Lecture 01/02 (Part II) EngGen 140

Topics:
- Global & NZ energy
  - sources
  - consumption
- Planetary energy balance

5.1 (& 5.2)

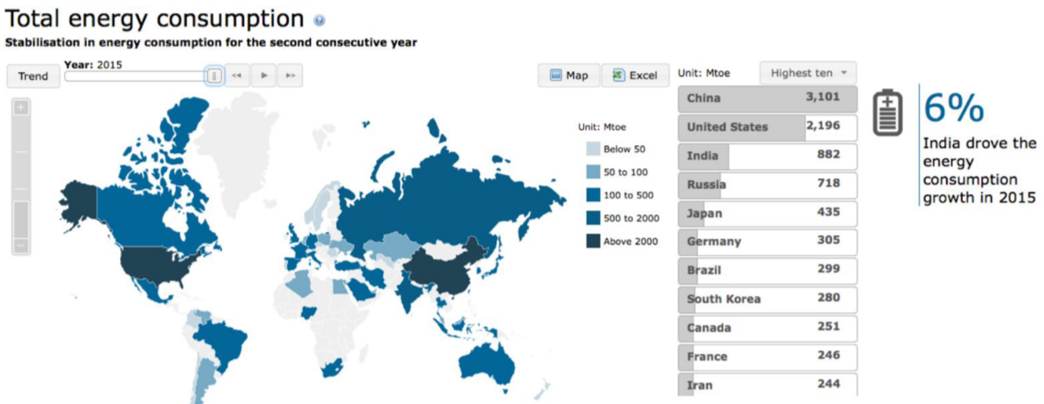
What you should be able to do
- Read basic graphs
- Identify & interpret basic trends etc
- Do basic calcs using data & units

see last page for example questions

Global energy consumption

consider:

1a.



1b.

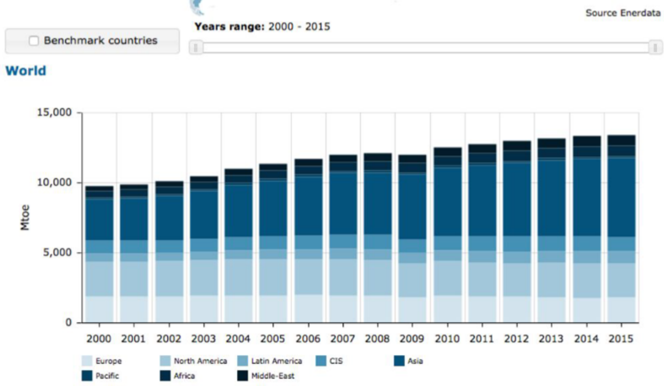


Figure 1: Total global energy consumption for 2015 and the world's energy consumption over the last 15 years. Units are presented in *tonne of oil equivalent* (toe), which is the amount of energy released by burning one tonne of crude oil. Data obtained from Enerdata Global Energy Statistical Yearbook [https://yearbook.enerdata.net/].

Mtoe.

What do we want to know/understand?

who, what, where, why etc.

Figure shows energy consumption

Q: who is using the most?

A: China (3,101 MToe)

(from 1a).

Mtoe?

(Mega tonnes of oil equivalent)

energy released by burning one tonne of crude oil.

Unit: Mtoe	Highest ten
China	3,101
United States	2,196
India	882
Russia	718
Japan	435
Germany	305
Brazil	299
South Korea	280
Canada	251
France	246
Iran	244

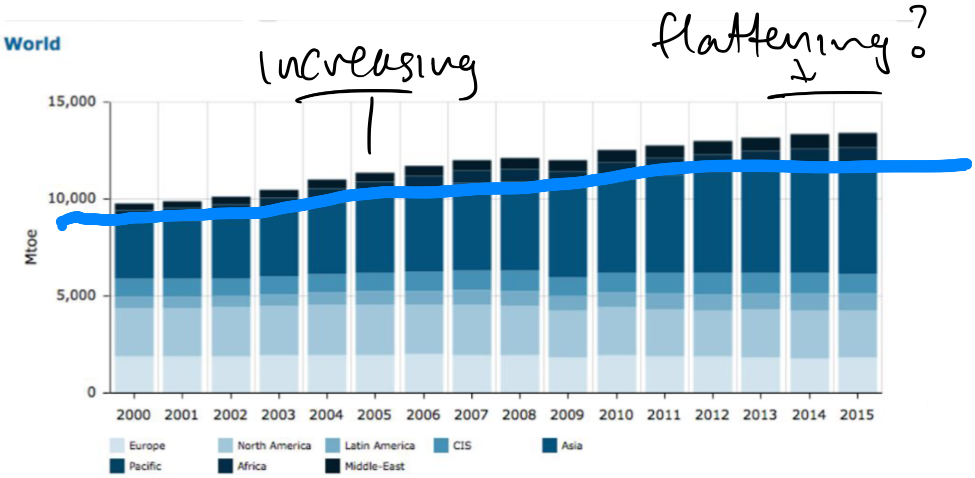
Q: What is the trend in consumption over last 15 years?

