Energy – how much do we need and how can we get it?

- Introduction.
- How much energy do we and will we need in the UK?
- How can we generate energy without the CO_2?
- Summary.

Introduction – measuring energy

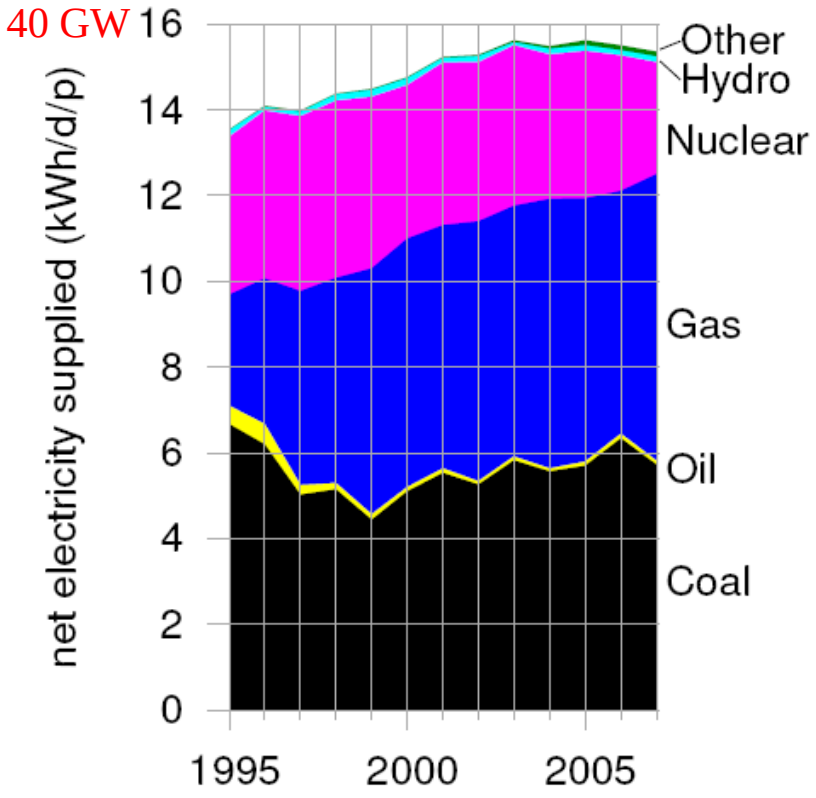
- Measure energy in joules (J).
  - 1000 J = 10^3 J
    = 1 kilojoule (1 kJ).
  - 1000 000 J = 10^6 J
    = 1 megajoule (1 MJ).
  - 1000 000 000 J = 10^9 J
    = 1 gigajoule (1 GJ).
  - 1000 000 000 000 J = 10^{12} J
    = 1 terajoule (1 TJ).
- Relate to "everyday" units:
  3.6 MJ = 1 kWh, costs about 10p.
- Measure power in watts (W).
- "Everyday" equivalent kWh per day:
  1 kWh/d = 40W.

How much energy do we need?

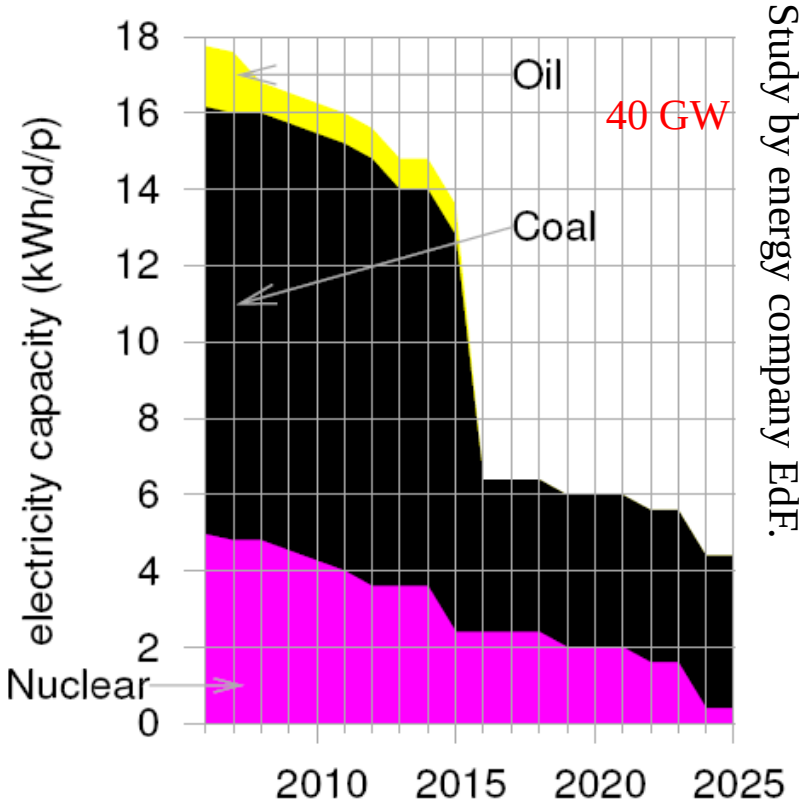
- Examples:
- Light bulb, power 40...100 W or 1...2.4 kWh/d.
- Energy used by 100 W bulb in 24 h is 8.6 MJ or 2.4 kWh.
- Average UK electrical energy consumption 16 kWh/d per person or about 58 MJ per person per day.
- This is a power of 0.68 kW per person.
- UK population about 60 x 10^6 so total current electrical power consumption ~ 40 GW.

