

Which of the following is a 'renewable' energy source?

nuclear

wind

natural gas

tides

hydro

biomass

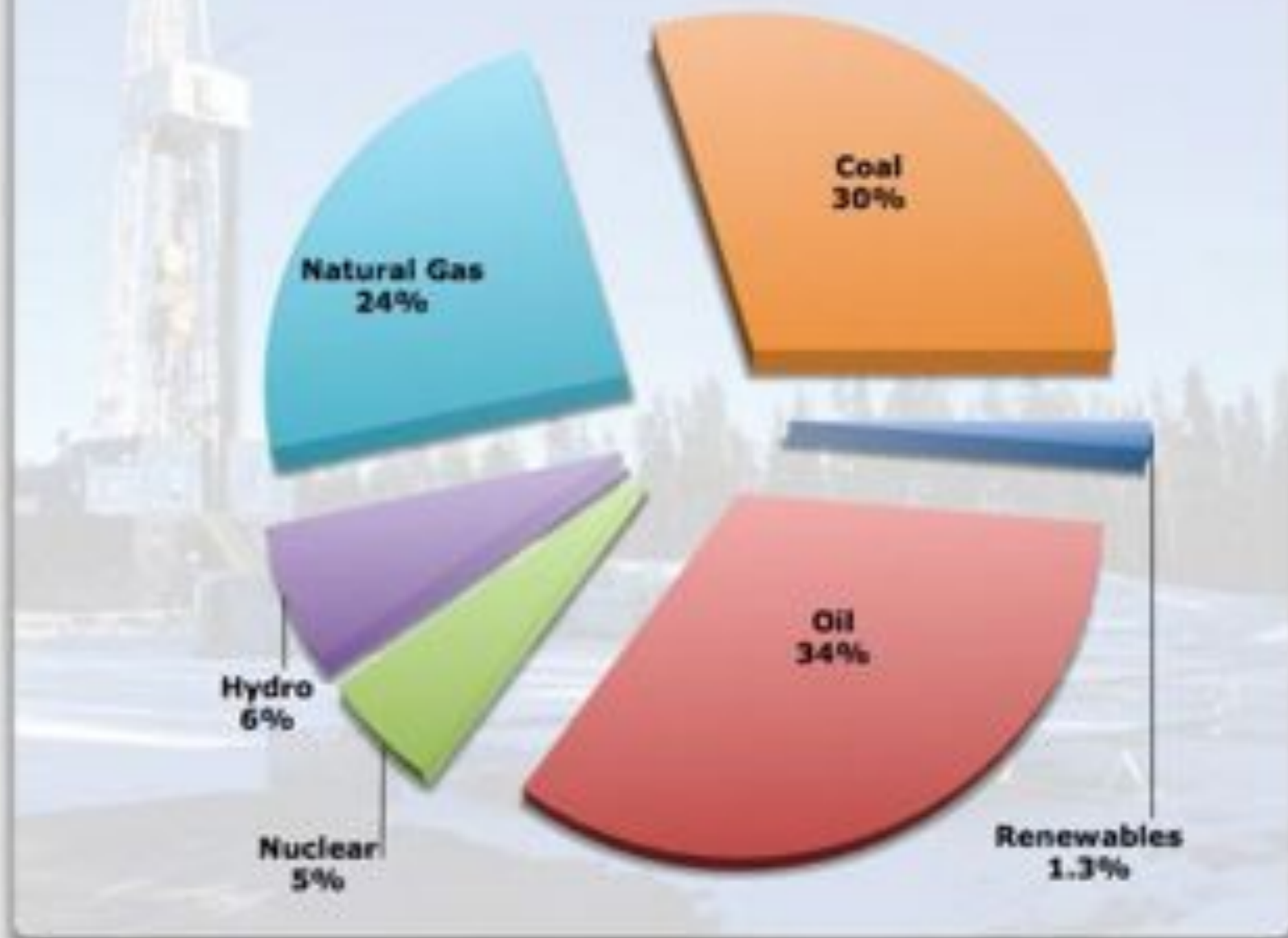
geo-thermal

# How to make N.S. the richest province in Canada?



- . water rises & falls ~ 10 m every 12 hours; basin area 100kmx100km
- . equivalent to a 10 GW power station; 1/6 of Canada's need

## Where the World Gets Its Energy



Energy beyond electricity: ~40% goes to electricity

# Conservation — it is also a form of energy

- *why conserve?*
- *can we cut energy use by 10?*



Reading: Muller (Energy for future presidents) Chapter 7, 16  
Recommended reading: David MacKay, Sustainable Energy without the Hot Air,  
<http://www.withouthotair.com>

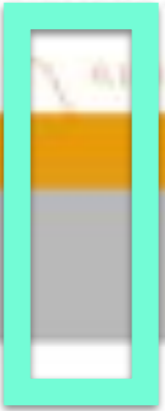
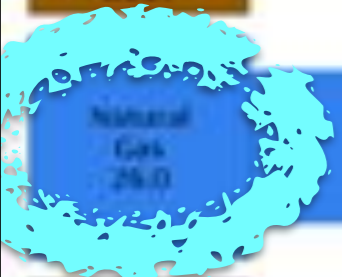
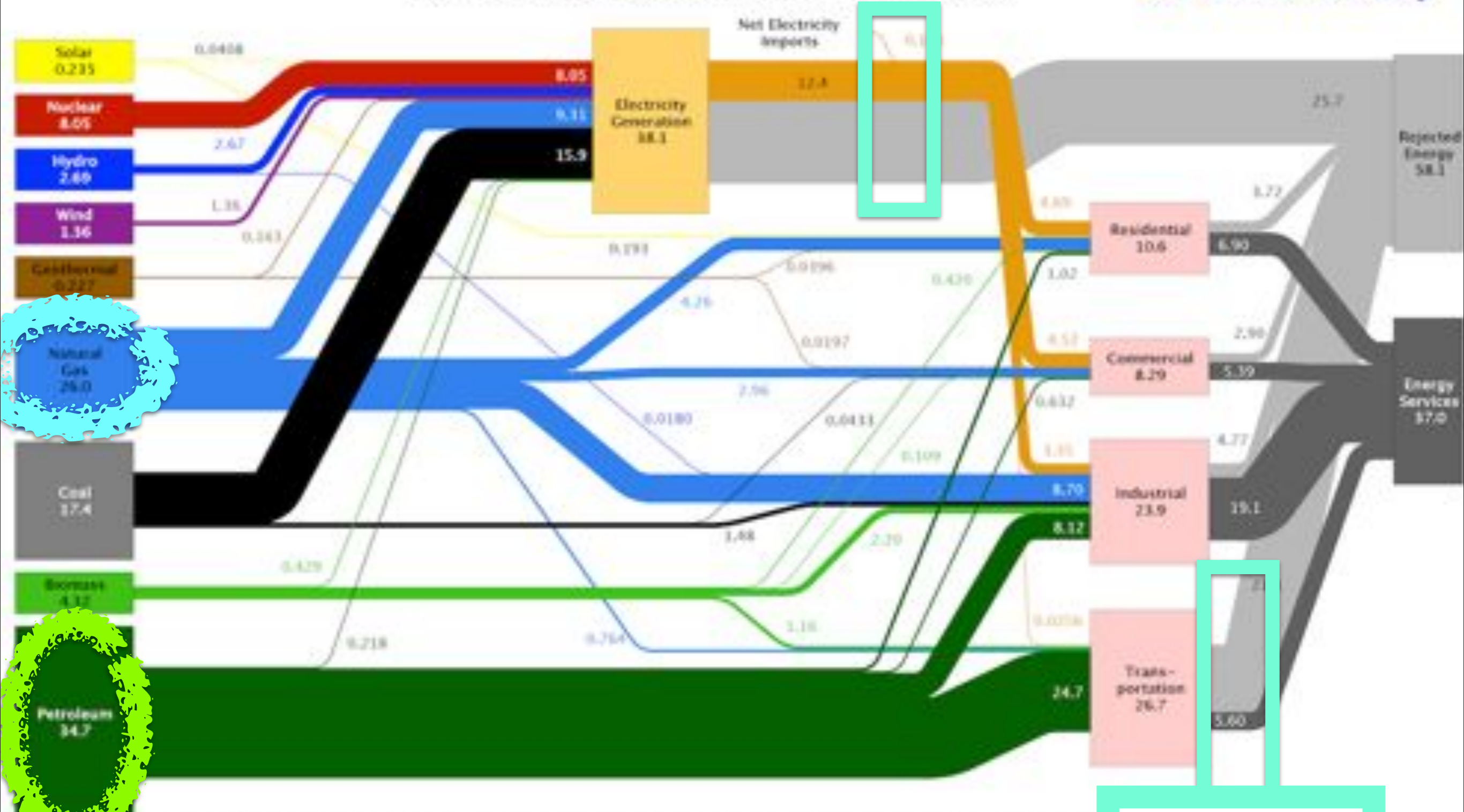
# Why conserve?

- . solar + wind + nuclear hold great promise... for electricity generation; but coal still dominates today
  - electricity is currently a high-grade energy
  - reducing electricity use means carbon-free earlier.
  - solar/wind revolution may not materialize
- . the remaining 60% are still from hydro-carbon.
  - natural gas for space/water heating (25%)
  - oil for transportation (35%)
- . currently no strong renewable candidates for these sectors
- . to shake off fossil fuel dependences — conservation!