overall:

(last two years)

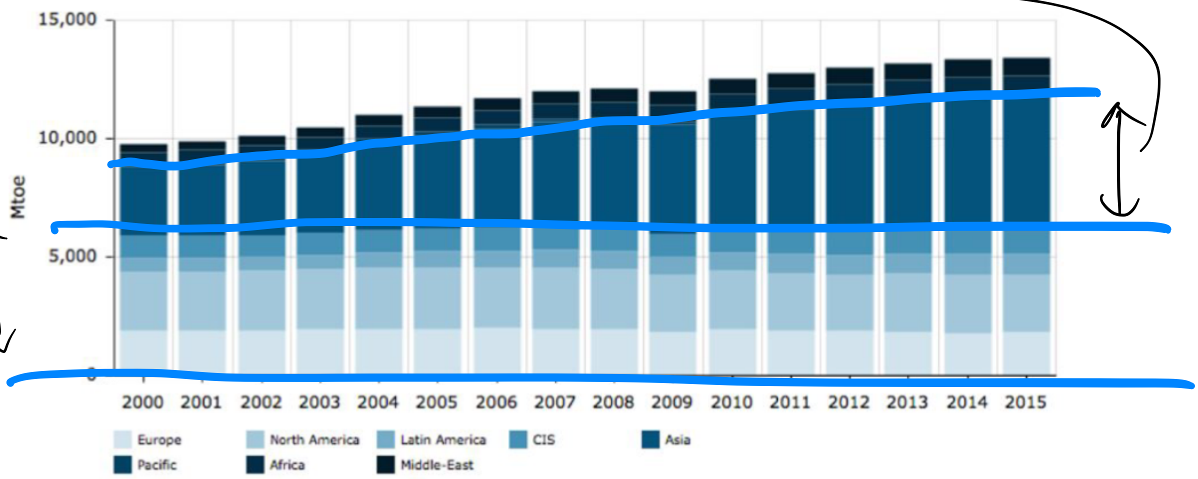
increasing

flattening?



Other trends?

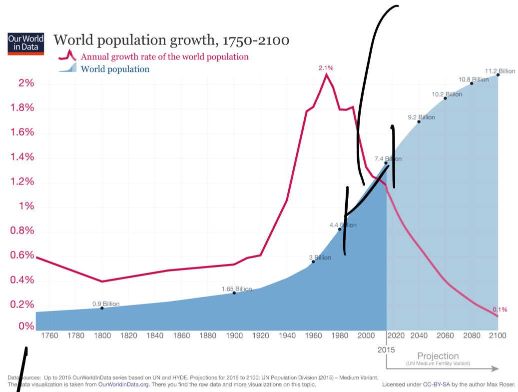
bigger growth: Asia



pretty stable: Europe, N. A etc.

Per person?

~4.5 → 7.5 Billion



Growth of population:

→ still quite exponential

→ Efficiency of energy use has increased

↳ slower growth in total consumption

$$\text{total} = \underbrace{\text{energy}/\text{person}}_{(\downarrow)} \times \underbrace{\text{person}}_{(\uparrow)}$$

Units : what are 'Mtoe'?

Mega = 1×10^6

toe = "tonnes of oil equivalent"

convert to joules!

eg $\boxed{1 \text{ Mtoe} = \_\ J\ ?}$

• Given $1 \text{ toe} = 42 \text{ GJ} = 42 \times 10^9 \text{ J}$

So

$$1 \text{ Mtoe} = 1 \times 10^6 \text{ toe} = (1 \times 10^6) \times (42 \times 10^9) \text{ J}$$

$$= 42 \times 10^{15} \text{ J} = 42 \text{ PJ}$$

peta Joules

$$\frac{1 \text{ Mtoe}}{42 \text{ PJ}} = 1$$

Table 2: Standard prefixes for the SI units of measure.

