Carbon footprint of electricity generation

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Parliamentary Office of Science and Technology

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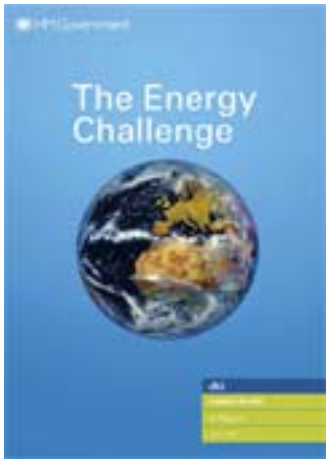
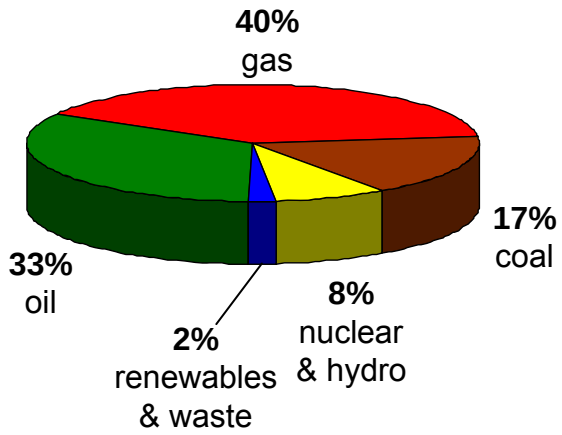
- NOT party political
- Independent, impartial, balanced – no recommendations
- Seek input from industry, academia, government, NGO's
- Peer reviewed by these external experts

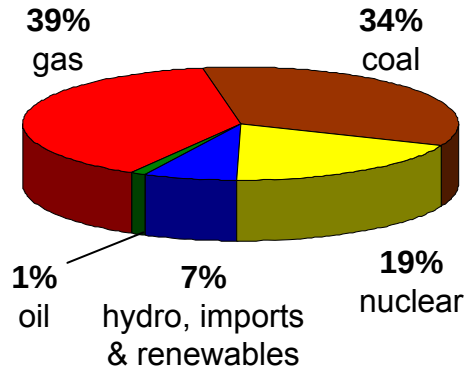
Policy context



- 2006 ‘Energy Review’
- Climate change & energy security
  - UK primary energy mix



  - UK electricity mix



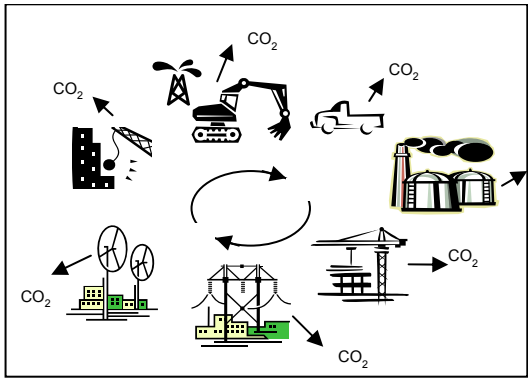
- Future policy – maintain diversity of energy mix

Background

- No electricity generation technology is ‘carbon free’
- All electricity generation technologies have a carbon footprint
- 8 different electricity generation technologies analysed

- In the context of fossil fuelled electricity generation…
  - where they are now? – current carbon footprint
  - where are they going? – future carbon footprint
  - how do they compare with other technologies?

Definitions



- What is a carbon footprint?

  The total amount of CO_2 and other greenhouse gases emitted over the full life cycle of a product or process, from extraction of raw materials through to decommissioning