# Sankey Diagram for US (Similar to that in Canada)



Estimated U.S. Energy Use in 2012: ~95.1 Quads

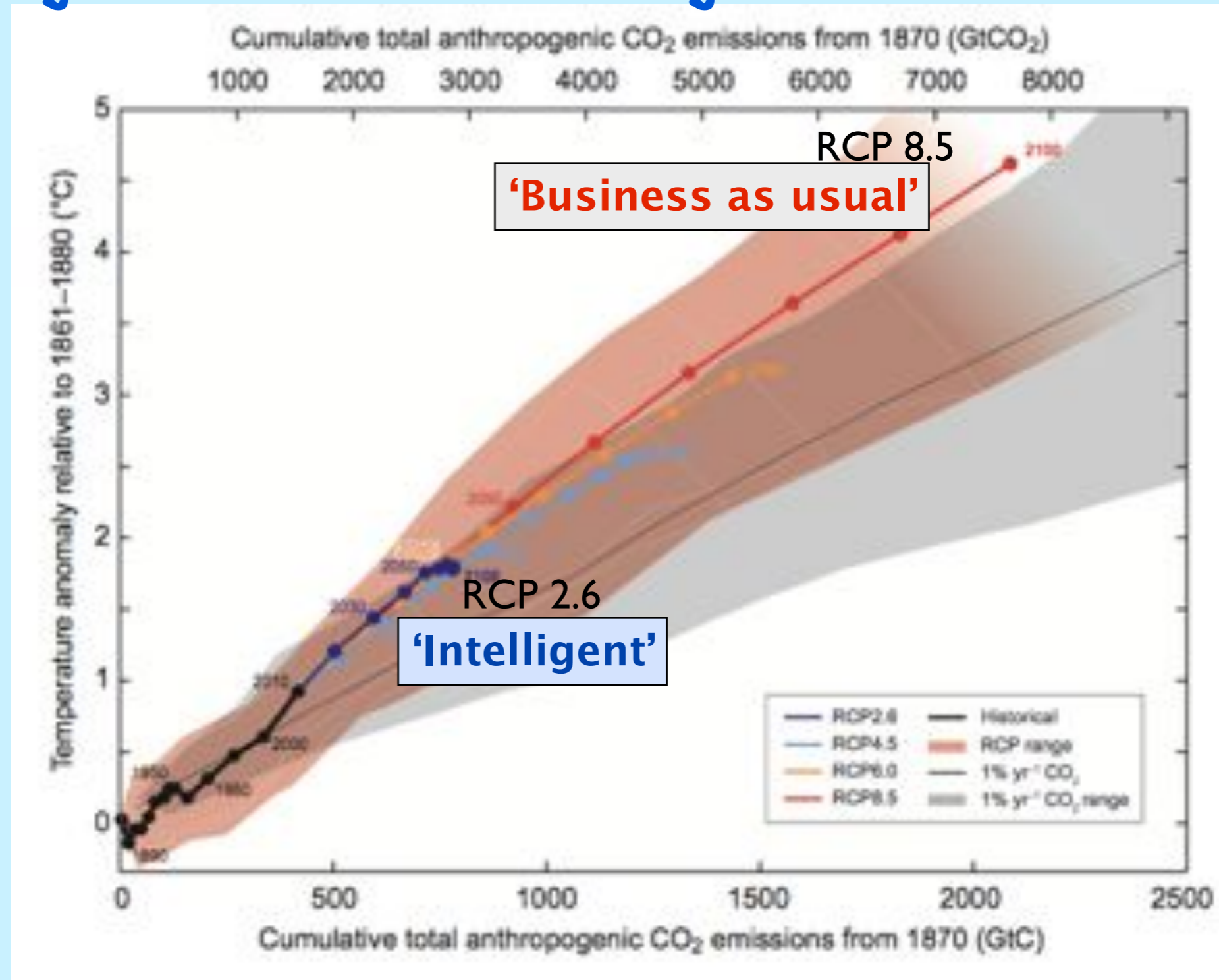


**Efficiency**

Source: EIA, 2013. Data is based on DOE/EIA-0015(2012-02), May, 2013. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include consumption of renewable resources (i.e., hydro, wind, geothermal and solar) for electricity in BTU-equivalent values by assuming a typical fossil fuel plant. The efficiency is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is indicated as 87% for the industrial sector, and 22% for the transportation sector. Totals may not equal sum of components due to independent rounding.

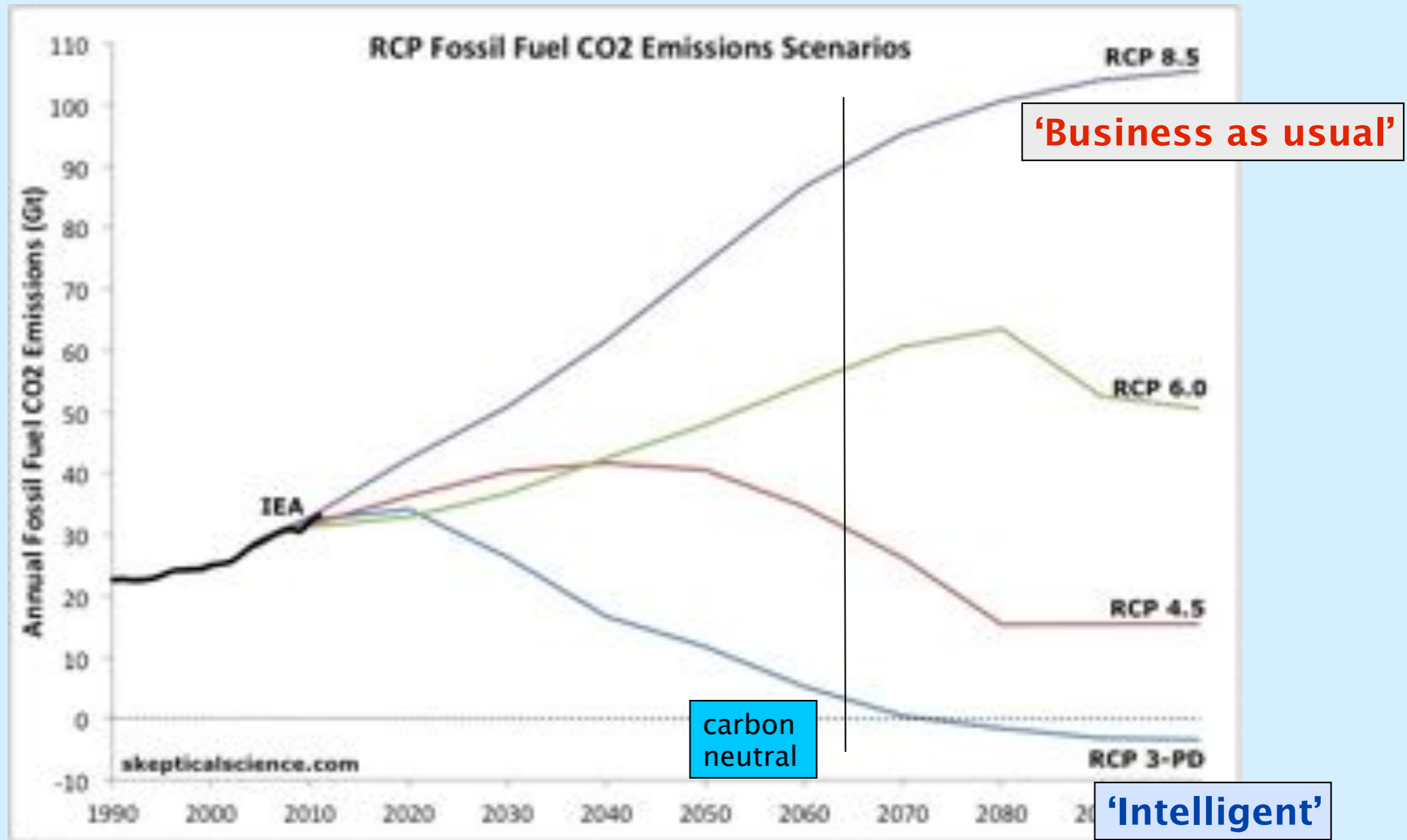
# Global Warming: how bad could it get?

(Nov 2013)



- 1) Every CO<sub>2</sub> doubling raises T by 1.5 - 4°C (IPCC '13)
- 2) Global warming has already occurred, seeing impacts now.

# what should we aim for?



We would like to cut global fossil fuel use by a factor of 10! (the sooner the better)

