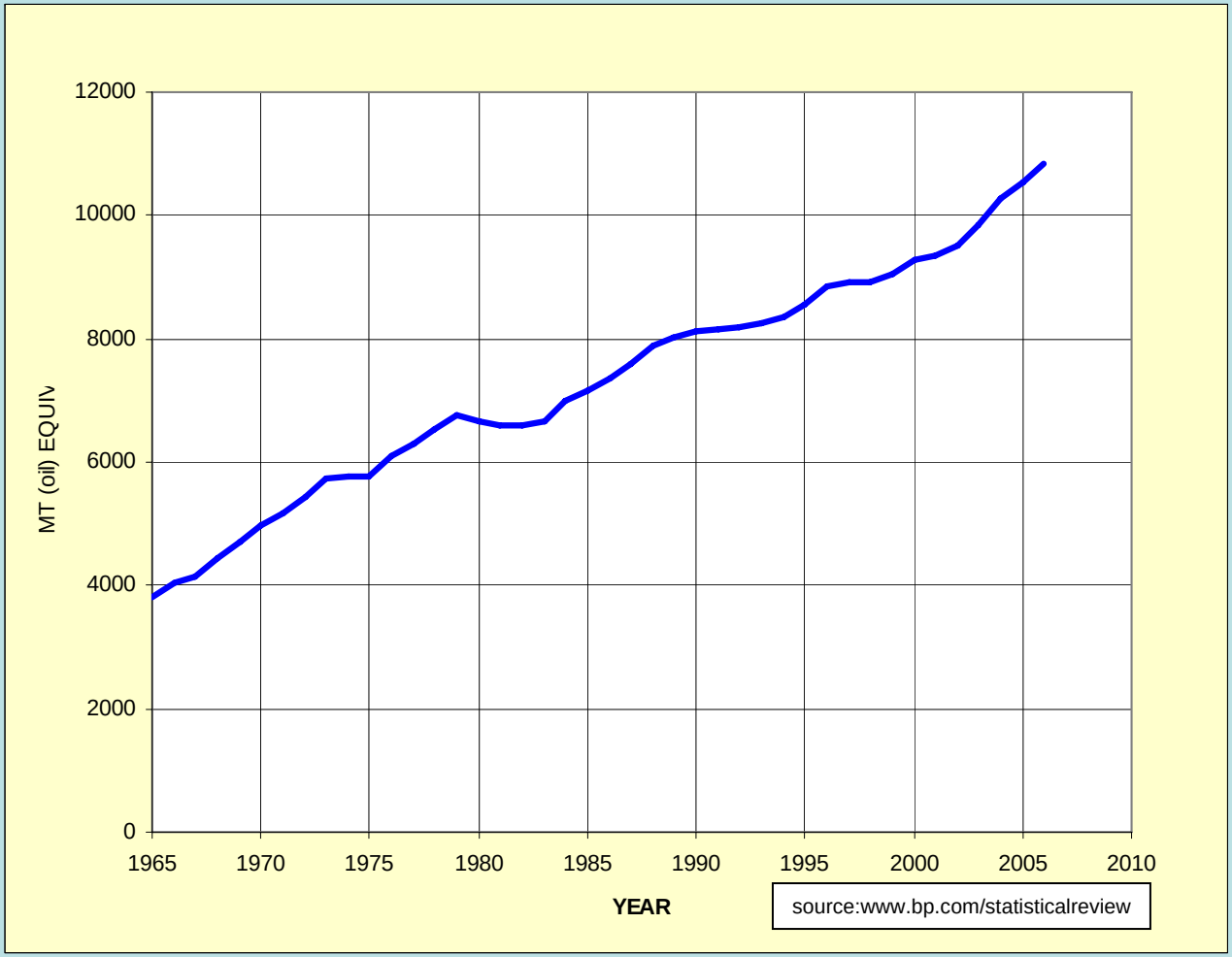
historic US retail gasoline prices



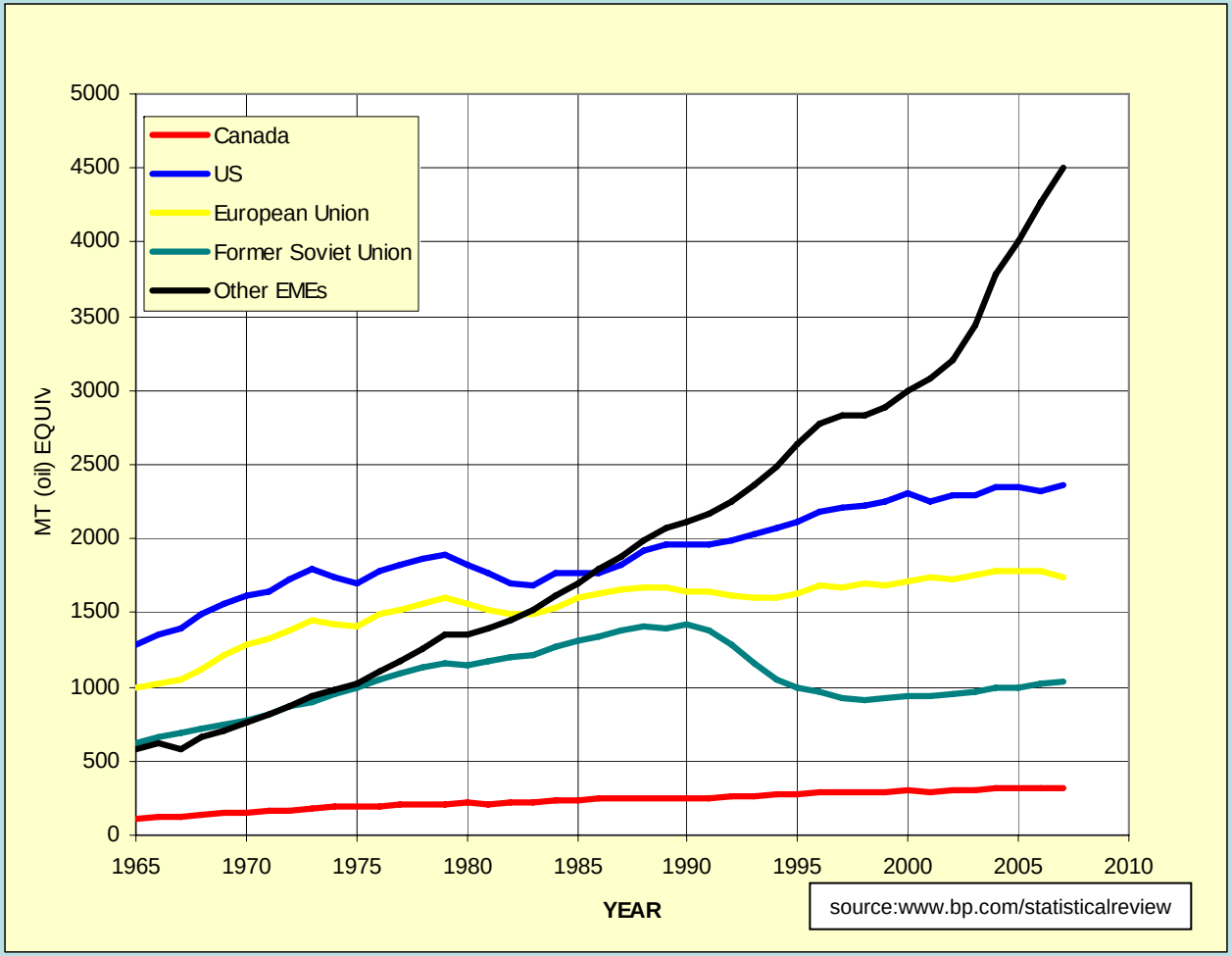
historic crude oil prices



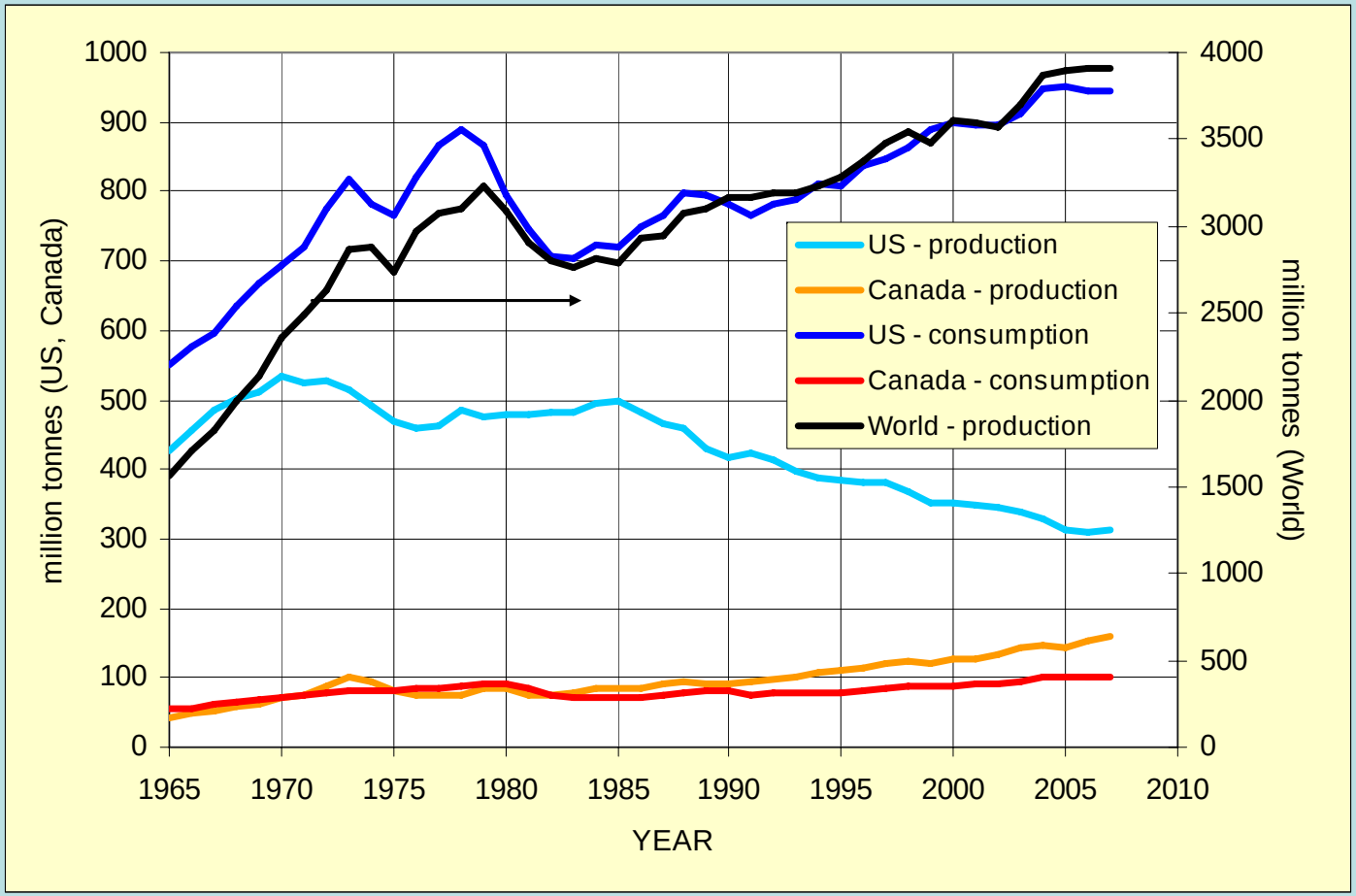
world primary energy consumption



primary energy consumption



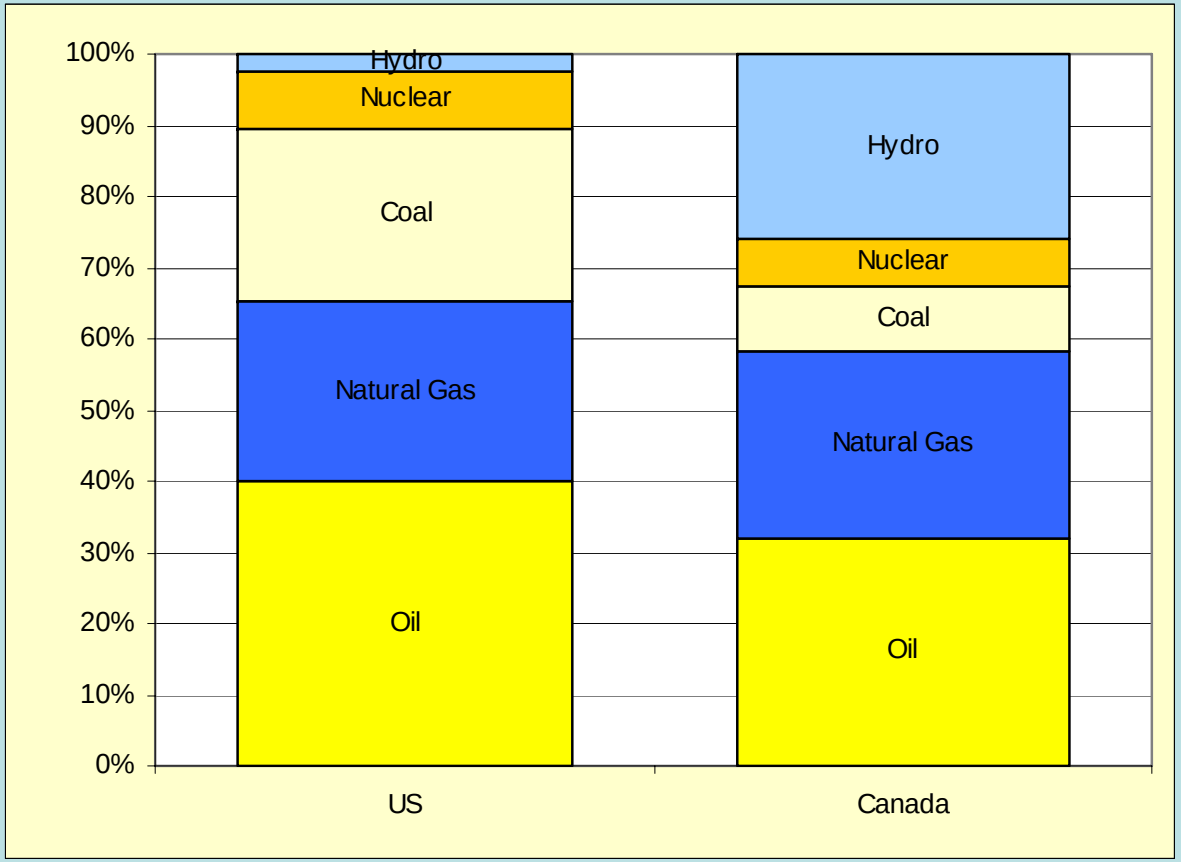
oil production and consumption



questions

- how much energy do we use?
- in what form does the energy come?
- what do we do with the energy?
- can we substitute different forms of energy and, if so, how?
- what can we, as Christians, do to minimize the impact of rising fuel prices on the poor?