- Expressed as gCO_2eq/kwh – account for different GWP of other GHG's

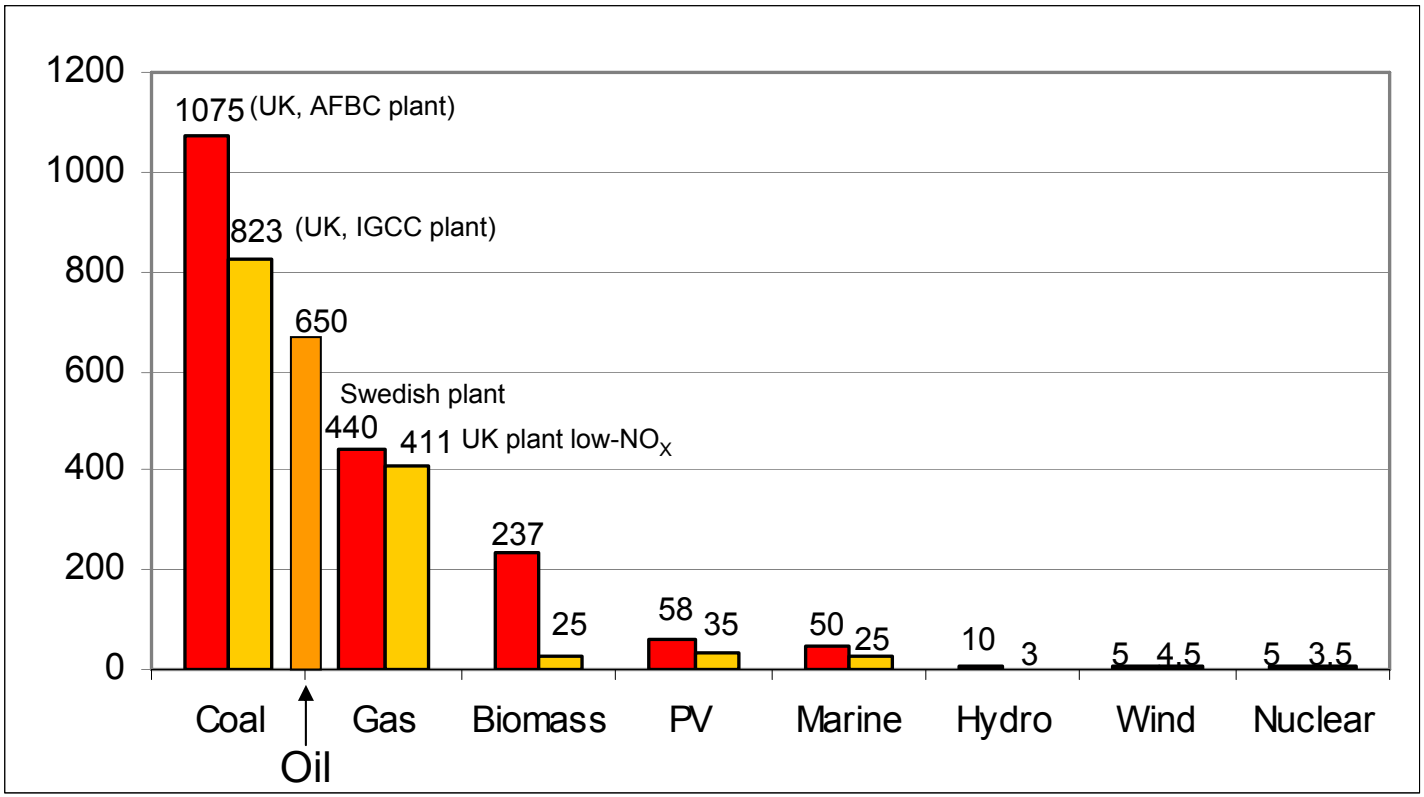
- Carbon footprints are calculated using Life Cycle Assessment (LCA)
  - 1. Boundary definition
  - 2. LCI – Life Cycle Inventory – the most objective result of LCA
  - 3. LCIA – Life Cycle Impact Assessment
  - 4. Interpretation & improvement

- LCA cannot replace the decision making process itself

Full life cycle carbon dioxide (CO_2) and other greenhouse gases (e.g. CH_4) emitted by electricity generation technologies

Carbon footprints of electricity generation technologies

(UK & European data 2004-2006)