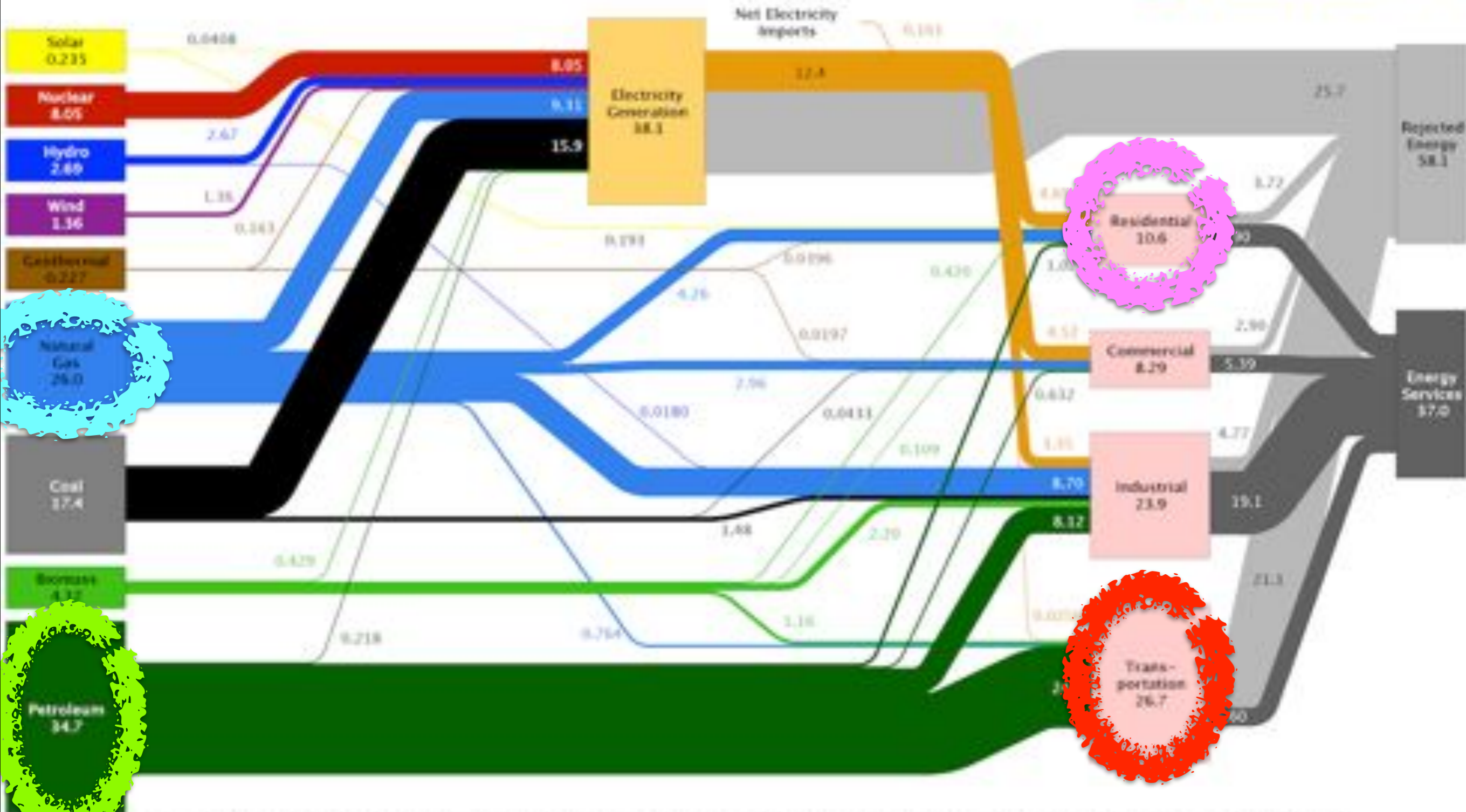


# 10x lower Energy Use

premises: it is very hard to convince people to change their life-style

# Sankey Diagram for US

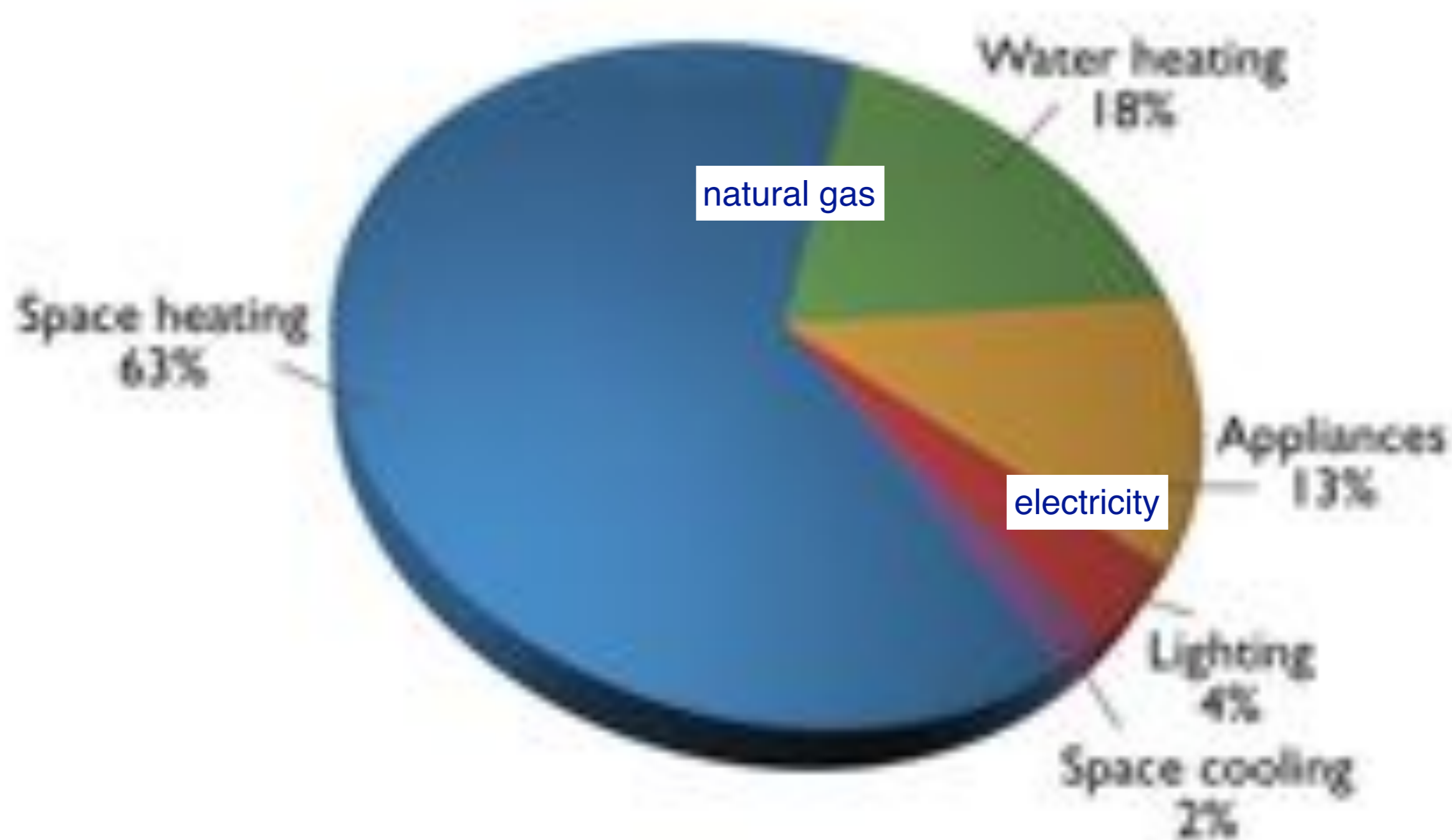
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# Let's first look at energy use at home.

Energy use of a Canadian house (Natural resources Canada)



# Space heating

- . needs more fuel if: outside temperature colder;  
inside temperature hotter;  
leakier building;  
heating system less efficient.
- . most gas furnaces convert fuel to heat efficiently (80% - 95%)

Over a typical winter day in Toronto (-5°C)

. a single detached house heated to 22°C	
. thermostat turned down to 18°C	-16%
. using programmable thermostat	
— temperature set to 13°C during sleep	-12%
— temperature set to 13°C when people out of home	-12%
Total energy saving	40%

All houses leak heat.



Heat that goes in has to go out — energy conservation.  
heat loss through walls, windows, floor, roof;  
biggest saving on heating is done by insulation

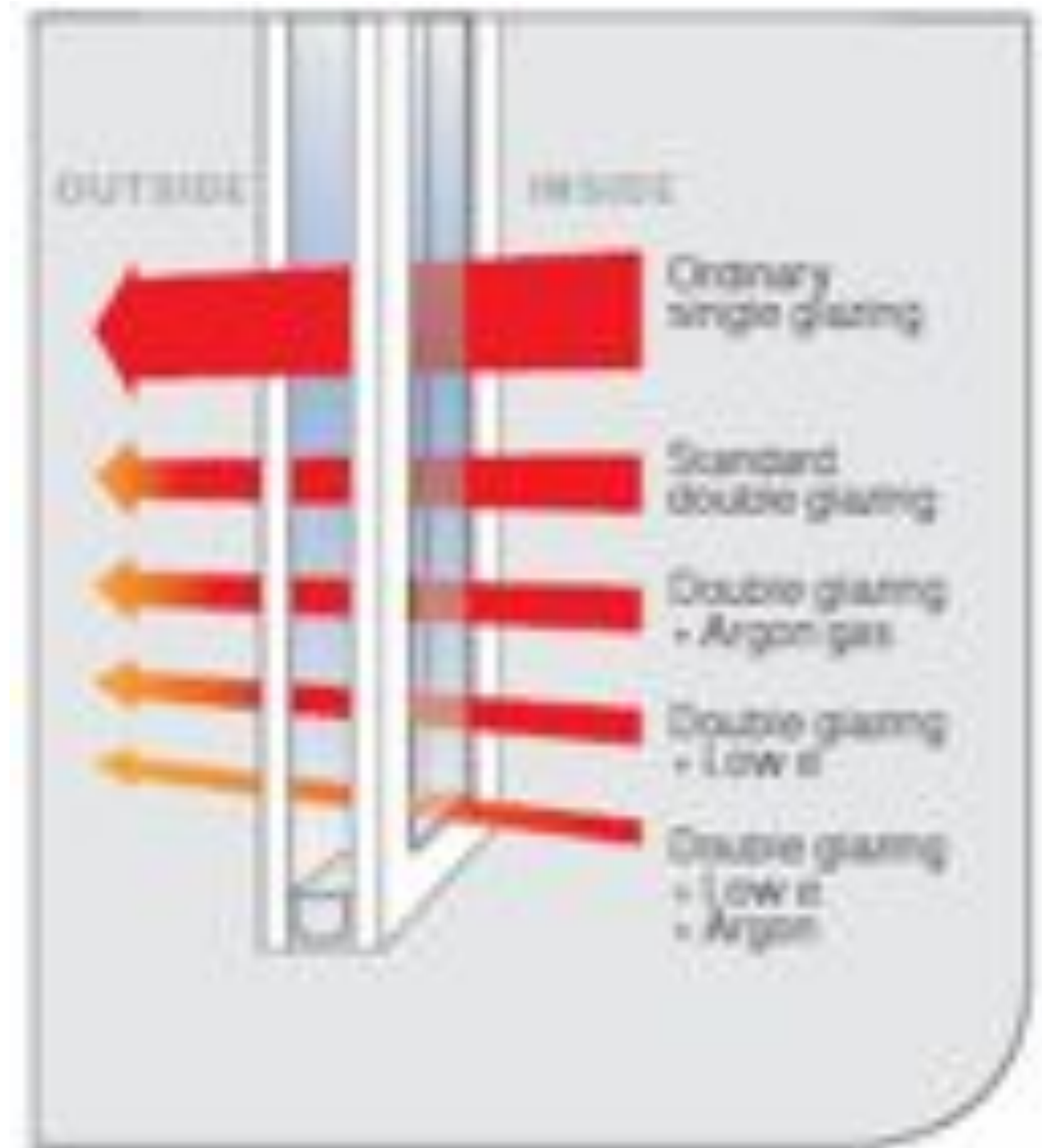
example of a well insulated house — zero heating bill!