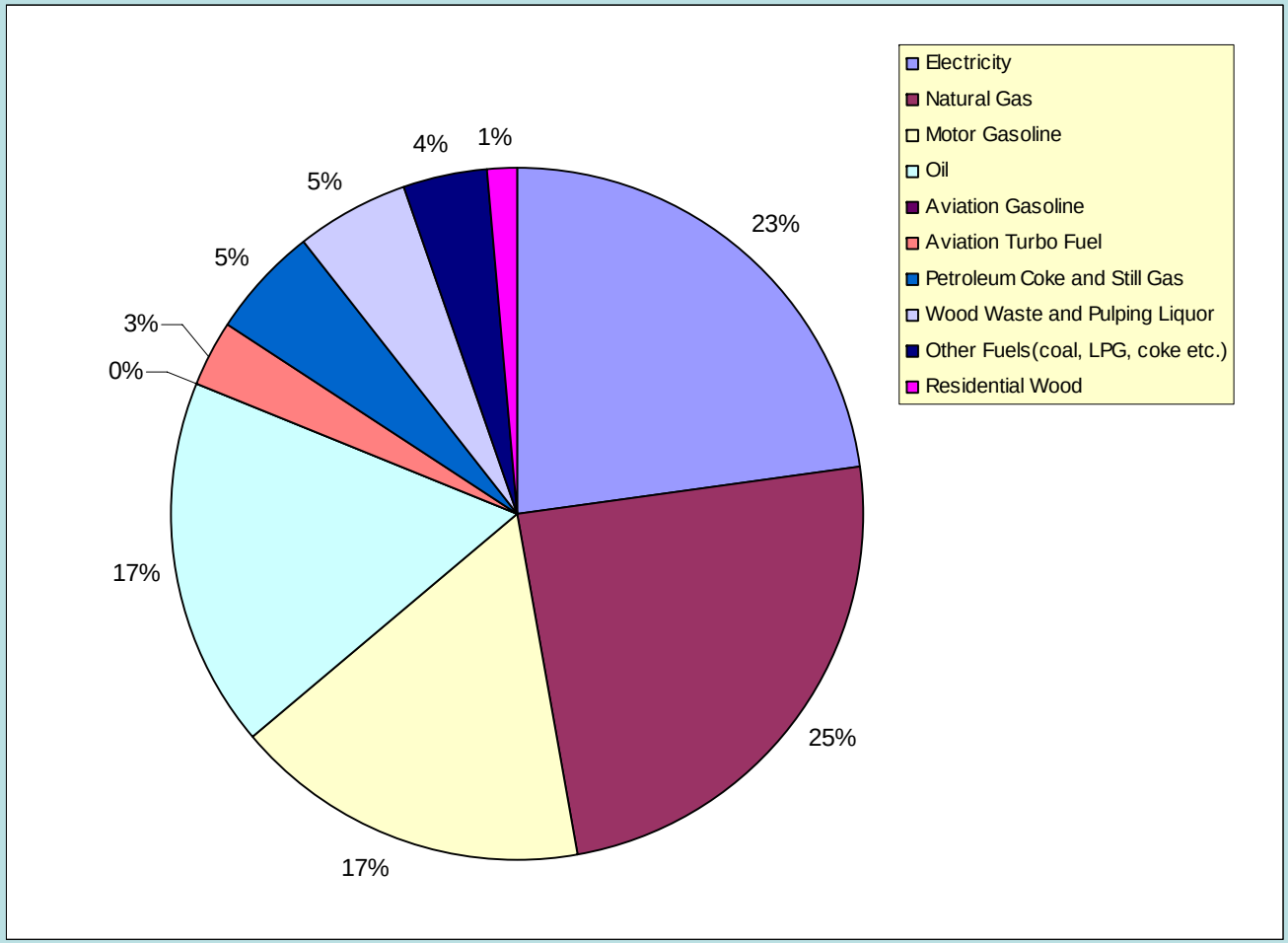
primary energy consumption by fuel



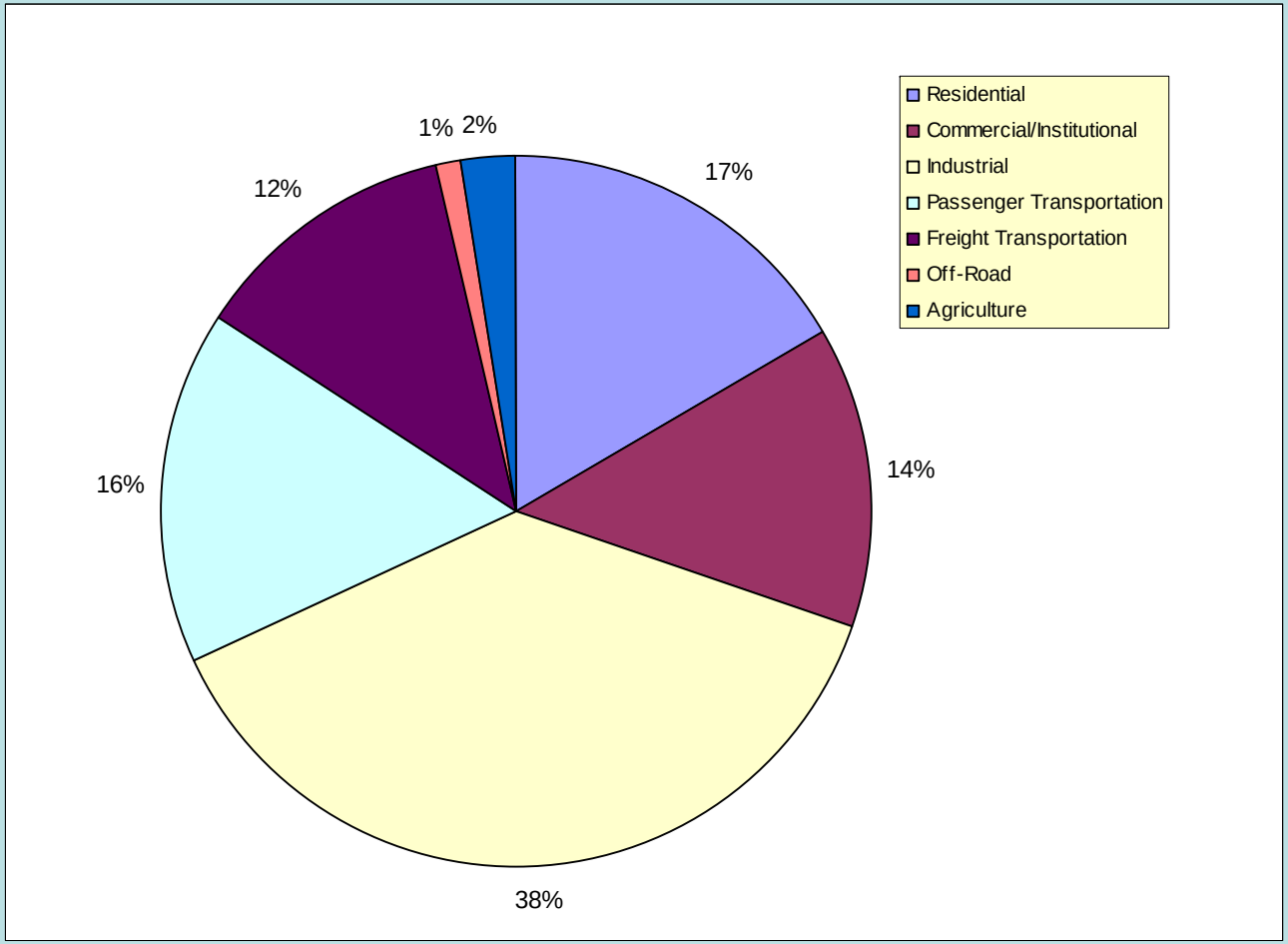
data for Canada

source:
Office of Energy Efficiency, Natural Resources Canada
(http://oee.nrcan.gc.ca/english/index.cfm?attr=0)