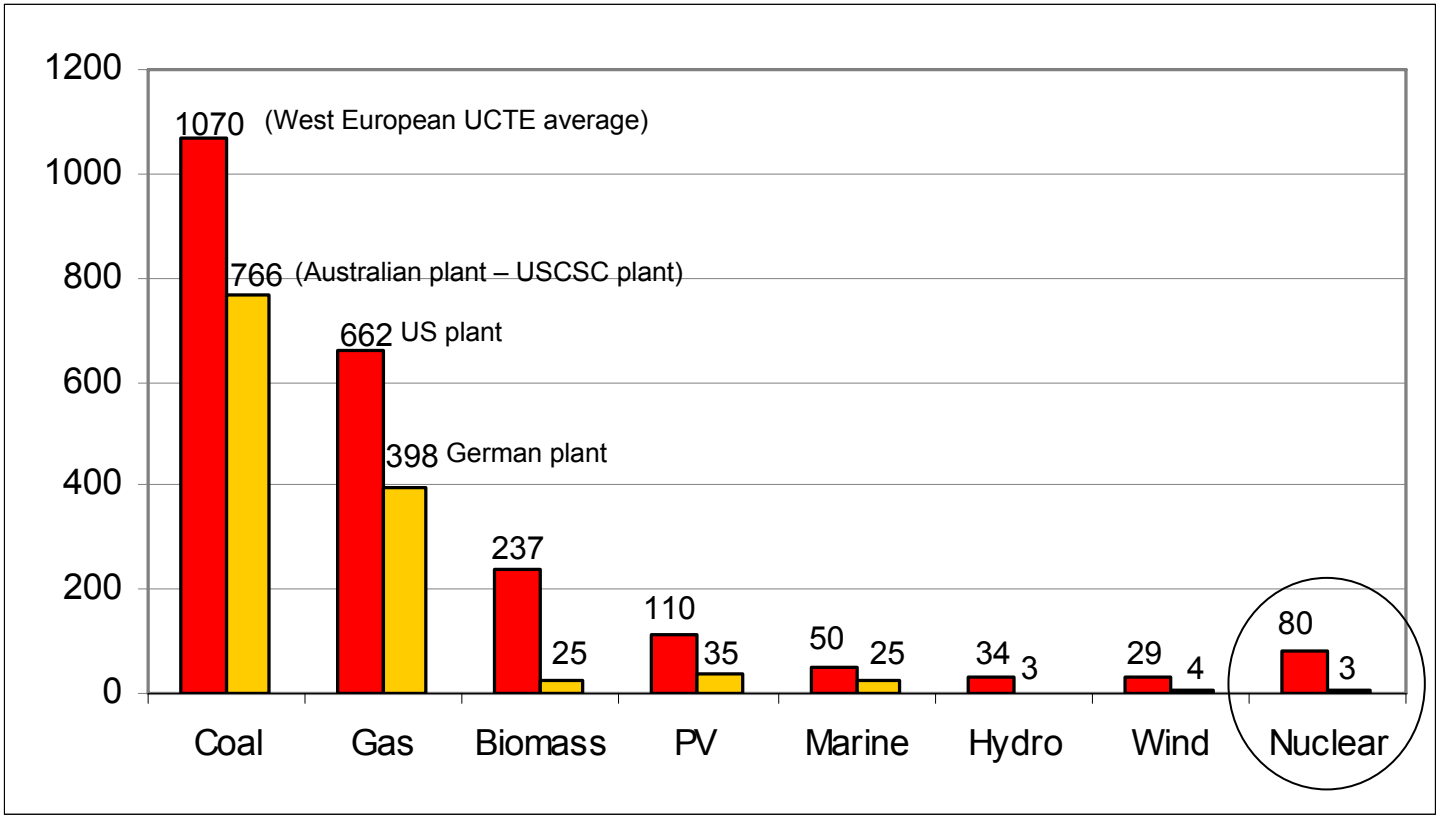


Ranges in each electricity generation technology are due to:

- Differences between individual plants – some older and/or less efficient
- Different technologies – e.g. run-of-river vs. reservoir storage
- Different LCA input (boundary definition) parameters
- Different studies – some studies older, so had older data (2000 was cutoff date)

Carbon footprints of electricity generation technologies

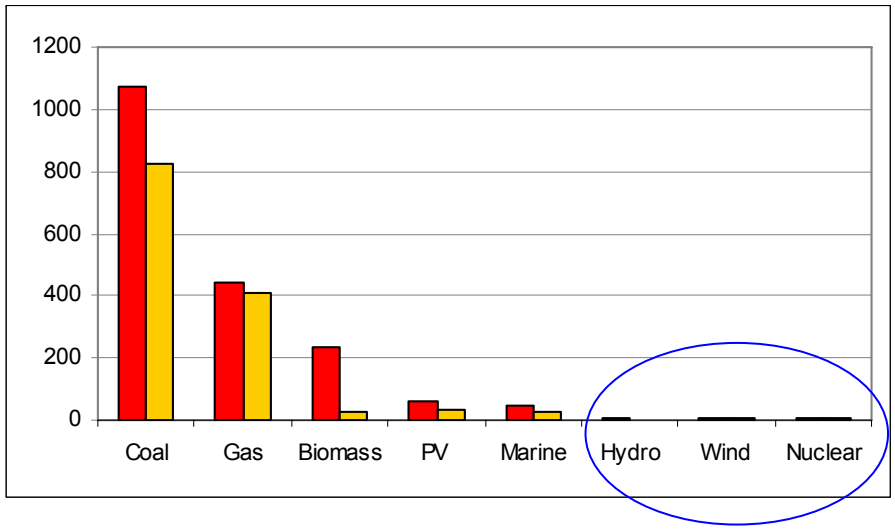
(global data, 2004-2006)



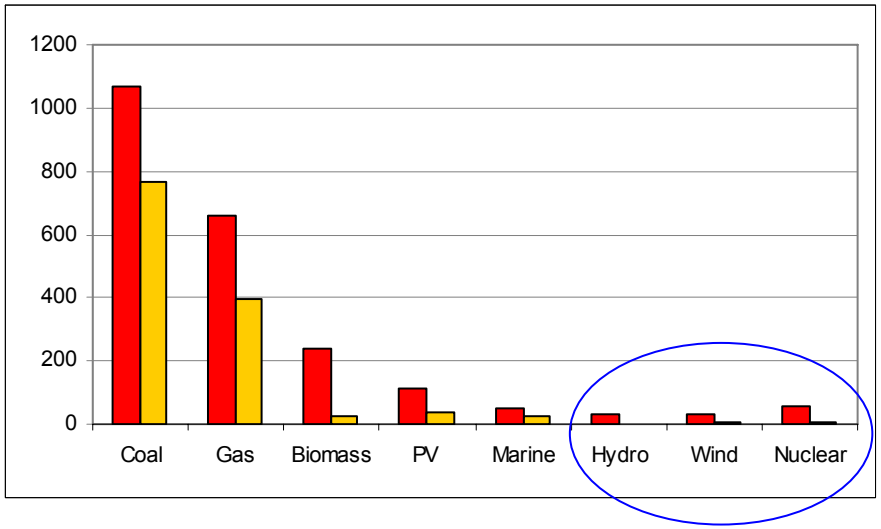
Carbon footprints variations

- Ranges are larger in the global data for 2 main reasons:
  - Older vintage technologies – less efficient
  - Use of LCA not as established – LCA identifies less efficient processes