# leaky window: conduction, heat radiation, air leakage

compared to single-pane glass, energy efficient windows can reduce heat loss by almost a factor of 10.

high performance glasses cost more.



What is wrong with these condos?



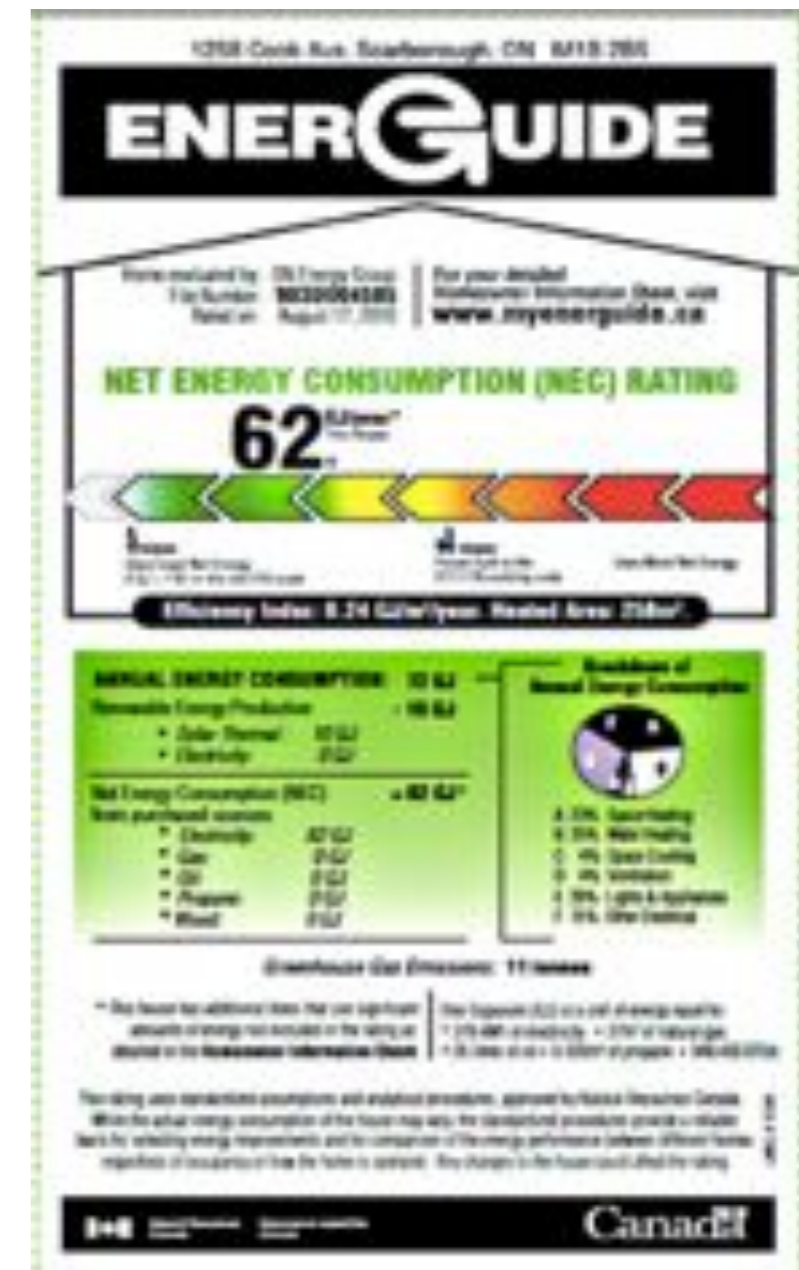
Glass towers are NOT green.





Year 2016: City council of Toronto

a new bill is being debated — energy-star certification for buildings.



- . every building will be rated by its energy consumption.
- . under-performing buildings need energy retrofit
  - high efficiency HVAC, light-bulb, insulations, thermal windows...
- . guaranteed low-interest loans for energy retrofit

# 10x lower energy use

premises: it is very hard to convince people to change their life-style

building space/water heating: possible to reduce energy use dramatically, without affecting life-styles; technology is here but... the attitude!

# Now let's look at transportation = car + plane

## Car travel:

- . 4 out of 5 Canadians commute by driving.
- . Average Distance travelled per day ~ 50 km.
- . also transport of goods

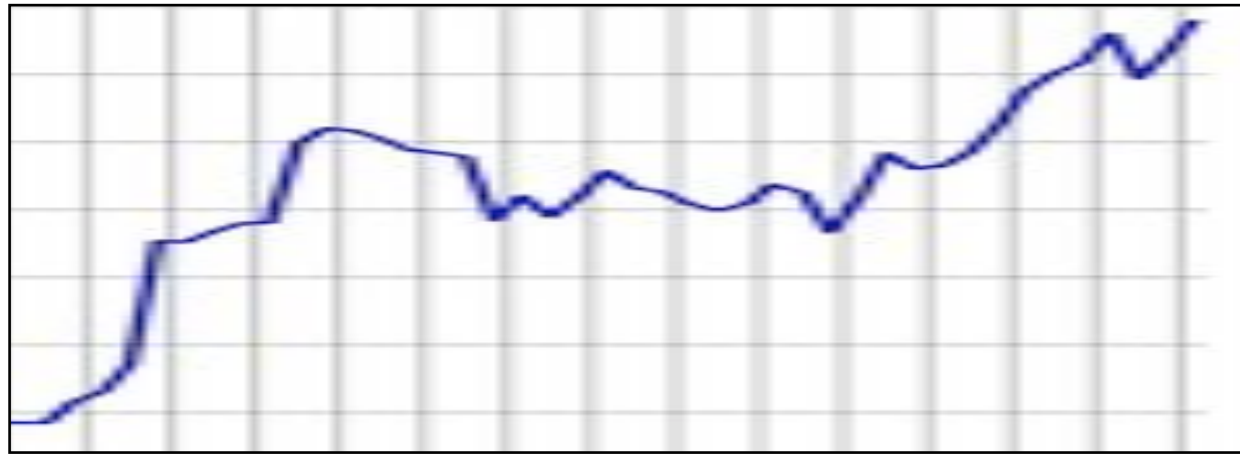
What about conscientious people who bike/walk/transit?

- . one inter-continental trip ~ driving 50km for 365 days

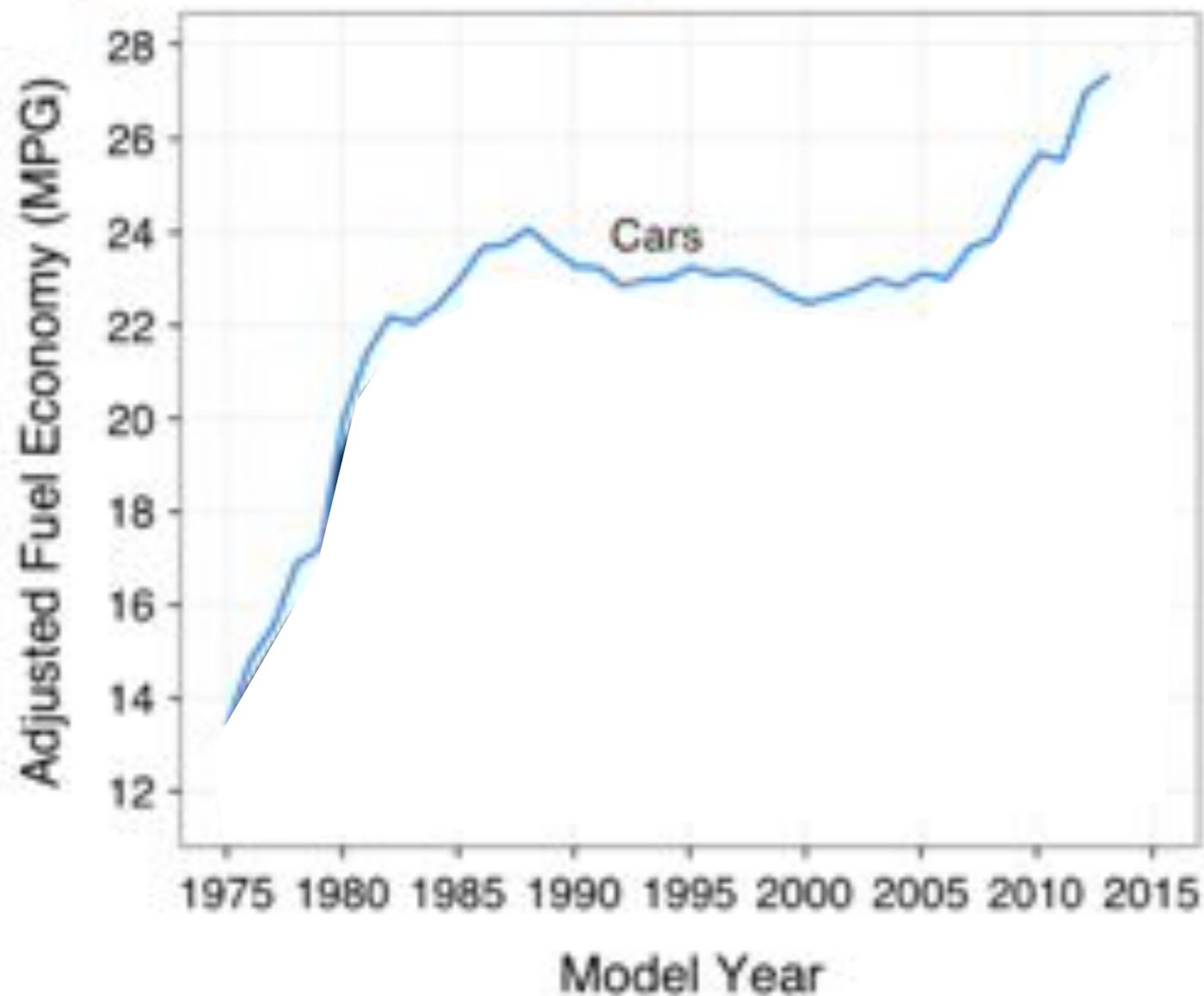
- Transportation: ~ 1/3 of our total energy use
- Higher income → more travelling.
- Demands for transportation strong and increasing.
- Transportation is almost exclusively fuelled by oil.
- this dependency seems hard to shake off. ?