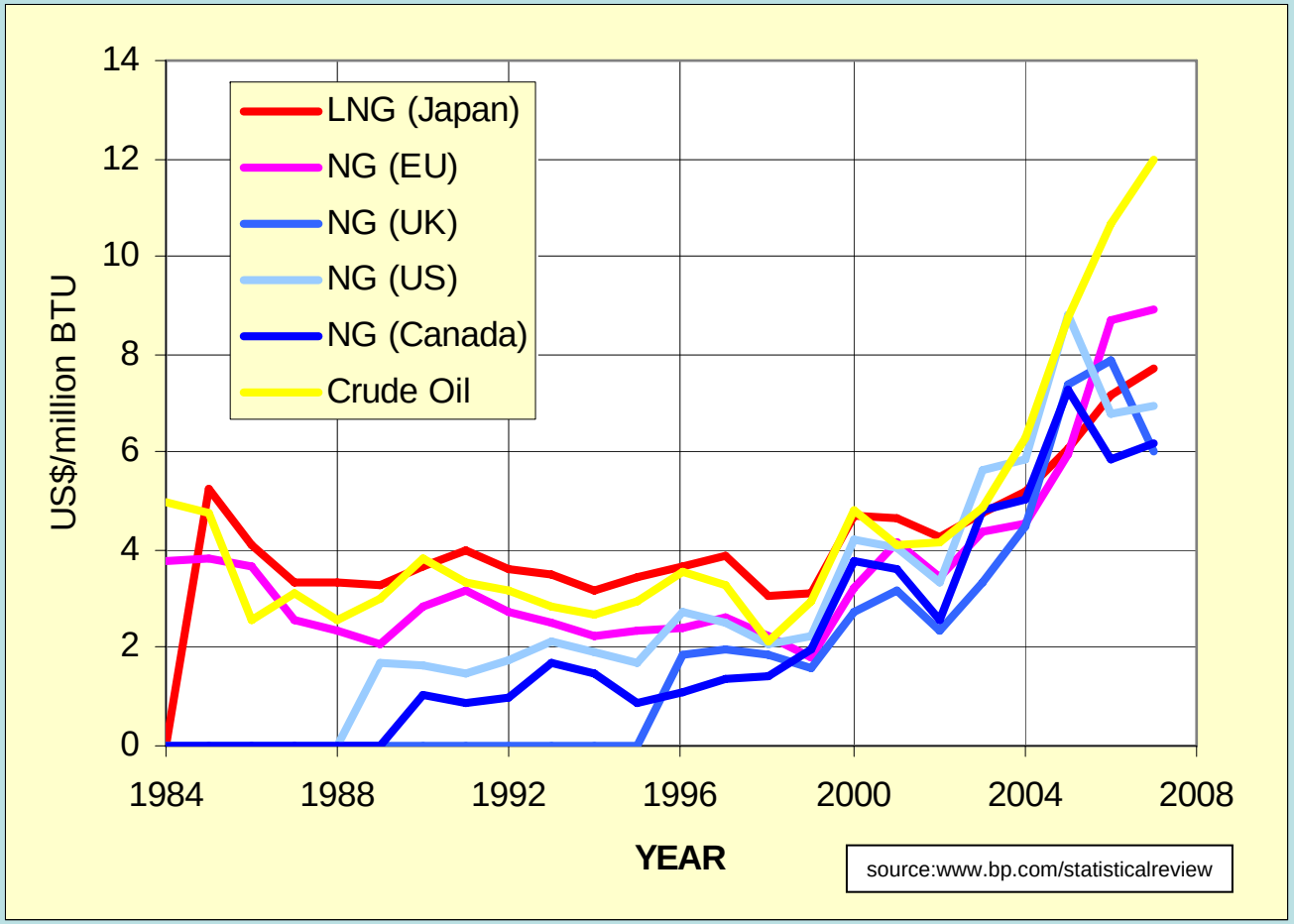
secondary energy use (PJ)