Multiples	Prefix name		deca	hecto	kilo	mega	giga	tera	peta	exa
	Prefix symbol		da	h	k	M	G	T	P	E
	Factor	10^0	10^1	10^2	10^3	10^6	10^9	10^{12}	10^{15}	10^{18}
Fractions	Prefix name		deci	centi	milli	micro	nano	pico	femto	atto
	Prefix symbol		d	c	m	μ	n	p	f	a
	Factor	10^0	10^{-1}	10^{-2}	10^{-3}	10^{-6}	10^{-9}	10^{-12}	10^{-15}	10^{-18}

eg China

3,000 Mtoe

=

$$3000 \text{ Mtoe} \times \frac{42 \text{ PJ}}{1 \text{ Mtoe}}$$

$\approx 126,000 \text{ PJ}$

Convert world consumption to TW ($T = \text{tera} = 10^{12}$)

1. TW·h

$$\underbrace{1 \text{ Mtoe}}_{\text{energy}} = \underbrace{11.63 \text{ TW} \cdot \text{h}}_{\frac{\text{energy}}{\text{time}} \times \text{time}} \quad \boxed{1 = \frac{1 \text{ Mtoe}}{11.63 \text{ TW} \cdot \text{h}}}$$

2. h.

$$\underbrace{1 \text{ year}}_{\text{time}} = \underbrace{8760 \text{ h}}_{\text{time}} \quad \boxed{1 = \frac{1 \text{ year}}{8760 \text{ h}}}$$

World consumption

In 2015 : used ~ 13,000 M toe (energy)

$$\left(\frac{\text{energy}}{\text{time}}\right) \rightarrow \boxed{\frac{13{,}000 \text{ M toe}}{1 \text{ year}} = \frac{13{,}000 \text{ M toe}}{1 \text{ year}} \times \underbrace{\left(\frac{1 \text{ year}}{8760 \text{ h}}\right)}_{\text{ie } (\times 1)}}$$

&

$$\boxed{\frac{11.63 \text{ TW}\cdot\text{h}}{1 \text{ M toe}} = 1}$$

so

$$\frac{13{,}000 \text{ M toe}}{1 \text{ year}} = \frac{13{,}000 \cancel{\text{M toe}}}{1 \cancel{\text{year}}} \times \left(\frac{11.63 \text{ TW}\cdot\cancel{\text{h}}}{1 \cancel{\text{M toe}}}\right) \times \left(\frac{1 \cancel{\text{year}}}{8760 \cancel{\text{h}}}\right)$$

$$= 13{,}000 \times 11.63 / 8760 \text{ TW}$$

$$\approx 17.26 \text{ TW} \quad (\text{energy}/\text{time} = \text{power})$$

China consumption

$$\frac{3000 \text{ M toe}}{1 \text{ year}} = \frac{3000 \cancel{\text{M toe}}}{1 \cancel{\text{year}}} \times \frac{11.63 \text{ TW}\cdot\cancel{\text{h}}}{\cancel{\text{M toe}}} \times \frac{1 \cancel{\text{year}}}{8760 \cancel{\text{h}}}$$

$$= \frac{3000 \times 11.63}{8760} \text{ TW}$$

$$\approx 4 \text{ TW} \quad (\text{almost } 1/4 \text{ of world})$$

Where does energy come from? (supply)