# Car fuel economy (miles-per-gallon) reflects oil price.

oil price



*Adjusted Fuel Economy for MY 1975-2013<sup>1</sup>*



Fuel economy:

- now 2x better than 70s
- Will oil price rise in the future?

However, the moderate gain in car economy is more than compensated for by the **rising car ownership**.

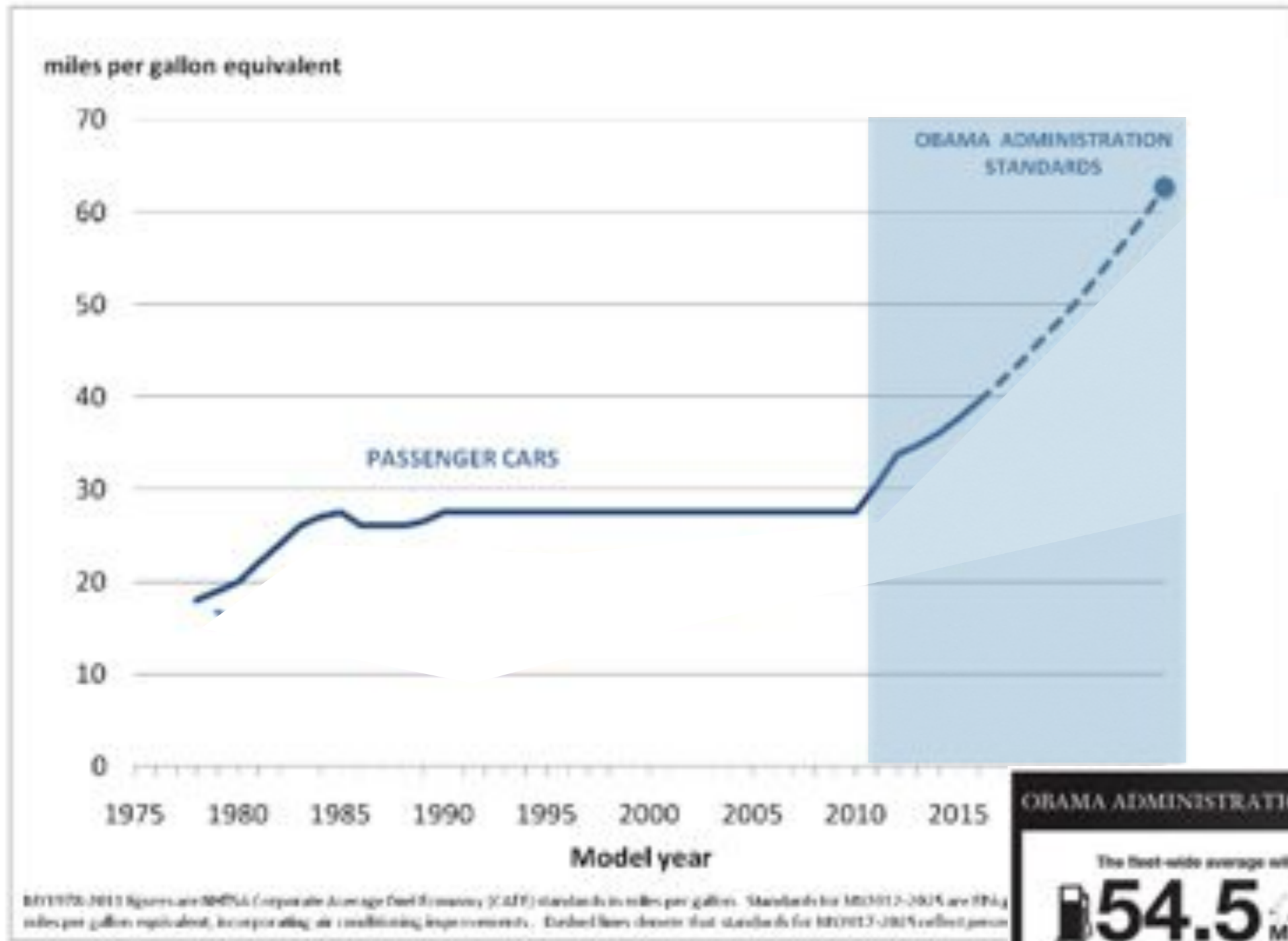
- pop. growth; wealth growth; life style).
- 3-4 billion vehicles on the road by 2050.

Also, **rising average driving distance**.



Drive-in theatre of the 1970s

# July 2011: US government + 13 major car-makers reached an agreement.



2025:  
2x improvement  
over today

MPG figures are EPA's Corporate Average Fuel Economy (CAFE) standards in miles per gallon. Standards for 2011-2015 are EPA's miles per gallon equivalent, incorporating air conditioning improvements. Dashed lines denote that standards for 2011-2015 reflect projections.

**OBAMA ADMINISTRATION Fuel Economy Standards** In the year 2025

The fleet-wide average will be

**54.5** MPG

Consumers will have saved

**\$1.7 TRILLION**

at the pump over the life of the program.

A family that purchases a new vehicle in 2011 will save

**\$8,200**

in fuel costs when compared with a similar vehicle in 2010.

Over the life of the program, the standards will:

Save **12** billion barrels of oil.

Eliminate **6** billion metric tons of carbon dioxide pollution.

This program, together with standards already put into place by the administration for Model Years 2011-2015, will result in significant cost savings for consumers at the pump, dramatically reduce air consumption, air pollution and global warming.

For more information, visit [www.epa.gov/obamaautos](http://www.epa.gov/obamaautos)

# As a car-maker, how to fulfill this agreement?

1. paint the car red!
2. make the car engine more efficient.
3. reduce friction in motor/wheels/axles...
4. make the car lighter.

# Can we make cars with 10x higher fuel economy?

## Efficiency of engines

(Nov 2013)

- . human turns food into mechanical energy: ~ 20%  
each kcal of food we eat, we get 0.2 kcal to use
- . 1<sup>st</sup> generation steam engine (1720) produces mechanical energy with efficiency ~ 0.5%
- . modern day internal combustion engine: ~30%  
30% of gasoline in your car actually does something
- . power plants (steam turbine) produce electricity: ~30%  
future target: 60%
- . the rest is heat and must be removed (cooling)  
coal cogeneration: if heat recaptured and used for heating

Thermodynamics (heat loss in exhaust gas) constrains this efficiency.