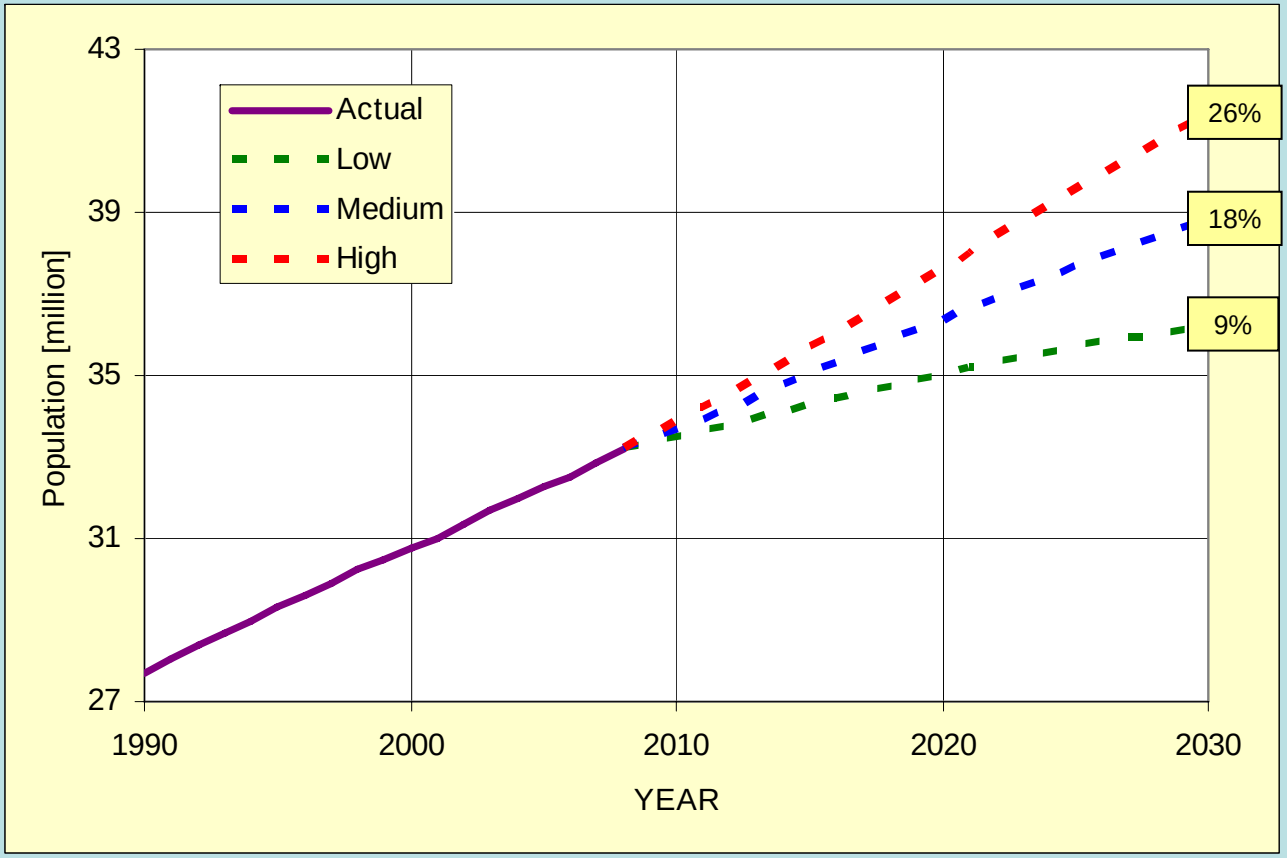
secondary energy use by sector



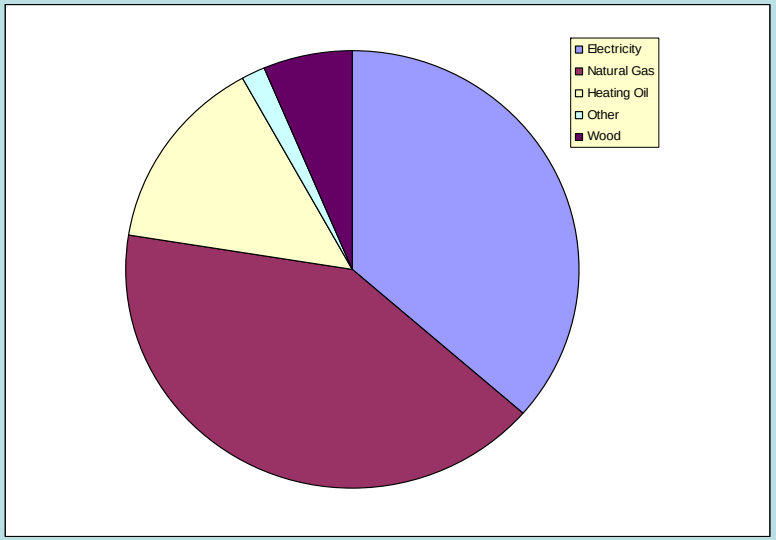
recent fossil fuel prices

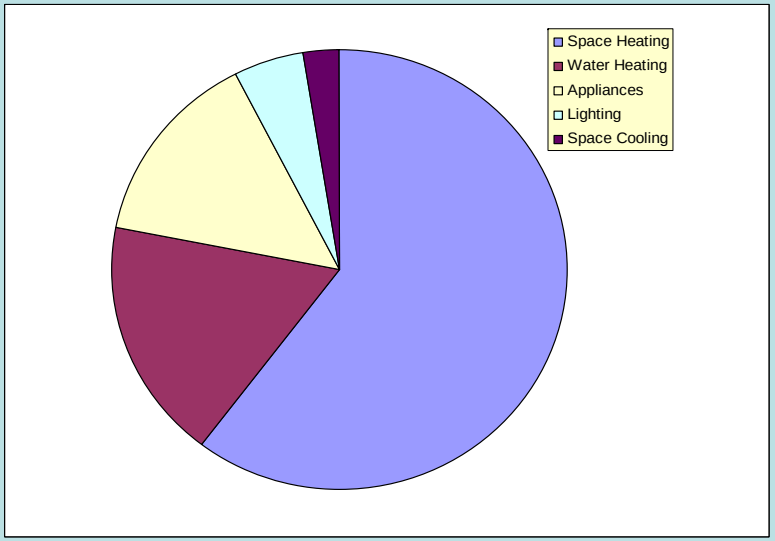


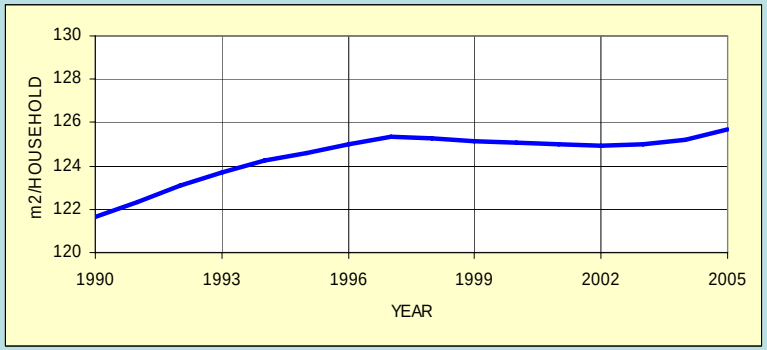
Canada: projected population to 2031



residential (17%)

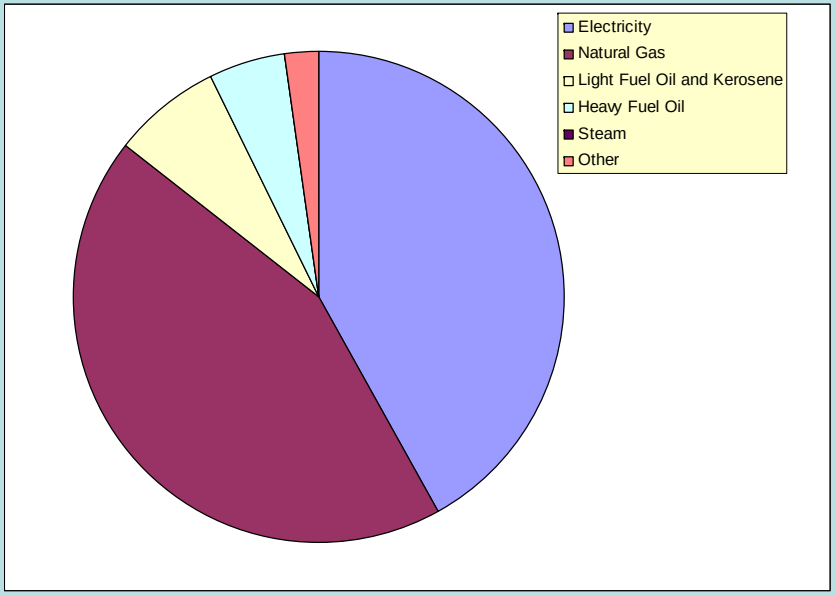


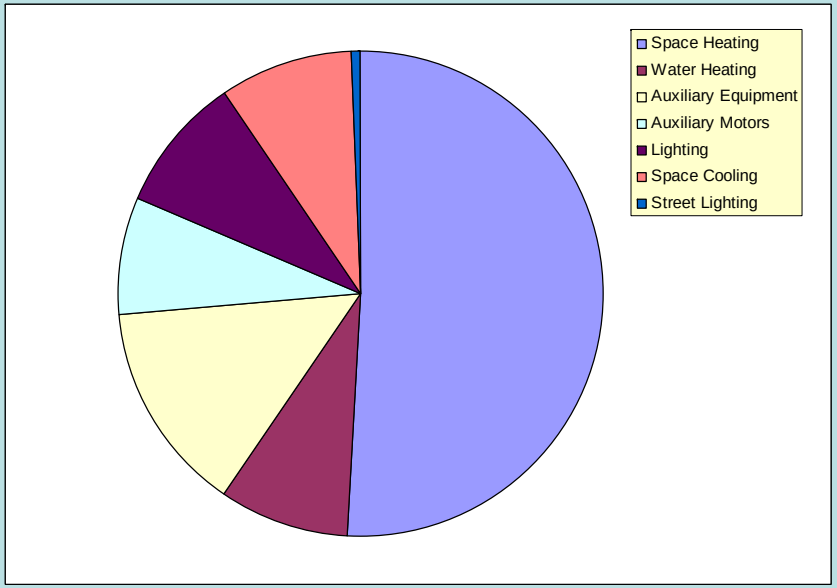




replacing oil used in home heating with electricity would reduce annual oil consumption by ~2 mmt or ~2% of Canada's oil consumption