- Global
- NZ

Consider

Global energy supply

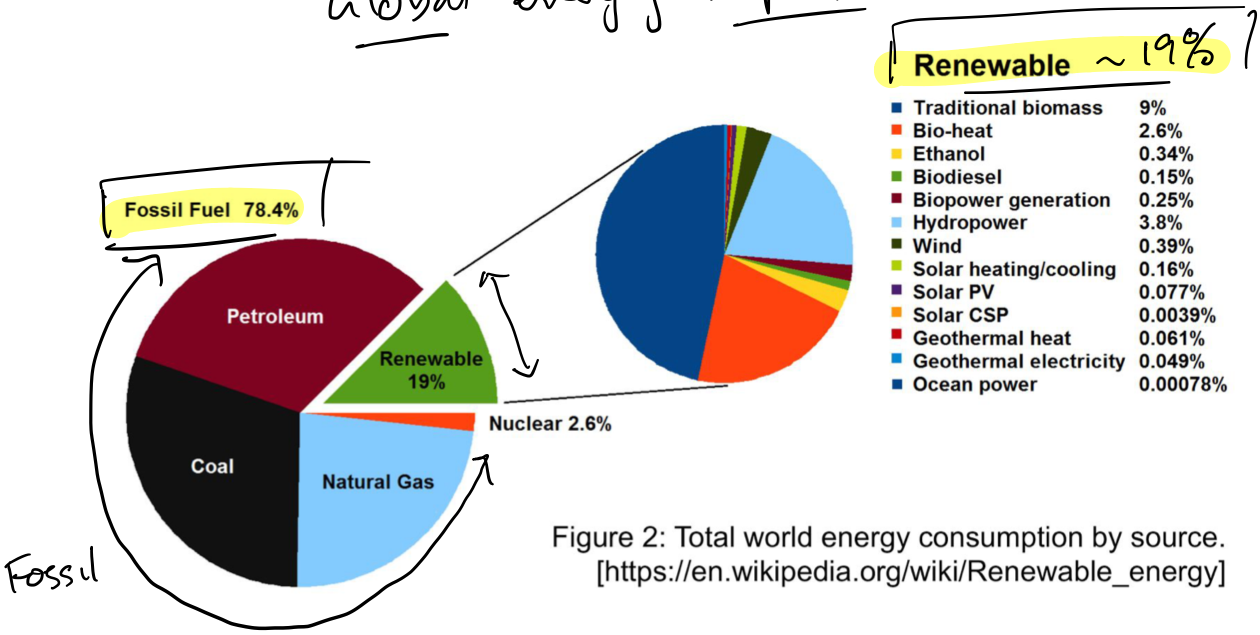


Figure 2: Total world energy consumption by source.
[https://en.wikipedia.org/wiki/Renewable_energy]

Which dominate?

Coal & Petroleum: Fossil fuels (78.4%)

A fossil fuel is a fuel formed by natural processes, such as anaerobic decomposition of buried dead organisms, containing energy originating in ancient photosynthesis.
Wikipedia

⇒ Non renewable

NZ Energy supply

Consider:

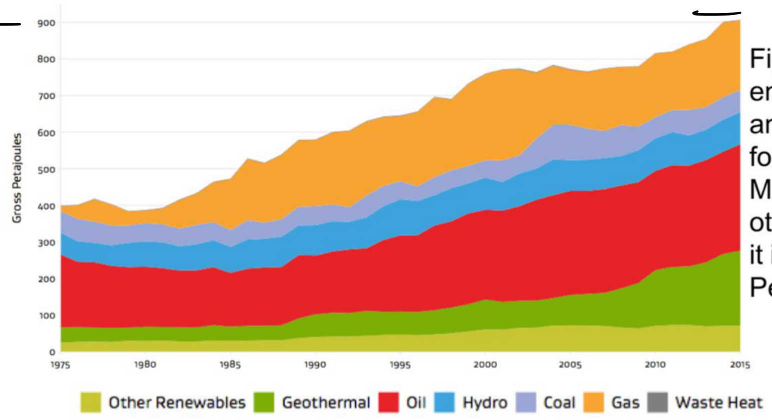


Figure 3: Total primary energy supply is the total amount of energy supplied for use in New Zealand. Much of it is converted to other forms of energy before it is used. Units are in Petajoules (i.e. 10^{15} J).
[Energy in NZ 2016, MBIE]

PJ

What? Total supply
Broken down by type

Q: Total supply in 2015?
900 PJ (NZ)

(recall: China consumption 3,000 Mtoe
ie 3000 Mtoe × (42 $\frac{\text{PJ}}{\text{Mtoe}}$)

~ 126,000 PJ ~ 140 × NZ supply!)

Q: How much from renewable?

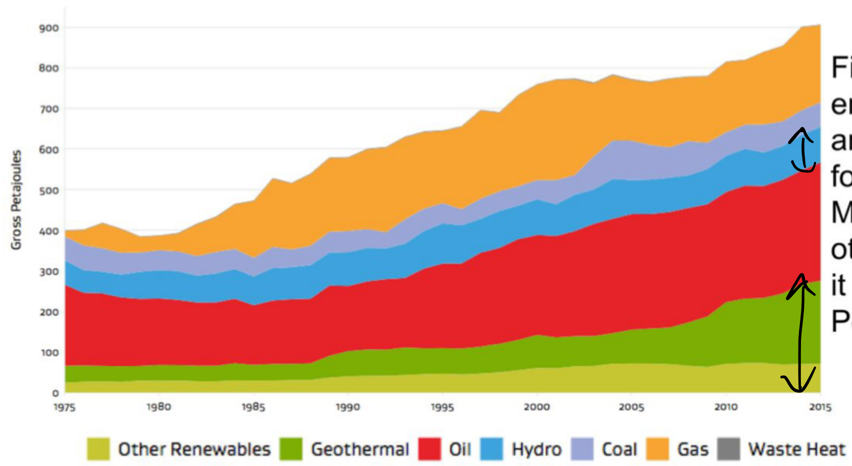


Figure 3: Total primary energy supply is the total amount of energy supplied for use in New Zealand. Much of it is converted to other forms of energy before it is used. Units are in Petajoules (i.e. 10^{15} J).
[Energy in NZ 2016, MBIE]