How do we generate energy?

- What we need now, current energy supply:



- Projection of electricity generating capacity using current resources:

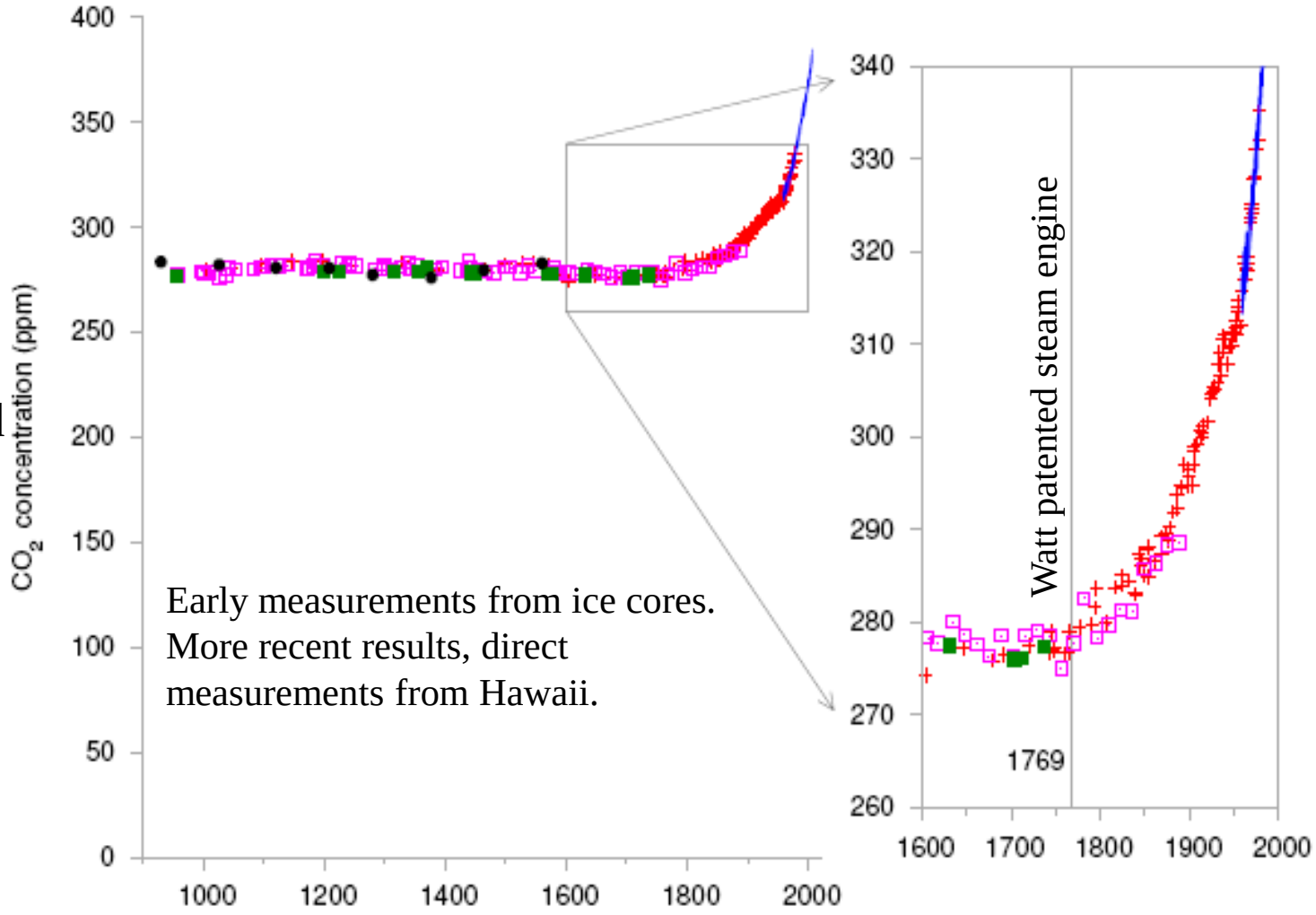


What should the “new” be?