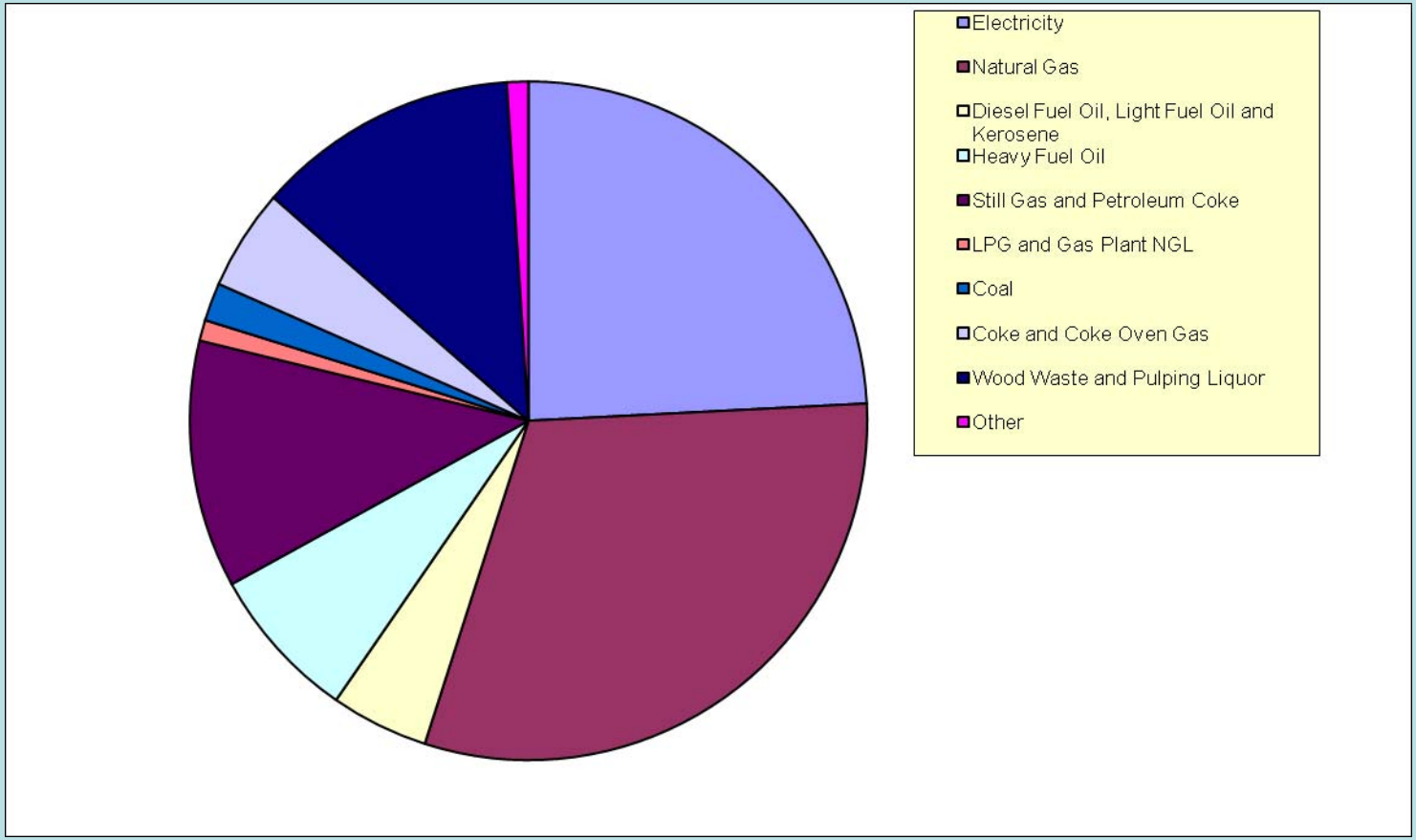
commercial – institutional (14%)



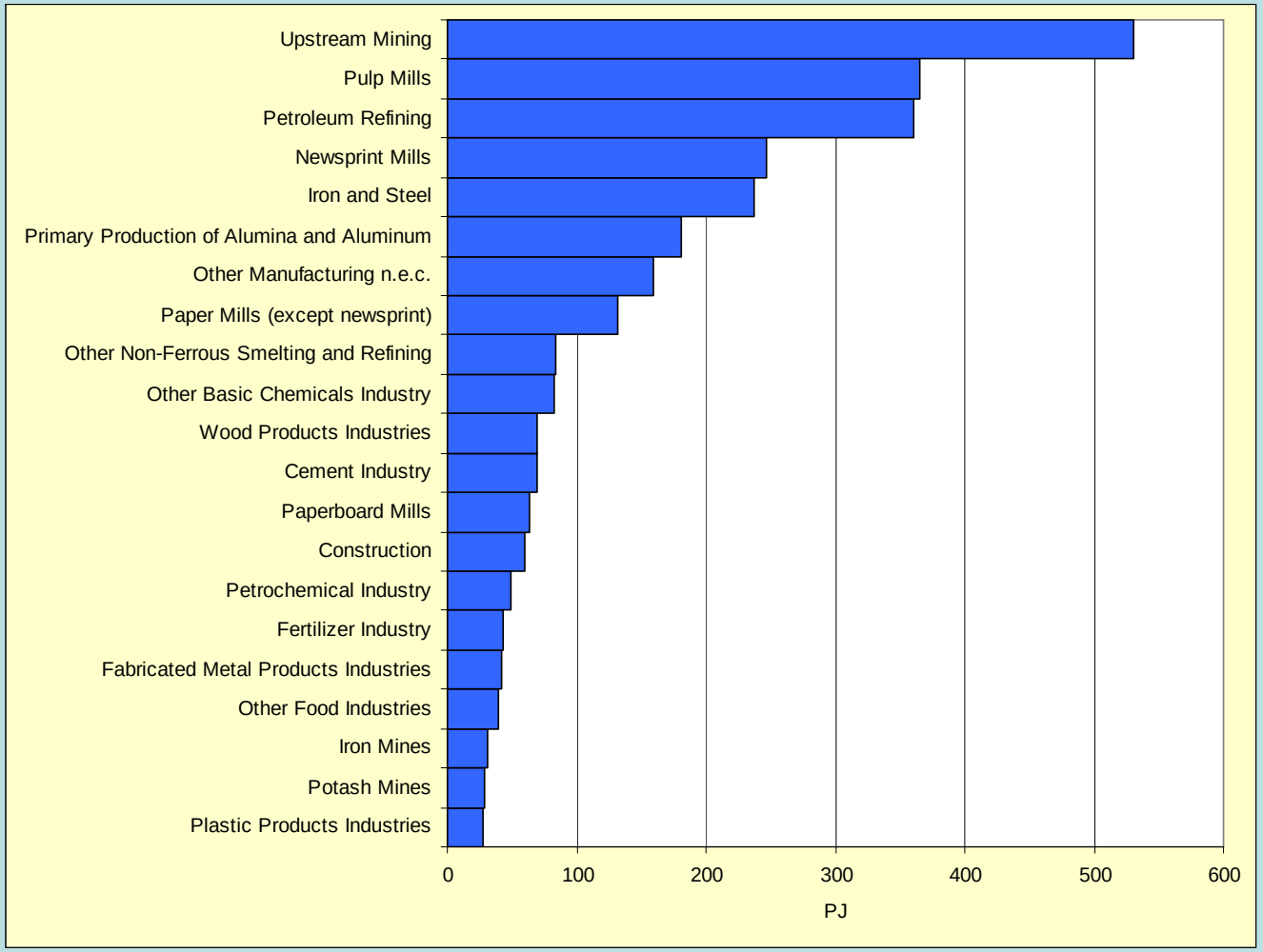


replacing all fossil fuels except natural gas with electricity would reduce annual oil consumption by ~4 mmt or ~4% of Canada's oil consumption