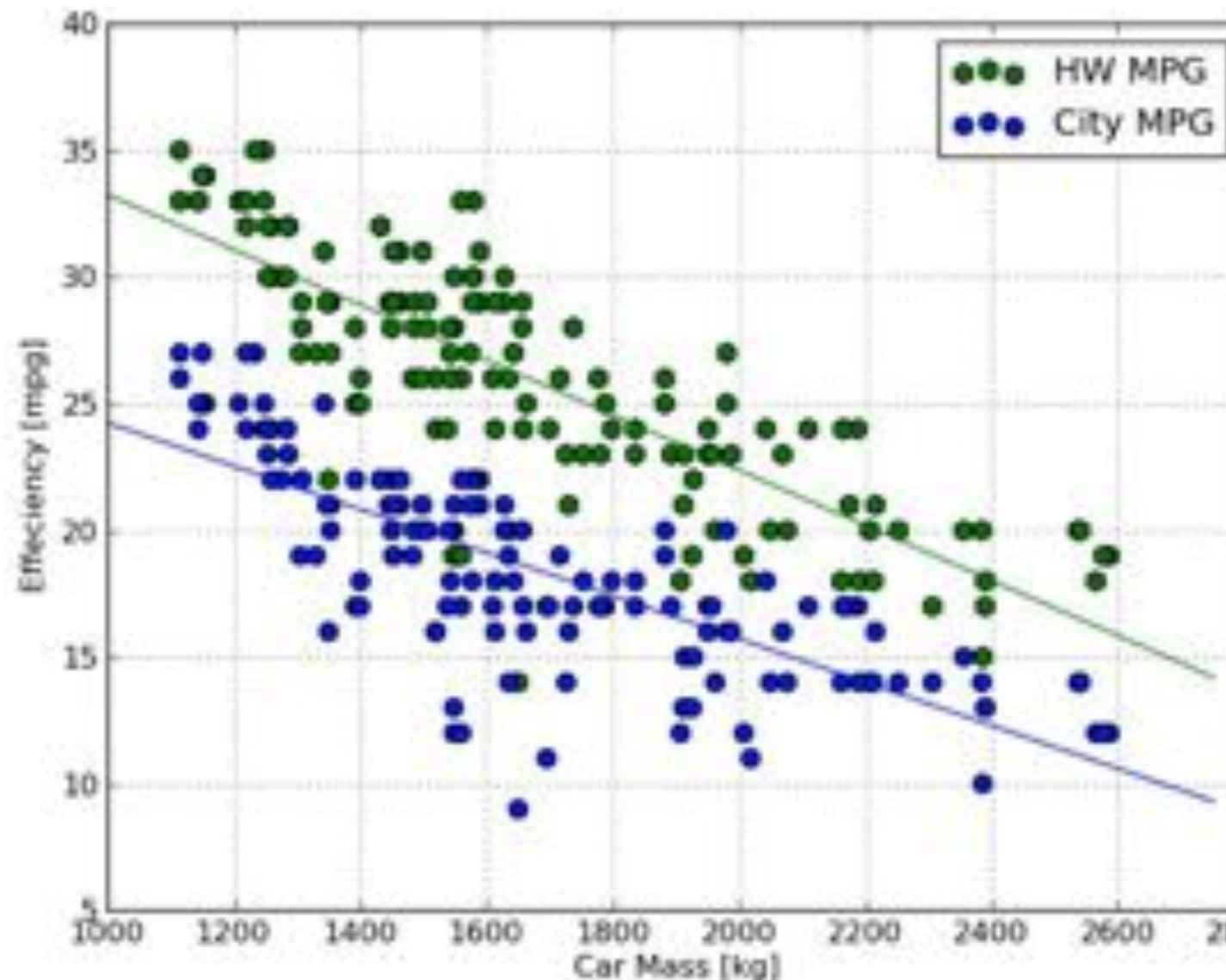


# As a car-maker, how to fulfill this agreement?

- Carnot's law limits the engine efficiency (turning heat into mechanical energy) to about 30%.
  - Internal mechanical friction reduces this further to  $\sim 20\%$ .
- However, a typical car weighs 1600kg.  $\sim 20\times$  of a typical driver. Most gasoline used to move the car, not the driver.



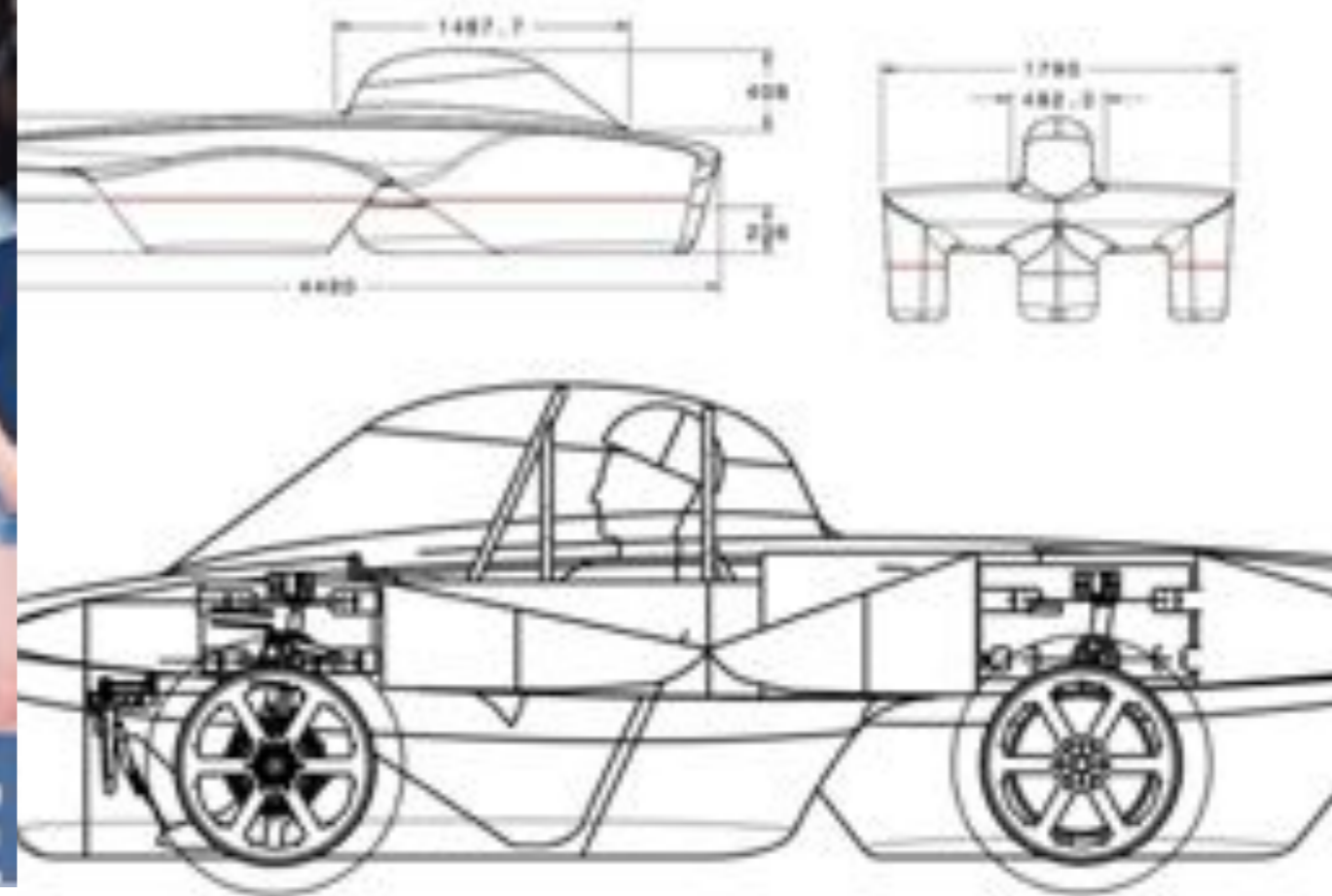
Smart for2:  
800kg  
36 MPG



4WD:  
2600kg;  
14 MPG



A car that is light enough can even run on — solar PV

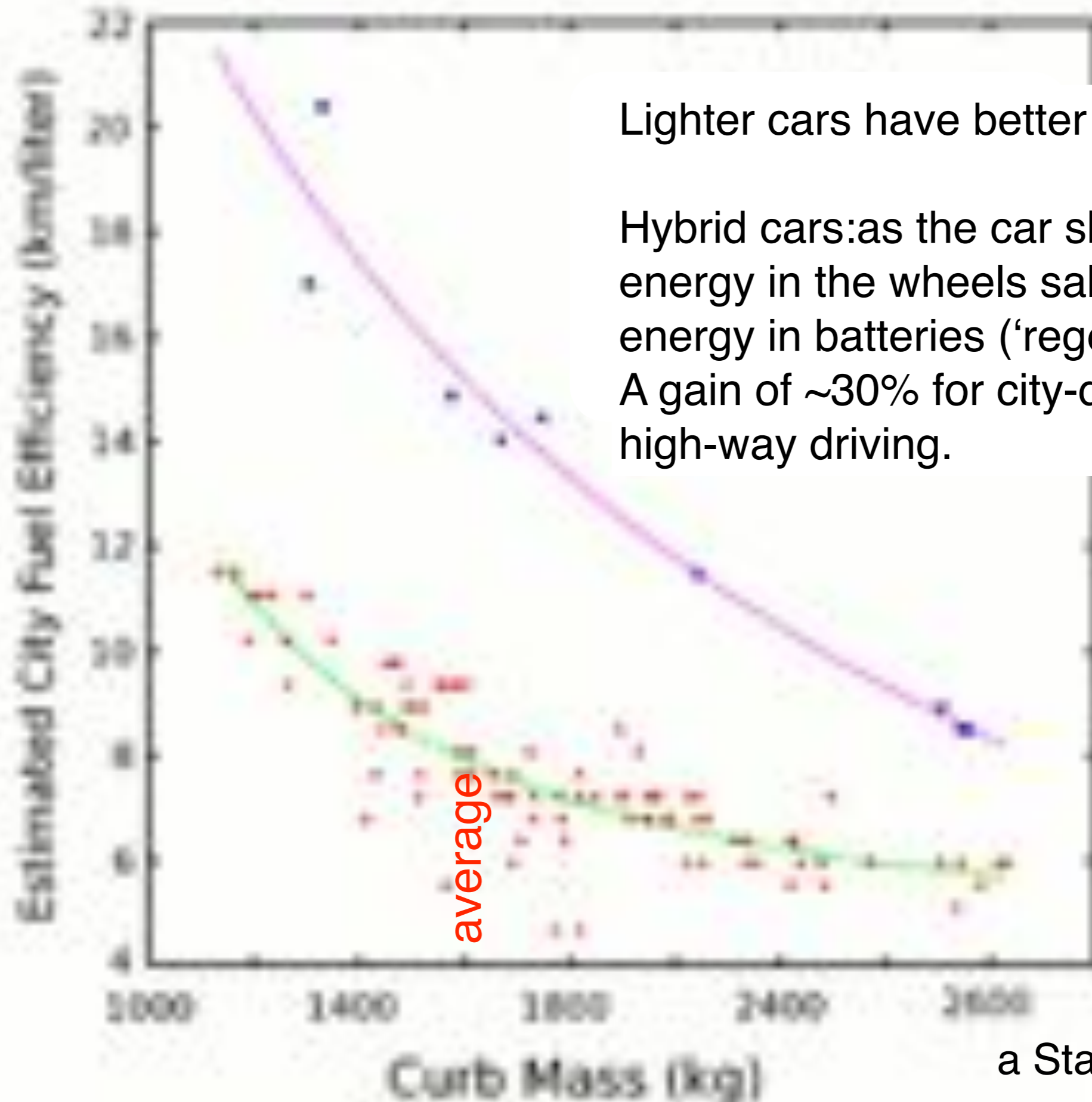


UofT Engineering  
Solar-powered Car

### B-7 Design Highlights

Weight:	170kg (without driver)
Cruising speed:	75km/hr
Aerodynamic drag:	0.01 (Cd. plan)
Chassis:	Carbon fibre monocoque
Solar Array:	SunPower C60
Maximum Array Power:	1.3kW