UK & European data

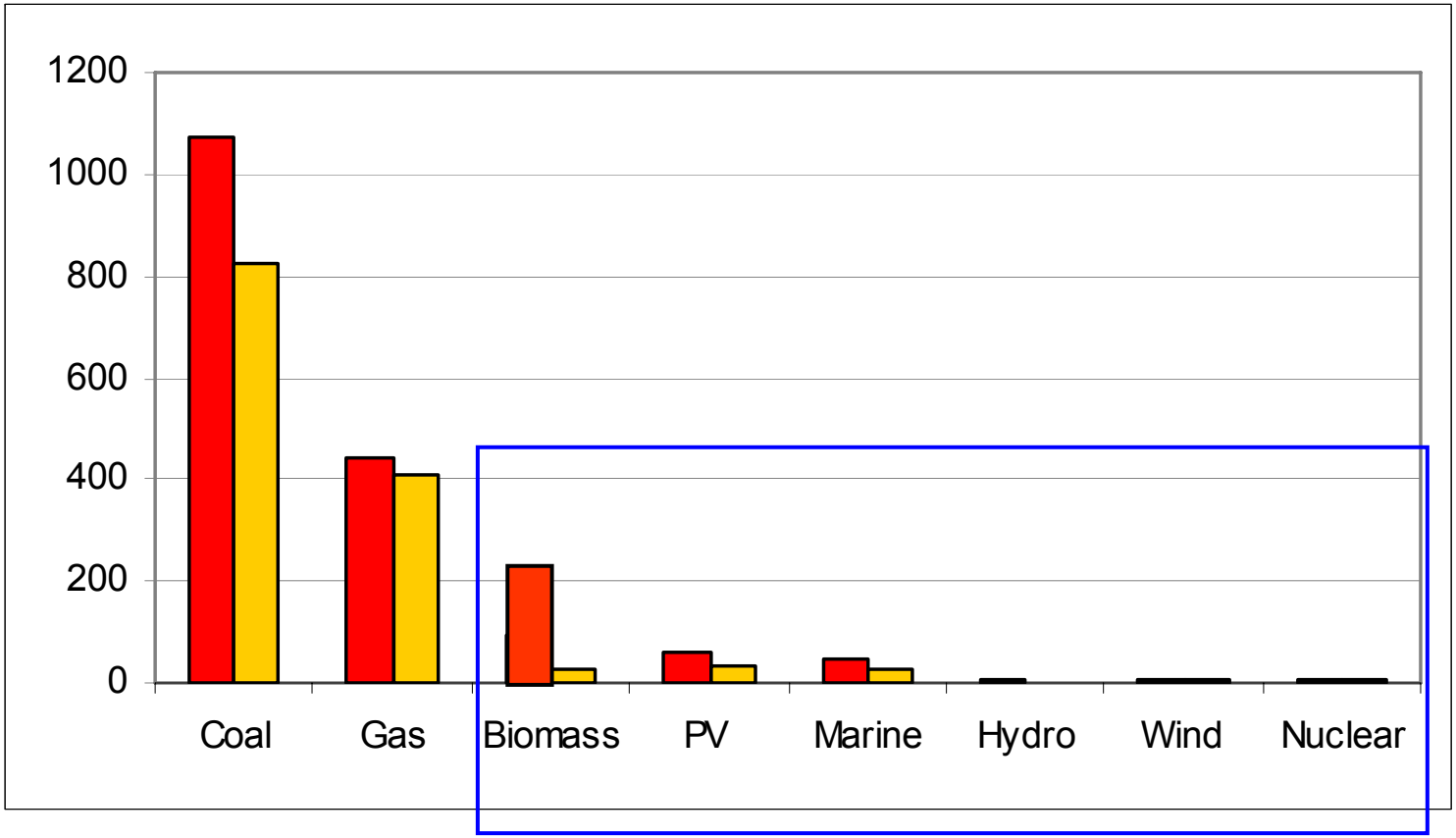


Global data

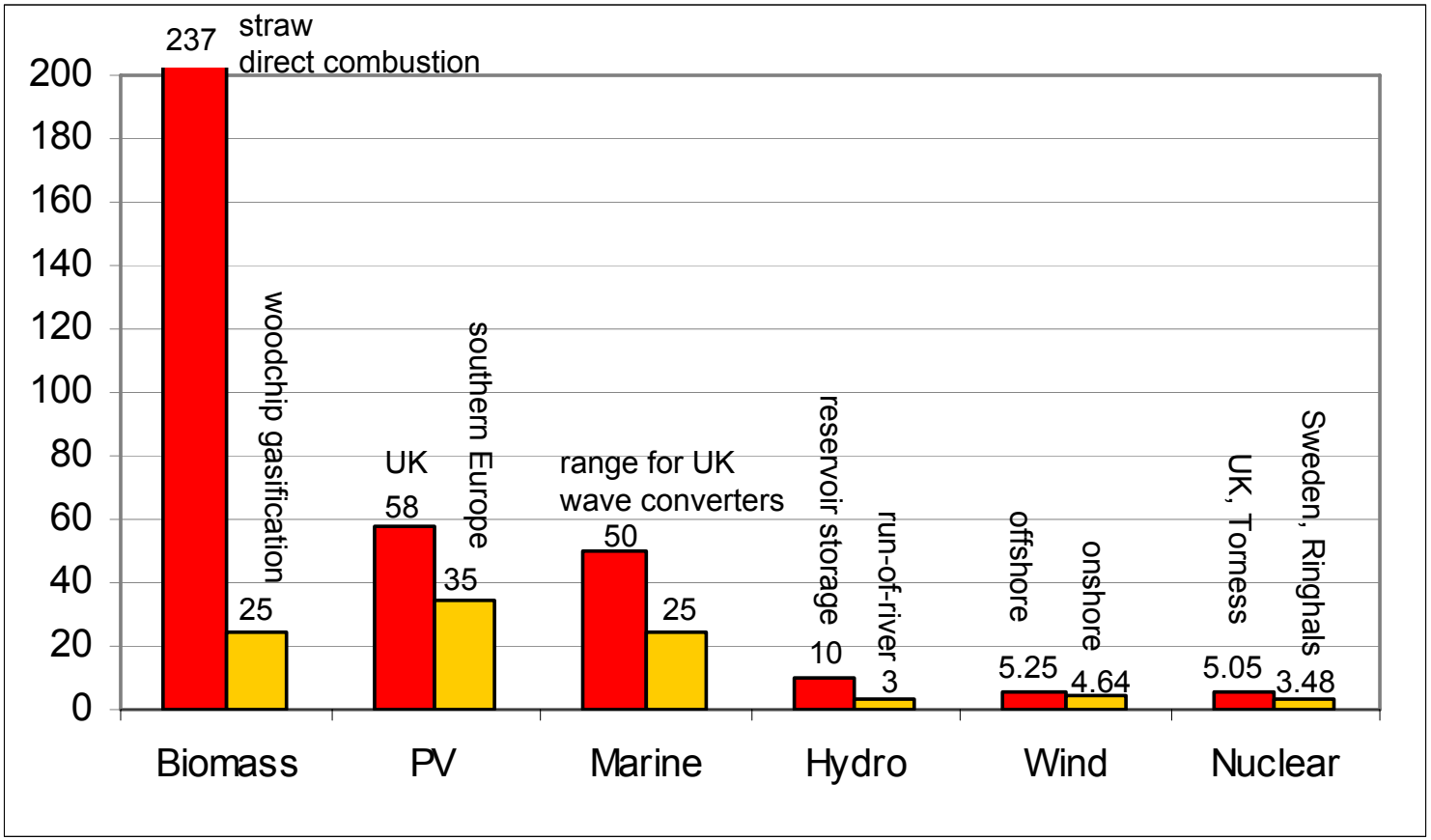


Carbon footprint of electricity generation technologies