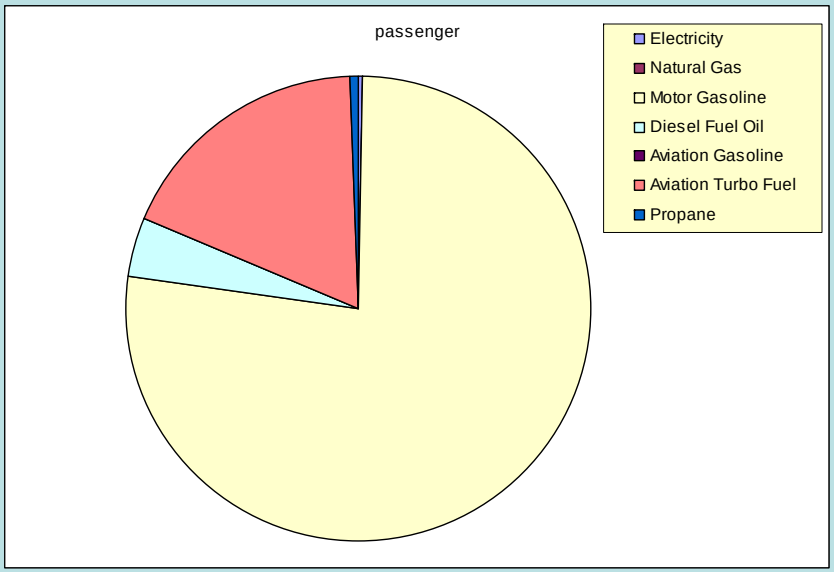
industrial (38%)

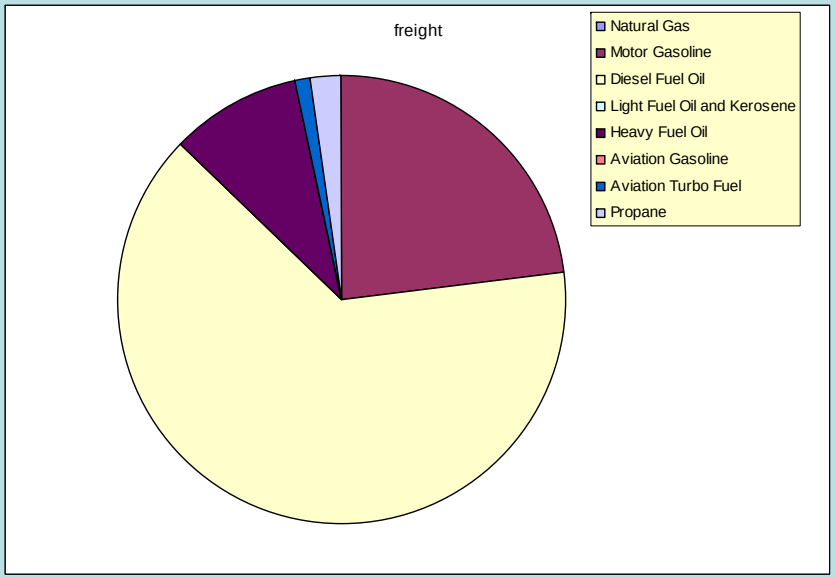


industrial users of 90% of energy

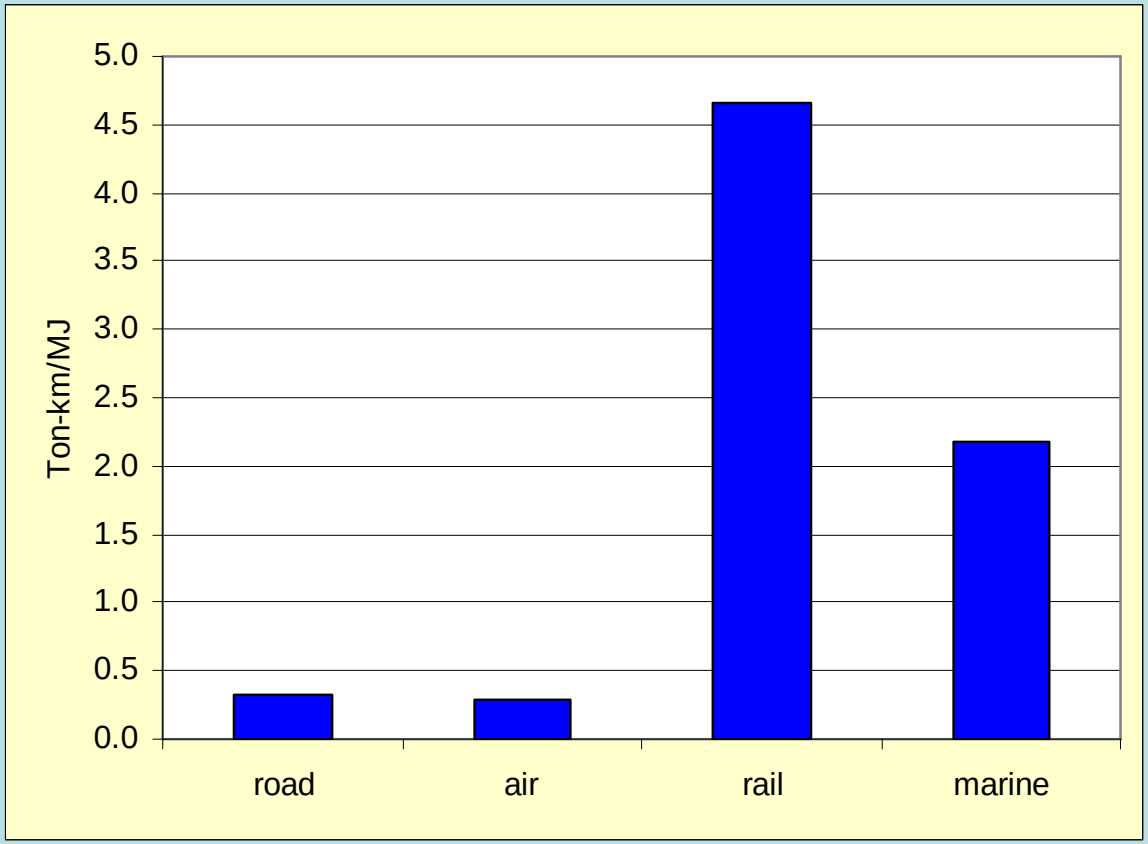


transportation (29%)





efficiency of freight transportation



shifting 25% of road transport to rail will free up 4.6 mmt of oil or 4.6% of Canada's oil consumption

electrifying 25% of the railway frees up another 0.54 mmt of oil

this energy could be generated by one 878 MW(e) CANDU nuclear power plant, [e.g. Darlington-1]