- The Imja glacier in the 1950s (top) and in 2007 (bottom):

What should the “new” be?

- “Manmade” CO_2 is causing potentially catastrophic changes in the climate.
- Because of global warming, we need electric cars, trains, heating... i.e. more electricity, not less...
- ...and we need to generate it without the CO_2!



How much energy will we need?

- In the UK, we now use roughly:
  - 1.6 kW per person on transport.
  - 1.6 kW per person on heating.
  - 0.7 kW per person of "electricity" i.e. computers, fridges, TVs...
- Assume in future use electricity for most transport, more efficient than current systems, so require 0.8 kW/p...
- ...and that we insulate buildings better, use heat pumps etc. so heating requirements 0.8 kW/p.
- Total electricity demand then about 140 GW.
- (C.f. current figure of 40 GW.)

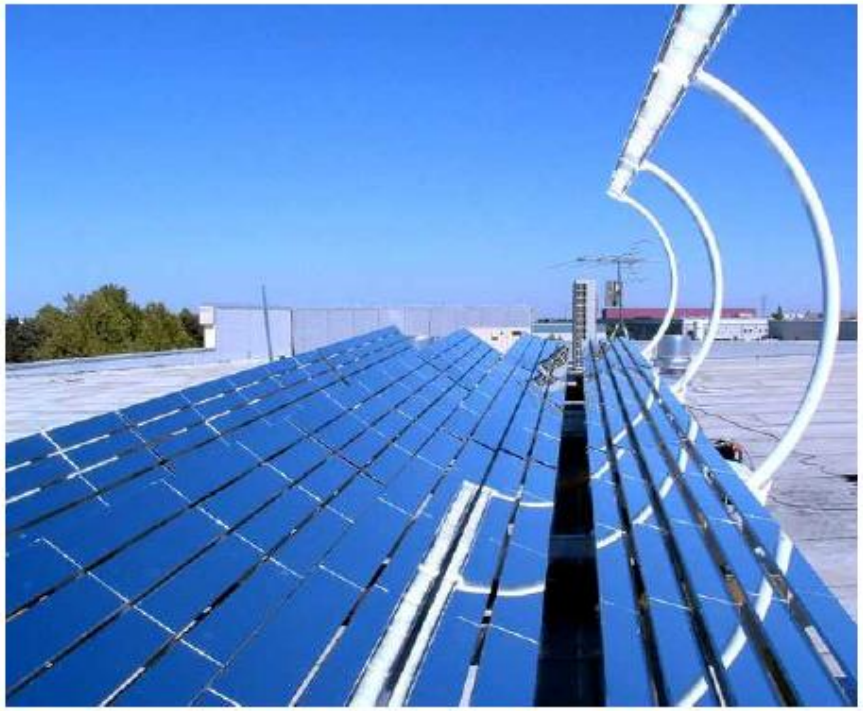
How can we get it without the CO_2?

- Renewable* energy resources:
  - Solar.
  - Biomass.
  - Wind.
  - Waves.
  - Tides.
  - Hydroelectric.
- Non-renewable energy:
  - Fusion.
  - "Clean" coal.
  - Fission.

* Naturally replenished in a relatively short period of time.

Solar power and biomass

- Solar constant 1.4 kW/m^2.
- At ground level ~ 1 kW/m^2.
- Correct for latitude, ~ 600W/m^2 peak... to average ~ 200 W/m^2...and for UK weather ~ 100 W/m^2.