~ 300-400 PJ?

of 900 ~ 30-45% of total supply

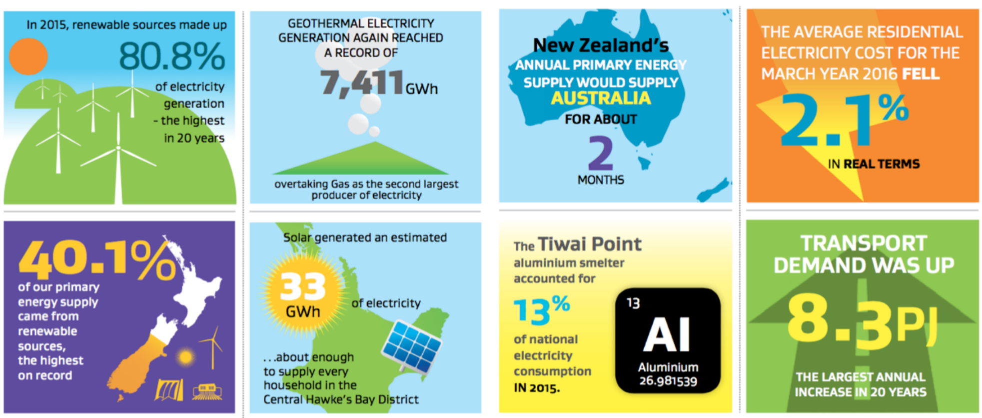
Q: Biggest growth?

→ Geothermal!.

Bonus data:

geothermal

yay! 30-45% ✓



[Energy in NZ 2016, MBIE]

NZ consumption (cf supply)

⇒ Trends in consumption?

⇒ what are we consuming?

⇒ what are we using this for?

Consider: NZ consumption

→ increasing consumption

oil still dominates

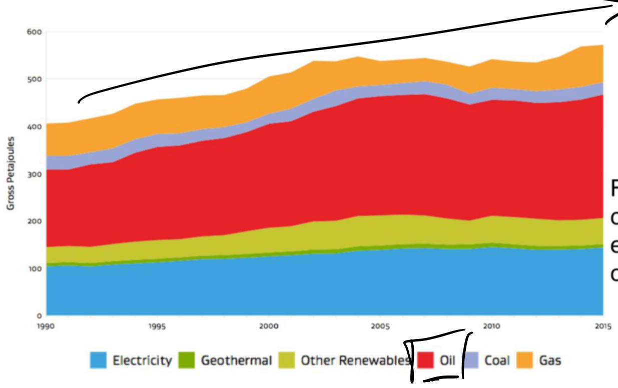


Figure 4: Total energy consumption includes all energy used by final consumers.
[Energy in NZ 2016, MBIE]

transport: growing demand

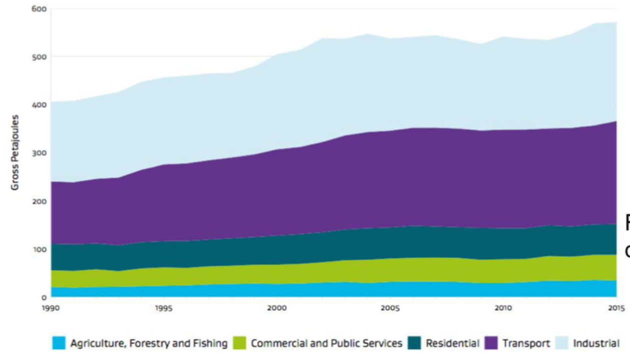


Figure 5: Consumer energy demand by sector.
[Energy in NZ 2016, MBIE]

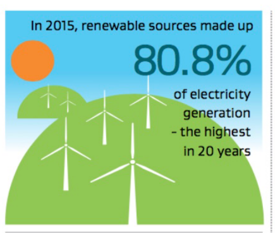
How could we alter?

eg ⇒ shift transport to renewable electric sources

⇒ electric cars

→ electric public transport

Recall:



Feasible?

⇒ depends!

Example

Electricity consumption : comparison to other countries

- NZ consumption per person in $\boxed{\text{kWh / person}}$ (vs) other countries.