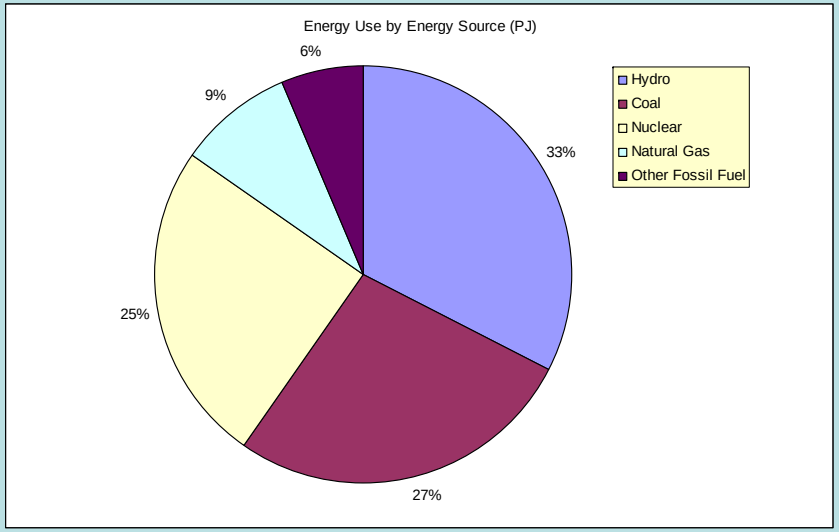
potential ways forward

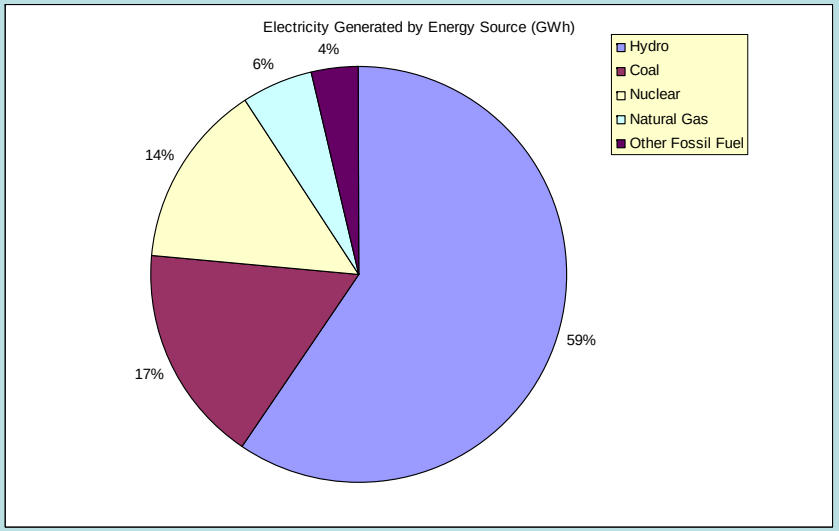
- residential
  - increase use of electricity
  - emphasize smaller homes
  - centralization - decentralization
- commercial/institutional
  - increase use of electricity
  - emphasize smaller homes
  - build smaller churches
- transportation
  - shift road transport to rail
  - electrify the railway system (if Russia can electrify the Trans Siberia Railroad, we should be able to electrify the railroads in Canada and the US)
  - redesign cities to be more compact so that [electric] urban transit is viable
- electricity generation
  - hydroelectric
  - nuclear
  - wind power
  - solar, where applicable

assumptions

- fossil fuel resources are finite
- energy prices will not decrease or not decrease substantially
- energy consumption will stabilize
  - populations in US and Canada will increase
  - increased energy efficiency is offset by population increase
- electorate is not altruistic

electricity generation





If all *current* electrical energy generated by oil were replaced by nuclear or renewable fuels, the offset would be equivalent to ~4 million barrels of oil and reduce Canada's oil consumption by ~4%

potential challenges

- time frame
  - do we have sufficient time to make the shift without adversely affecting the people at the economic margins?
- financial costs of infrastructure
  - building new hydro dams, nuclear power plants, wind generators, solar panels is expensive; if it were not, they would have been built earlier
    - hydro (Manitoba Hydro)
      - Wuskwatim: 200 MW; 1600 M$ [8 k$/kW]
      - Conawapa: 1485 MW; 5000 M$ [>3 k$/kW]
      - Pointe du Bois refurbishing; 120 MW; 800M$ [~7 k$/kW]
    - nuclear generating stations: 1000 MW; 1000 – 3000 M$ [1 – 3 k$/kW]
    - wind generators: 1.5 MW; ~3M$ [2 k$/kW]
    - Sarnia [ON] solar farm: 40 MW; 300M$ (+ 365 ha!) [7.5 k$/kW]
  - as energy becomes more expensive, construction costs increase (concrete for dams)
- energy costs of infrastructure
- socio-environmental costs
  - NIMBY
  - impact on environment
  - impact on aboriginal societies

increased residential electricity use

- reference community
  - 10 000 residences
  - 25 000 inhabitants
  - only oil replaced by 1.5 MW wind turbines
    - 8.4×10^4 GJ required
      - 2 wind turbines @ 100% availability
      - 5 – 7 wind turbines @ 25 – 33% availability
  - all fossil fuel replaced by wind turbines
    - 6.8×10^5 GJ additional energy required
      - 14 wind turbines @ 100% availability
      - 40 – 60 wind turbines @ 25 – 33% availability
  - “full service” electrical supply required from utilities

nuclear power?

Country	Installed Capacity [MW(e)]	Under Construction [MW(e)]	Planned [MW(e)]
USA	99 049	0	15 000
Canada	12 652	1 500	3 300
UK	11 035	0	0
France	63 473	1 630	0
Japan	47 577	2 285	14 945
R O Korea	17 533	3 000	6 600
P R China	8 587	6 700	26 320

known recoverable U resources (130$ US/kg)

	tonnes U	%
Australia	**1,143,000**	**24%**
Kazakhstan	816,000	17%
Canada	**444,000**	**9%**
USA	**342,000**	**7%**
South Africa	341,000	7%
Namibia	282,000	6%
Brazil	279,000	6%
Niger	225,000	5%
Russian Fed.	172,000	4%
Uzbekistan	116,000	2%
Ukraine	90,000	2%
Jordan	79,000	2%
India	67,000	1%
China	60,000	1%
Other	287,000	6%
World total	**4,743,000**	

Source	[U] (ppm)
High-grade ore - 2% U,	20,000
Low-grade ore - 0.1% U,	1,000
Granite	4
Sedimentary rock	2
Earth's continental crust (av)	2.8
Seawater	0.003

Current usage ~68 000 tU/a

source: http://www.world-nuclear.org/info/inf75.htm

what about the future?

- fuel
  - as price of U increases, lower grade ore deposits will be become more economic to mine
    - 3.8 Mt U @ 80$US/kgU
    - 4.7 Mt U @ 130$US/kg U
  - doubling the cost of U increases cost per kWh by ~20%
  - extract U from seawater
  - reprocessing
- reactor design
  - improved efficiency (>30%)
  - breeder reactors

methods to extent fissile supply

- fast breeder reactors (Pu-U MOX)
  - convert fertile ^{238}U to fissile ^{239}Pu
    - USA (EBR-1 [Idaho])
    - France (Phenix, SuperPhenix)
    - Japan (Monju)
    - UK (Dounray)
- thermal breeder reactors (Th-U MOX)
  - convert fertile ^{232}Th to fissile ^{233}U
    - India (research only)
    - Canada (research only)

concluding comments

- societies based on current energy mix cannot be sustained
- drastic decrease in energy consumption cannot be legislated
- fossil fuels should be reserved as chemical feedstock and to power mobile equipment
- considerable energy savings can be achieved by shifting transportation from road to rail
- residential and commercial/institutional sectors should increase use of electricity
- electricity generation should include a mix of nuclear and renewable (wind, solar) sources
- time to take action was ten years ago

Thank You