(UK & Europe)



Carbon footprint of low carbon electricity generation technologies
(UK & Europe)

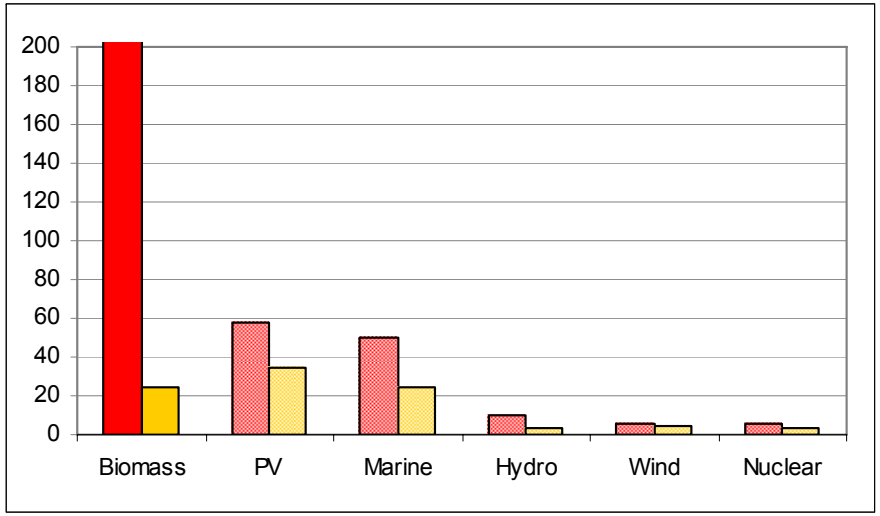


Biomass

Carbon footprint range:

Highest: 237 gCO_{2eq}/kWh (direct combustion of straw)

Lowest: 25 gCO_{2eq}/kWh (gasification of wood chip)



Issues:

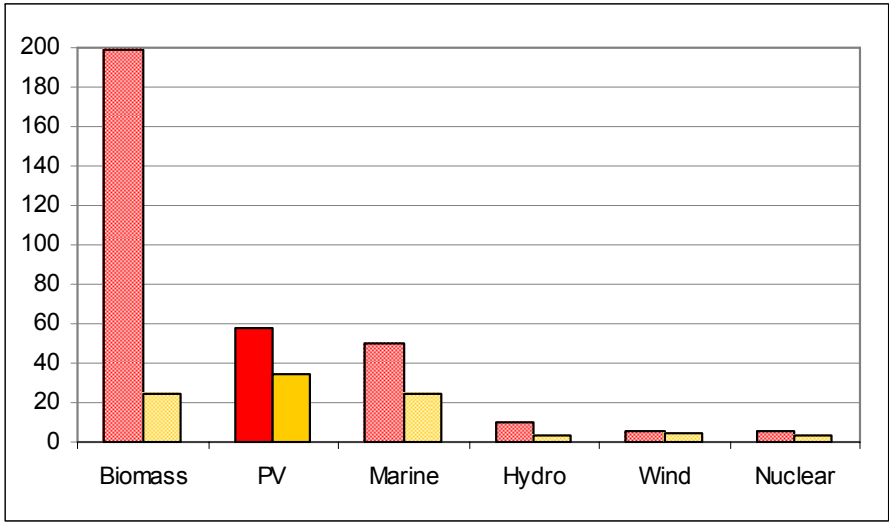
- Biomass is 'carbon neutral' → CO_2 absorbed (growth) = CO_2 released (burning)
- Transport contributes the largest amount of life cycle CO_2, also fertilizers, harvesting
- Large range of carbon footprints → related to differences in energy and density
- Co-firing biomass + fossil fuels can reduce the carbon footprint of fossil fuelled power

Photovoltaics

Carbon footprint range:

Highest: 58 gCO_{2eq}/kWh (UK)

Lowest: 35 gCO_{2eq}/kWh (southern Europe)



Issues:

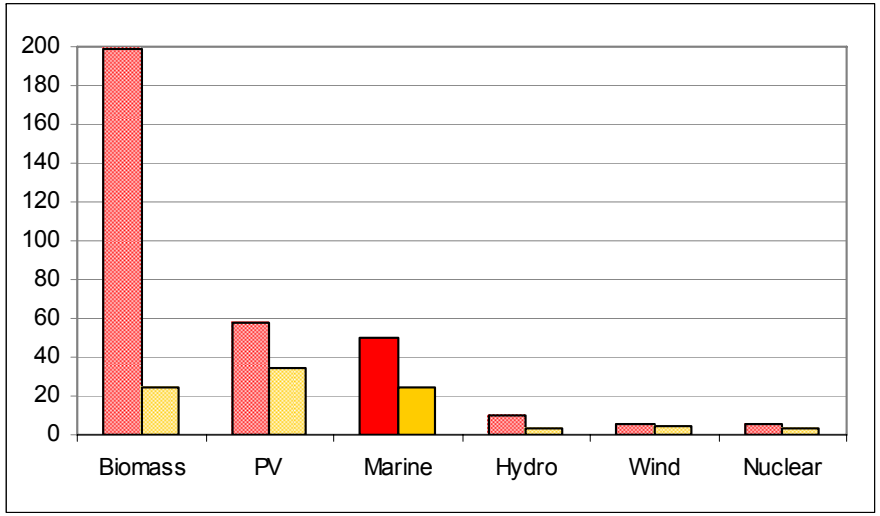
- PV cells predominantly made of high grade silicon
- Silicon extraction and purification is most energy intensive phase (60% of CO_2)
- Future reductions in silicon use (e.g. thin film) will lower carbon footprint
- Carbon footprint lower in southern Europe because greater operating hours

Marine
(wave & tidal)

Carbon footprint range:

Highest: 50 gCO_{2eq}/kWh (range for UK wave converters)

Lowest: 25 gCO_{2eq}/kWh



Issues:

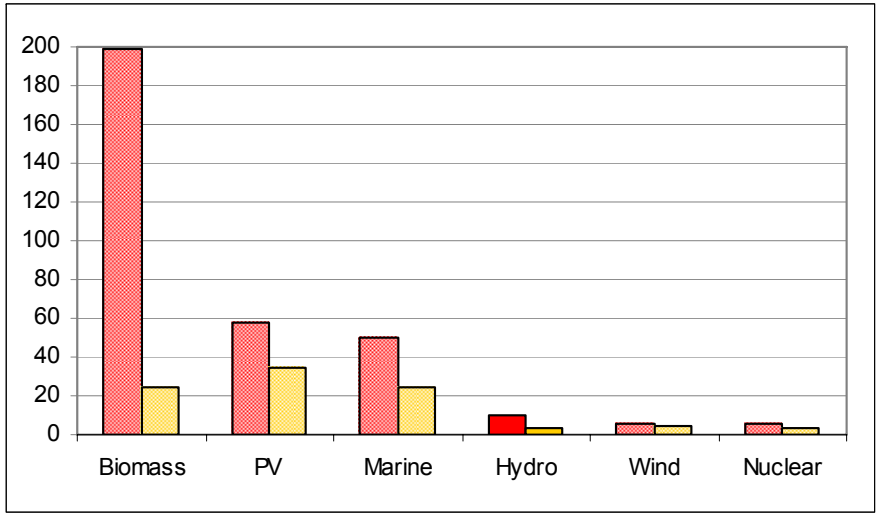
- Two main types of devices: wave energy converters & tidal stream/barrage devices
- Marine electricity generation still an emerging technology – most still prototypes
- No commercial marine powered electricity generation in the UK yet
- Marine carbon footprint currently equivalent to PV, but may reduce to level of wind

Hydro

Carbon footprint range:

Highest: 10 gCO_{2eq}/kWh (non-alpine reservoir storage)

Lowest: 3 gCO_{2eq}/kWh (non-alpine run-of-river)



Issues:

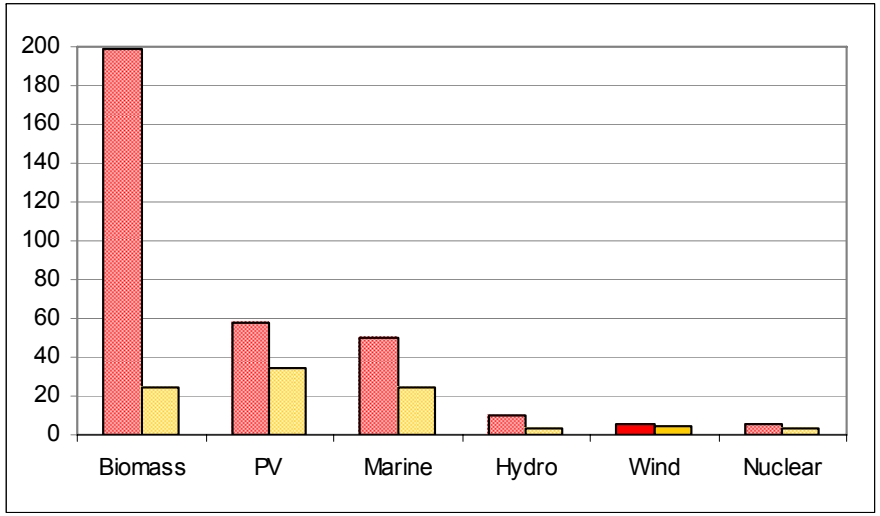
- Two main schemes: reservoir storage (large scale), run-of-river (small scale)
- Storage schemes have higher carbon footprint since a dam is constructed
- Run-of-river schemes have the smallest carbon footprint of all technologies
- Hydro has small CO_2 emissions, but some methane (CH_4) is also emitted

Wind

Carbon footprint range:

Highest: 5.25 gCO_{2eq}/kWh (UK offshore)

Lowest: 4.64 gCO_{2eq}/kWh (UK onshore)



Issues:

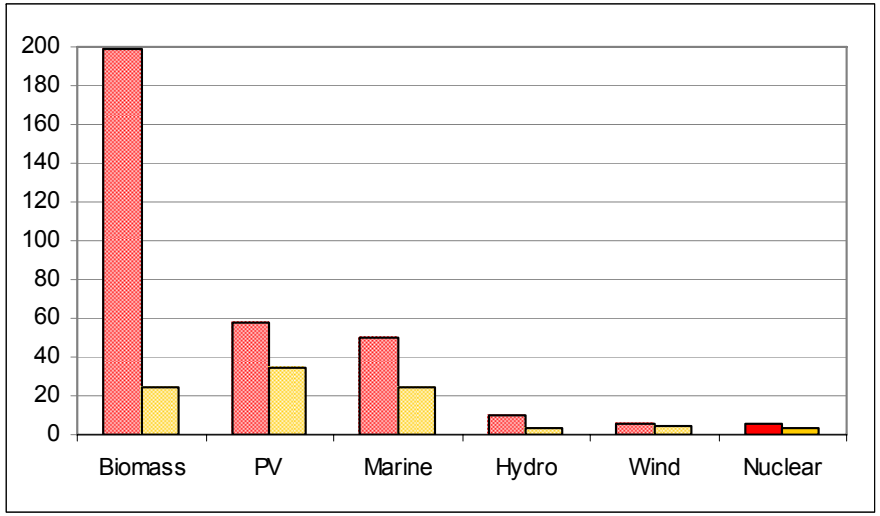
- Wind has one of the lowest carbon footprints
- 98% of emissions arise during manufacturing & construction (steel, concrete)
- Remaining emissions arise during maintenance phase of life cycle
- Footprint of offshore turbine is greater due to larger foundations