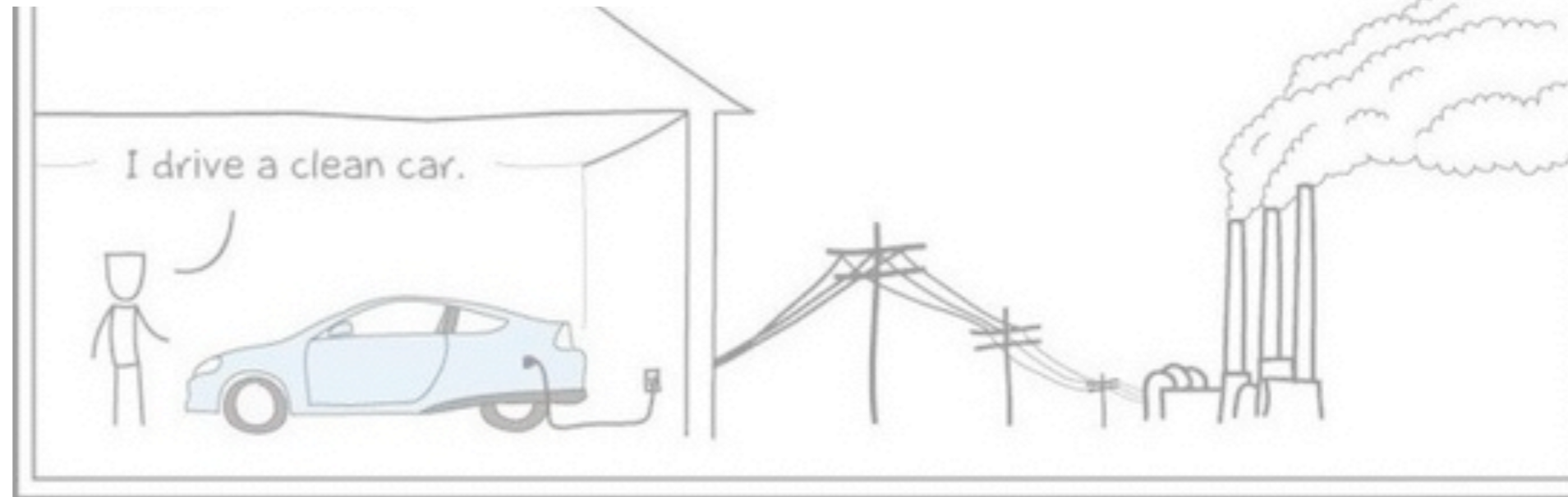
# Hybrid cars improve city-driving fuel economy.



Lighter cars have better fuel economy.

Hybrid cars: as the car slows down, kinetic energy in the wheels salvaged as chemical energy in batteries ('regenerative braking'); A gain of ~30% for city-driving, but little for high-way driving.

# What about cars that don't live on oil?



	Conventional	Hybrid-Electric	Plug-in Hybrid Electric	Battery Electric
				
	<b>CV</b>	<b>HEV</b>	<b>PHEV</b>	<b>BEV</b>
<b>Power Convertor</b>	<b>Engine</b>	<b>Engine &amp; Motor</b>	<b>Engine &amp; Motor</b>	<b>Motor</b>
<b>Battery Pack</b>	-	Small	Medium	Large
<b>Gasoline</b> 	✓	✓	✓	
<b>Electricity</b> 			✓	✓

- There are lots of hypes.
- Most electricity today is generated from fossil fuel, with 30% efficiency.
- Batteries in Tesla Roadster weigh 800kg, cost \$40,000, for 500 recharges.
- The Battery Challenge

# What about cars that don't live on oil?



# You are travelling from Toronto to Vancouver. What are the energy costs for different transports?

	fuel cost (\$)
car	\$500
Boeing 747	\$250
train	\$10

- Car travel is fuel in-efficient. Planes are similar.
- Planes lifting-off/staying-afloat requires massive energy.
- Plane tickets reflect fuel cost.
- Planes can only use oil (kerosene). No alternatives in view.
- Trains are by-far the most economical.

Trains are by-far the most economical.



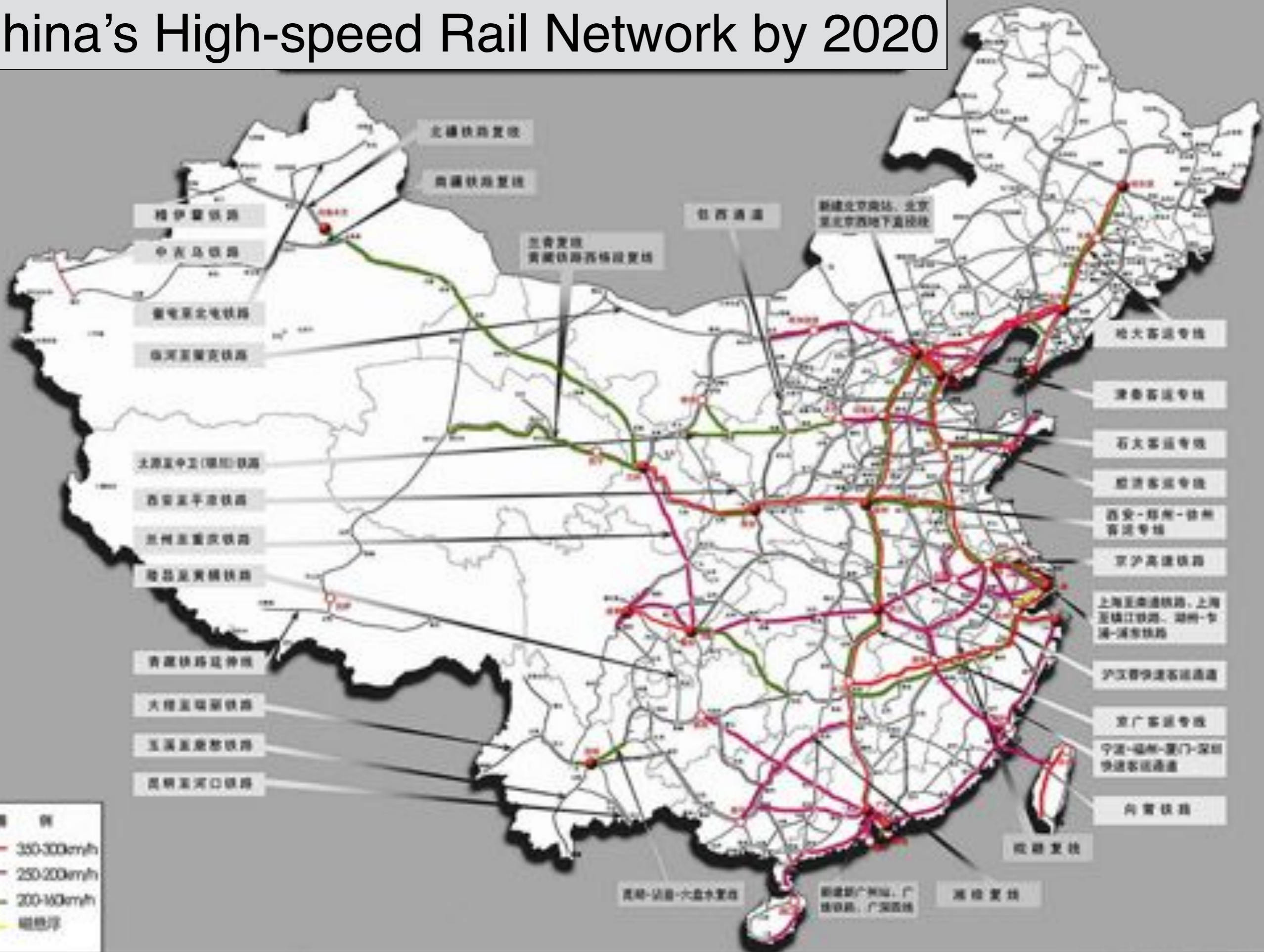
- . Boeing 747: cruise speed 1000km/hr
- High-speed trains: typical speed 300km/hr
  - competitive travel time (to/from city centre) coast to coast
- . High-speed trains that connect major cities are developed in China, France, Germany, Japan....
  - why not UK, US, Canada?
- . Trains today are powered by electricity.

# The future of flying?





# China's High-speed Rail Network by 2020



# 10x lower energy use

premises: it is very hard to convince people to change their life-style

space/water heating: possible to reduce energy use dramatically, without affecting life-styles; technology is here but ... the attitude!

transportation: technology still evolving.