NZ

Assume

- pop ~ 4.5 million $= 4.5 \times 10^6$ people
- tot. electricity use ~ 160 PJ $= 160 \times 10^{15}$ J
- 1 kWh $= 3.6 \times 10^6$ J

Units

$$\Rightarrow \frac{1\,\text{kWh}}{3.6 \times 10^6\,\text{J}} = 1$$

So **Total use (NZ)**

$$160\,\text{PJ} = 160 \times 10^{15}\,\text{J}$$

$$= 160 \times 10^{15}\,\cancel{\text{J}} \times \left(\frac{1\,\text{kWh}}{3.6 \times 10^6\,\cancel{\text{J}}}\right)$$

$$= \frac{160}{3.6} \times 10^9\,\text{kWh}.$$

$$\text{Total use / person}_{NZ} = \left(\frac{160}{3.6} \times 10^9\right) \times \left(\frac{1}{4.5 \times 10^6}\right)$$

$$\approx \boxed{9900\,\text{kWh / person}} \quad (\text{NZ})$$

Comparison:

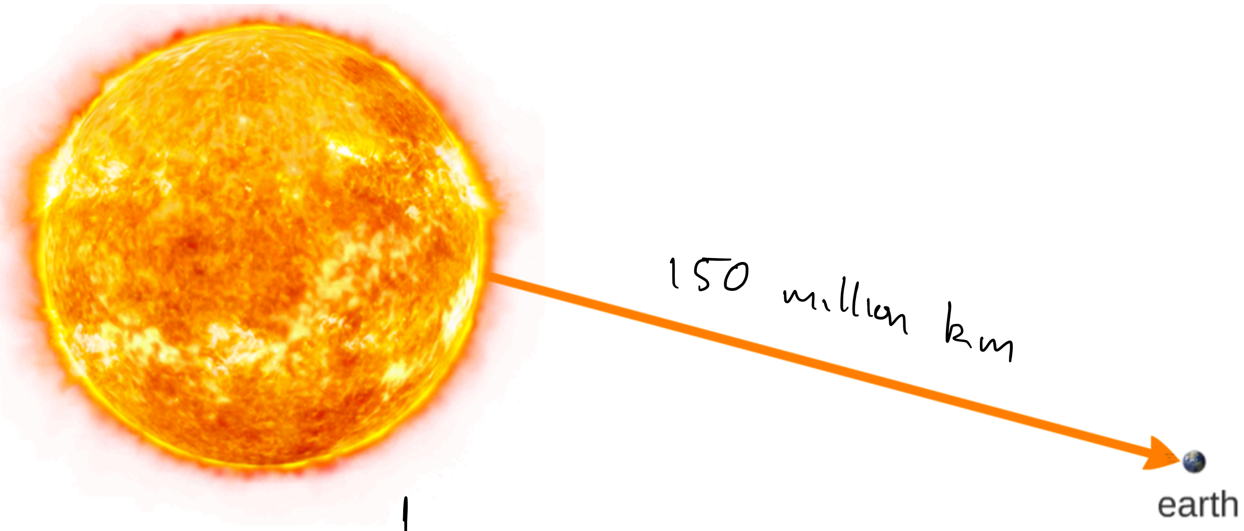
USA : ~ 14 000 kWh / person

Mexico : ~ 2,500 kWh / person

Norway : ~ 25,000 kWh / person

Planetary Energy Balance (5.1.3).

Where does our energy come from in the first place??



The sun!

⇒ Radiates energy (from nuclear fusion reactions)

⇒ only a small fraction actually reaches earth

We could calculate (eg last year...)

a) The total radiant energy of the sun

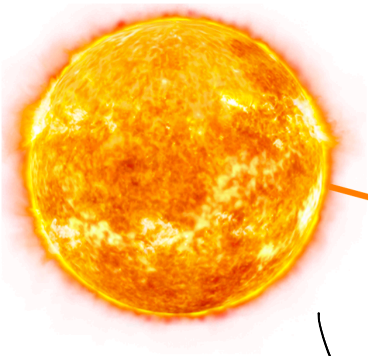
b) How much reaches earth from the sun

c) What happens to the energy that reaches earth

Let's start from here

How much reaches earth from the sun?

$3-5 \times 10^{26}$ Watts at surface →



150 million km

pretty far away!

earth – pretty small!

this far away & hits

spread out over area

Far away

+

Small area of earth

Then |flux/area| 'this far away'

ie => how 'intense' is radiation 'this far away'

=> expect less

since

Tot Flux = const.
+
Area ↑

} $\frac{\text{Flux}}{\text{Area}}$ ↓

Same total energy, more spread out.

$\frac{\text{Flux}}{\text{area}} \times$ area of earth

How much reaches earth from sun?