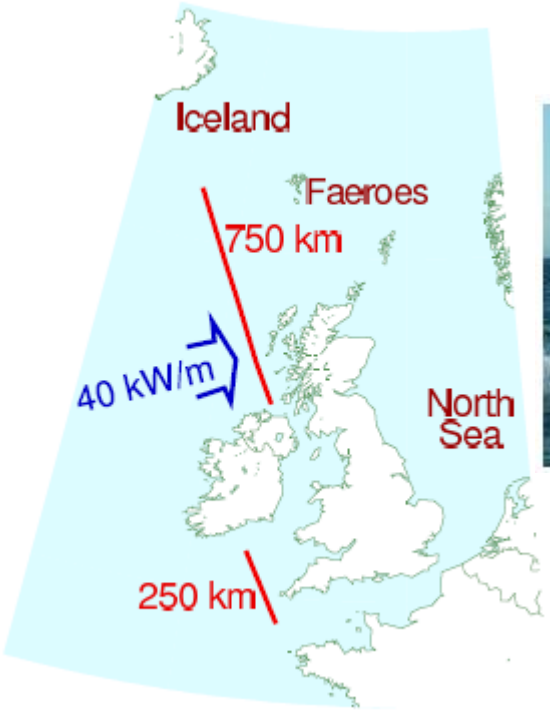
- Supplying 140 GW with solar cells of efficiency ~10% requires area of 14×10^9 m^2.
- This is 6% of land area of UK...
- ...and more than 100 times the photovoltaic generating capacity of the entire world.
- Feasible for ~ 10% of UK needs?
- Interesting globally: return to this later.

- Efficiency of conversion of solar energy to biomass about 1%...

Wind

- Average UK wind speed ~ 6 ms^{-2}.
- K = ½ mv^2, efficiency, max. packing, give wind power density of about 2 W/m^2.
- Need 30% of UK (70×10^9 m^2, i.e. Scotland) to provide 140 GW.
- Off shore, wind speed higher, power density ~ 3 W/m^2.
- Need turbines on ~ 45×10^9 m^2.
- Shallow (10...25 m depth) offshore sites available about 20 000 km^2...
- ...but many competing uses and technical problems.
- Provide perhaps 10% of UK's future electricity?

Waves



Pelamis wave energy collector

- Energy in waves hitting UK ~ 40 GW.
- Difficult to use efficiently, many competing interests.
- Perhaps provide about 5% of UK's future electrical energy?

Tides

- Lots of energy in principle (~250 GW).
- How can it be used efficiently?
- Competing interests?
- Perhaps 5% of UK's future electricity?

Hydroelectric

- UK power density ~ 0.1 W/m^2, so cannot make large contribution.
- Largest hydro-electric power station is Three Gorges Damn on Yangtse, projected output 20 GW.
- Displaced ~ 1.2 × 10^6 people, caused, and will cause, ecological problems.

Renewable balance

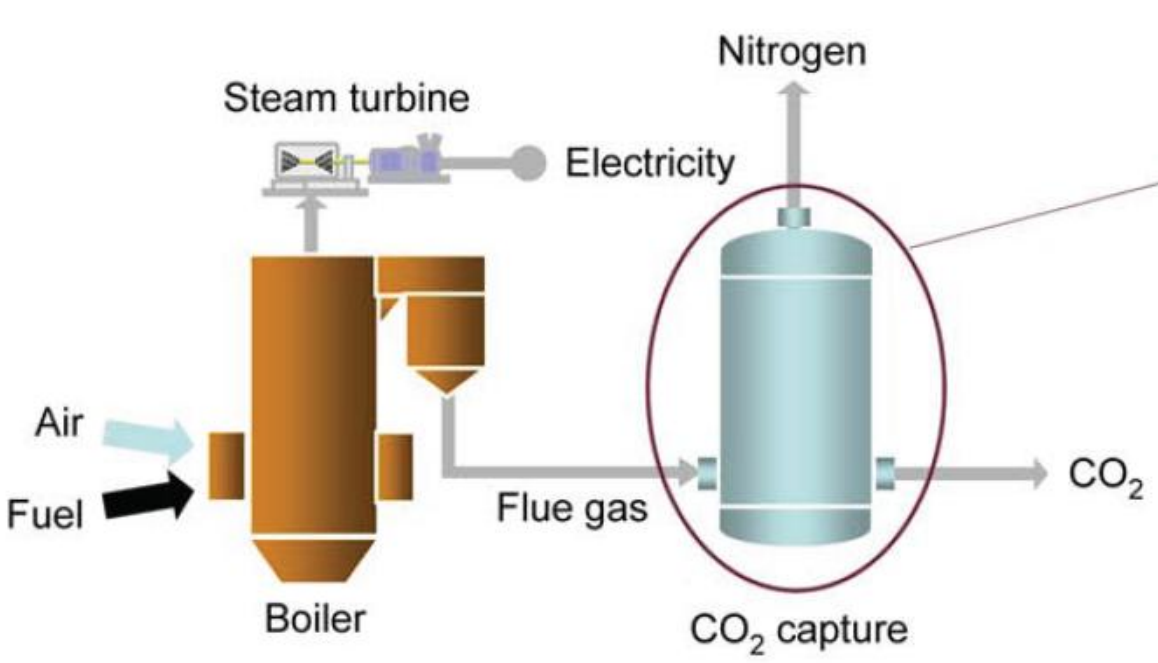
- Tally for UK so far:

Energy source	Prop. of electricity
Solar	10%
Wind	10%
Wave	5%
Tidal	5%
Other	5%
Total	35%

- We are still missing the lion's share...
- ...and the UK is particularly well off for wind, wave and tidal power!
- What about "clean" coal, nuclear fission and fusion and global solar power?

“Clean” coal

- Burn coal, capture ~ 90% of CO^2, permanently store in e.g. depleted oil reservoirs.
- Efficiency of power production decreases from ~ 40% to ~ 30%.
- UK coal reserves ~ 250 years at current rate of consumption.
- Globally very important (China building two new power stations every week).
- Use technology for cement factories...



Example: Chemical Solvents

The most common chemical solvents used for CO_2 capture from low-pressure flue gas are amines. After the CO_2 reacts with the solvent in the absorption vessel, the CO_2-rich solvent passes through the stripping column, where it is heated with steam to reverse the CO_2 absorption reaction. The CO_2 collected in the stripper is compressed for transport and storage, and the CO_2-lean solvent is recycled to the absorption stage.

Nuclear fission and fusion

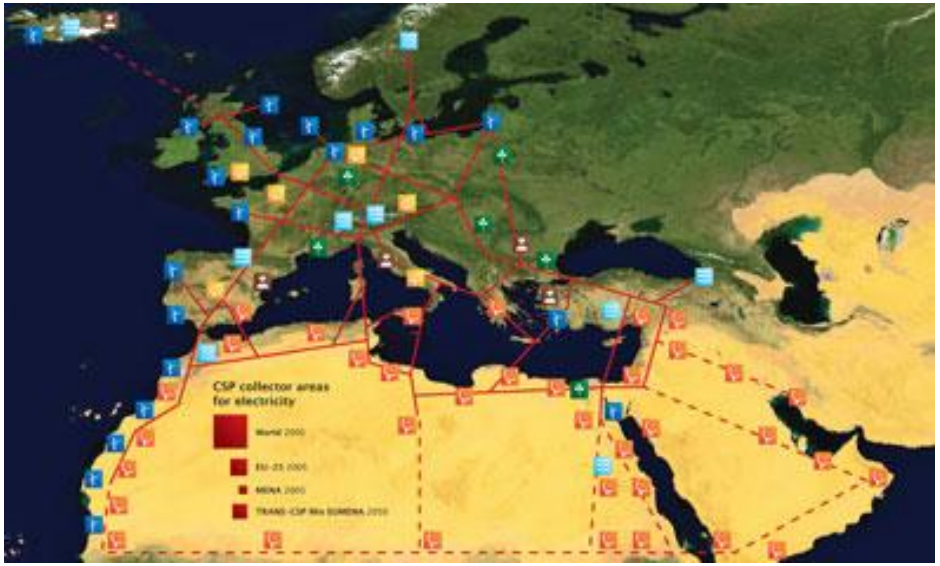
- Fission currently provides ~ 20% of UK electrical energy.
- But many (perceived) problems:
- Safety:
  - Chernobyl.
  - Three Mile Island.
- Waste:
  - Actinides with half lives of many thousands of years.
- Proliferation.
- Uranium reserves uncertain (extract from oceans, use fast breeder reactors?).
- New approaches needed: ADSR and thorium?

- Fusion under investigation by ITER.
- Construction until 2017, first deuterium-tritium plasma 2026?

International solar power

- More than 90% of world's population live less than 3000 km from a desert.
- Could be supplied with solar power.
- Use solar thermal collectors to heat oil, produce steam, generate electricity, or with Stirling engines:

- HVDC lines to efficiently transfer to coast (electrolysis to produce H_2) and to centres of population.
- Less than 10% of desert area needed to supply world's energy needs.
- Proposal for Europe: Desertec-Eumena.



Summary

- Producing enough electricity without causing climate change is a challenge.
- Renewables can provide ~ ⅓ of UK future energy needs (global approach, solar much more).
- Investigate all feasible CO_2-free energy supply (and distribution) technologies – some may not work!
- Rapid progress needed to avoid severe consequences of climate change.