- higher fuel economy for cars ...
- electric cars on the horizon, but problems now...
- air travel much less promising;
- high-speed rail needs serious government support.

# Recycling — is it worth it?

- . batteries, electronic-waste should be recycled!
  - contains lead, nickel, cadmium, beryllium...
- . what about metals? plastics? paper?



Reduce, first.



videos in <http://storyofstuff.org>



# Why do we recycle?

## **Environmental impacts**

heavy metals, chemicals...

## **Limited resources on Earth**

e.g., plastics are made from refined petroleum (fractional distillation)

metals are from mines...

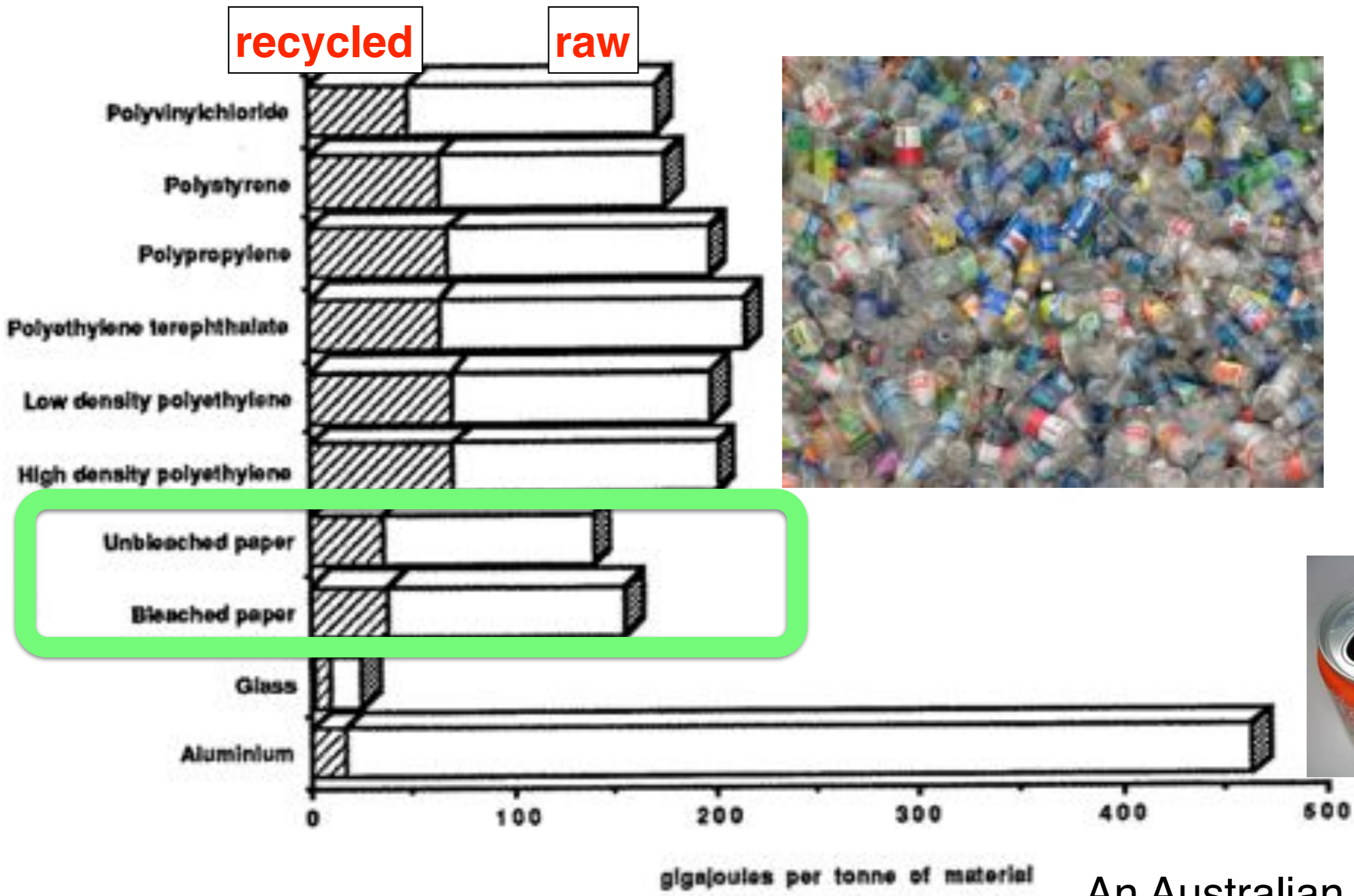
## **Energy cost of production**

Producing from raw material:  
energy in mining  
energy in refining  
energy in manufacture

vs.

Producing from recycled material:  
energy in collecting,  
energy in sorting  
energy in manufacture

# Total energy required to produce products from raw materials and from recycled materials — recycling wins.



An Australian study

# *Feel-Good Measures That Don't Necessarily Work*

Buses

Recycling Paper

Muller Chapter 7.5

## RECYCLING PAPER

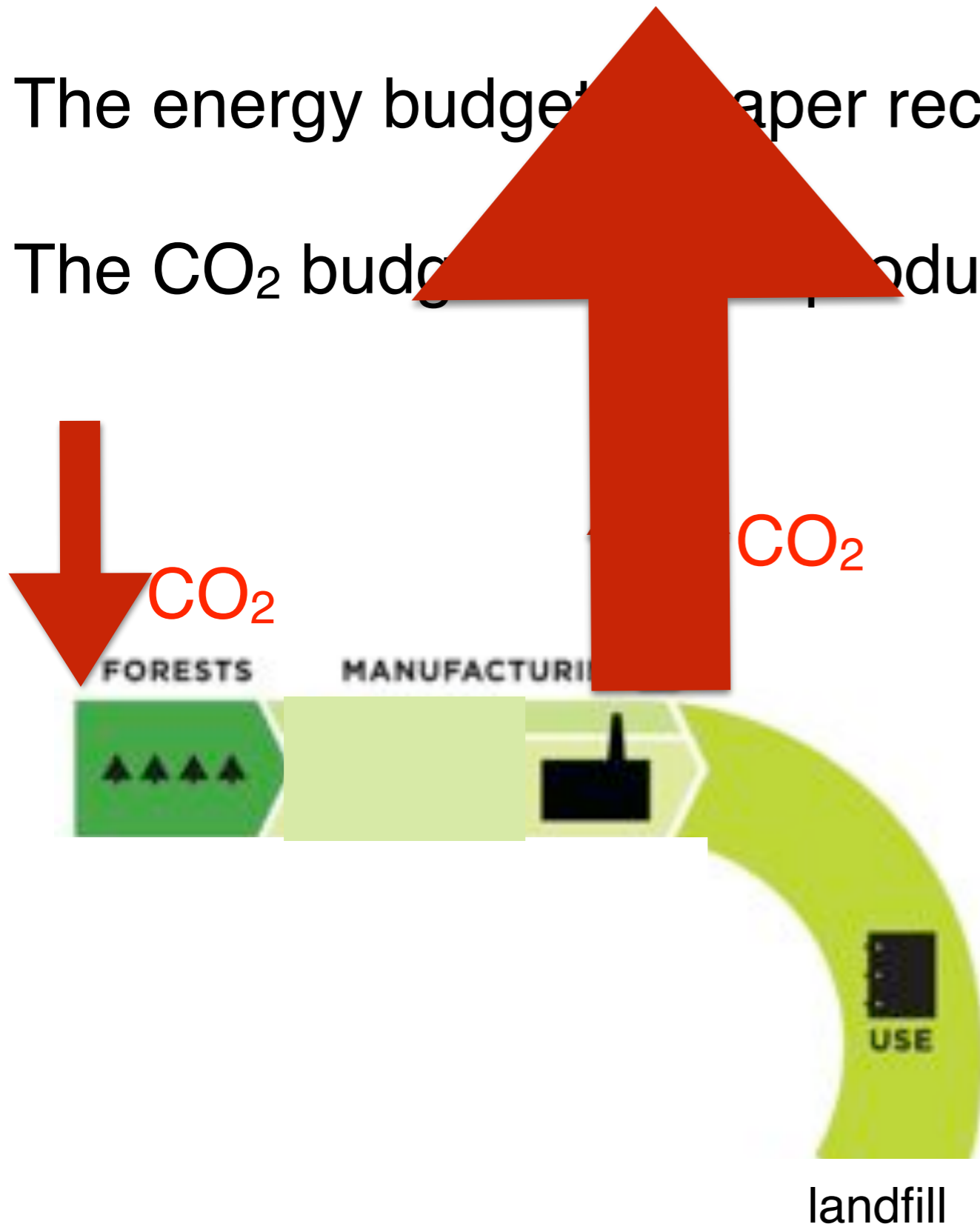
There are a lot of fads and useless measures. Some of them may have psychological value—such as schoolteachers asking children to recycle paper in order to increase their awareness of waste. In fact, virtually all paper used in the United States comes from trees specifically grown for that purpose, so recycling paper doesn't save trees.

when used as landfill, it is sequestering carbon taken from the air by the trees grown to make it.

So, recycling paper neither saves trees nor reduces greenhouse emissions. There's nothing wrong with recycling paper. The key issue is how you justify it.

The energy budget of paper recycling: saves ~ 40% in energy.

The CO<sub>2</sub> budget of paper production?



but numbers matter:

producing one pound of paper releases ~ 5 pounds of CO<sub>2</sub>

EPA, '06



“My parents pass me down an old fridge that is not energy efficient. Should I ditch it for a new ultra-efficient fridge?” (or, car, TV, ...)