- only about $173{,}000 \times 10^{12}$ Watts

ie $\boxed{173{,}000 \text{ TW}}$ (tera watts)

of approx

$4 \times 10^{26} = 4 \times 10^{14} \times 10^{12}$ Watts

$= \boxed{400{,}000 \times 10^{9}}$ TW

note!

reaches earth, ie

$\frac{173 \times 10^{3}}{400 \times 10^{12}} \approx$ 4×10^{-8} % of the sun's power output

---

Even then:

not all of this is actually absorbed.

Remember:

b) How much reaches earth from sun

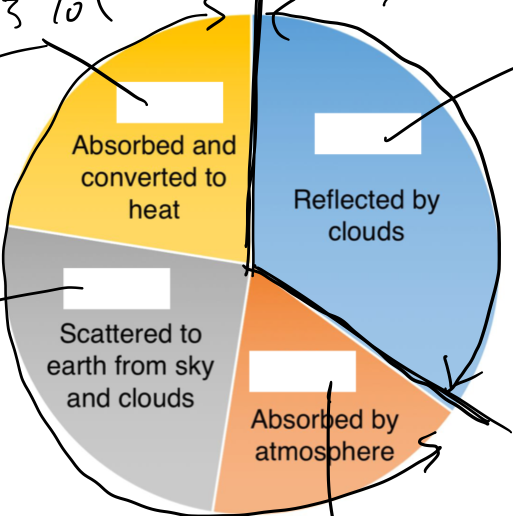
c) What happens to the energy that reaches earth

Let's start from here

What happens to the energy that reaches the earth from the sun?

back to space

~ 23%



30-35% reflected by clouds

~25%

Figure 6: The relative distribution of the Sun's energy that reaches earth.

~17%

absorbed by earth in some way

~ 65-70%

ie. 30% space

Sun → atm. → 70% earth

→

What happens to the energy that is absorbed on earth?

(~30% of 173,000TW reaching earth.)

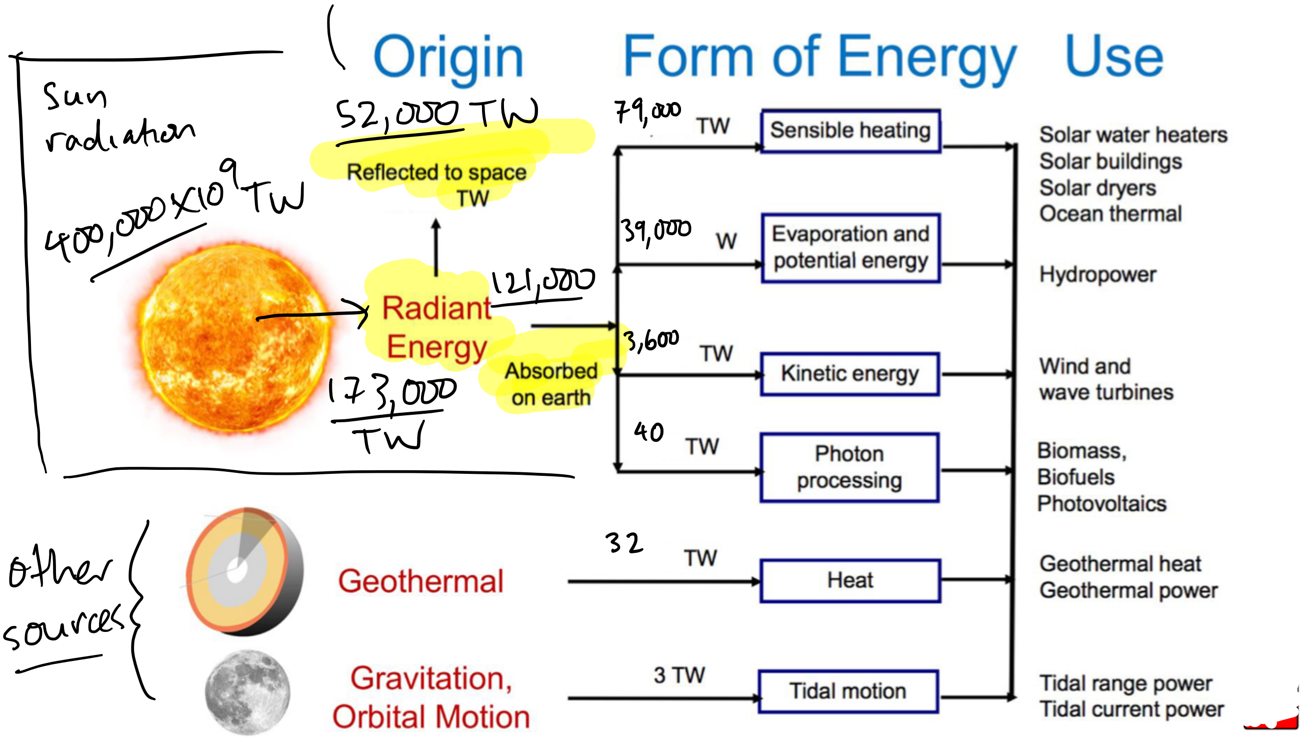


Figure 7: Planetary energy balance. Radiant energy from the sun provides orders of magnitude greater energy compared to geothermal or gravitational energy. 1TW = 10^{12}W.

→ Radiant energy from sun
~ 173,000 TW

→ Energy from geothermal + gravitational
~ 35TW

ie sun provides ~ 5000 x that provided by geothermal/gravit.

Some questions

(ie gravitational ...)

- Potential for tidal to supply world energy?

in 2015 (from before):

- Total $\boxed{\frac{13{,}000 \text{ Mtoe}}{1 \text{ year}} \approx 17.26 \text{ TW}}$

$$\left(\frac{\text{energy}}{\text{time}} = \text{power} = \frac{\text{energy}}{\text{time}} \right)$$

- tidal (assume = gravitational)

$\sim 3 \text{ TW}$

ratio $\frac{17}{3} \approx 6$

ie World consumption is $\approx 6 \times$ gravitational

(so not feasible to supply all)

Questions / comments

- Why could geothermal be considered nuclear energy?
  - ⇒ ultimately comes from radioactive decay of potassium, thorium & uranium in earth's interior.

- Refrigerators?
  - Geothermal promising for heat pumps
    - heat pump = refrigerator run backwards

- solar thermal vs solar voltai.?

5.2 Practice Problems

Worldwide energy production (WEP) in 1987 was 320 quadrillion (320×10^{15}) Btu (British thermal units; 1 Btu = 1.055 kJ = energy to heat 1 pound of H_2O from 60° to 61° F). By 1996, it had increased by 55 quadrillion Btu.

1. Determine the magnitude of energy production in 1996 in joules and the percentage increase from 1987. Calculate the average annual rate of increase in WEP between 1987 and 1996.

2. In 1996, the USA produced 73 quadrillion Btu, more than any other country. Calculate the contribution of the USA to WEP in 1996.

3. Only about 0.025% of the Sun's radiant energy that reaches Earth is captured by photosynthetic organisms. Calculate the magnitude of this energy (in $kJ.s^{-1}$), using the data provided in section 5.1.3 above. Find the ratio of WEP_{1996} to the Sun's energy captured by photosynthetic organisms.

4. Assuming that $173{,}000 \times 10^{12}$W of the energy reaches Earth and is then either reflected or absorbed, calculate the total energy output of the Sun (1 W = 1 $J.s^{-1}$). (Diameter of Earth = 12,756 km; area of a circle = p x $(\text{diameter}/2)^2$; surface area of a sphere = 4 x $(\text{diameter}/2)^2$; mean distance of Earth from Sun = 149.6×10^6 km).

5. Using your result from the previous problem, calculate the number of moles of ^2H consumed when a heat this large is released. Calculate the energy equivalent of the Earth (mass = 5.976×10^{27} g). Compare the mass energy of Earth to the radiant energy of the Sun that reaches Earth in one year.

[from Haynie, D. T. 2008. Biological Thermodynamics. Cambridge University Press]

Exam – some relevant questions

Physics of Energy – 18 marks

21) Global energy use has steadily increased over the last 15 years, except for the last two years. This is surprising, given the continued increase in the world's population. What is the main cause of this 'plateau' in global energy consumption? **(1 mark)**

Answer:_________________________________

22) Worldwide energy consumption in 2005 was 488 EJ (exa=10^{18}). In class we estimated 2015 worldwide energy consumption to be 13,000 Mtoe (1 toe = 42 x 10^9 J). What has been the percentage increase in worldwide energy consumption in the last 10 years? **(2 marks)**

Percentage Increase: ______________

23) Which of the following sectors is mainly responsible for the growth in NZ energy consumption over the last 15 years? **(1 mark)**

A. Industrial
B. Residential
C. Transport
D. Commercial and Public Services
E. Agriculture, Forestry, and Fishing

Answer:__________

24) The radiant energy from the Sun that reaches the Earth is 1.74 x 10^{17} W. Approximately 52% of these photons are either reflected back to space, or absorbed by the atmosphere. We know that 0.025% of the energy that reaches the land is absorbed by photosynthetic organisms. Calculate the radiant energy that is converted by photosynthetic organisms over one year. **(3 marks)**

These & more: will cover in tutorial & then will post answers on Canvas