Nuclear

Carbon footprint range:

Highest: 5.05 gCO_{2eq}/kWh (UK, Torness plant)

Lowest: 3.48 gCO_{2eq}/kWh (Sweden, Ringhals plant)

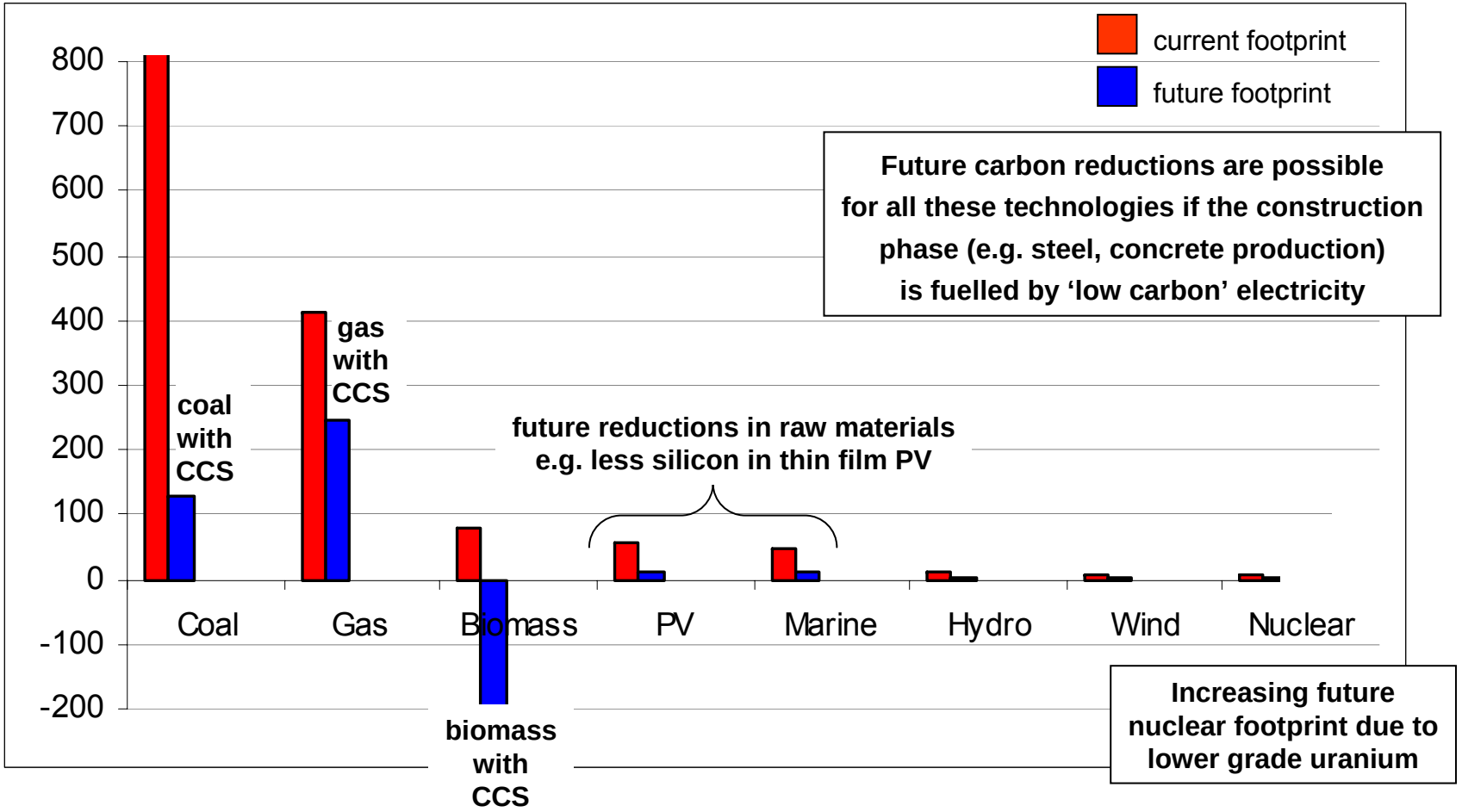


Issues:

- Nuclear also has a very small carbon footprint
- Most CO_2 emitted during uranium mining (40% of life cycle CO_2)
- Global uranium reserves – lower grades may cause footprint to rise in future
- 3 studies: AEA (↑ to 6.8g), Öko (↑ to 30-60g), Storm van Leeuwin (↑60 to 120g)

Future carbon footprint reductions

(or increases!)



Future carbon footprint issues

Coal:
- co-firing with biomass
- CCS – not yet demonstrated for electricity generation

Gas:
- co-firing with biomass (where biomass is gasified)
- CCS – not yet demonstrated

Biomass:
- CCS – unlikely since most biomass plants <50MW

PV & Marine:
- Reduction in raw materials

Nuclear:
- Footprint may rise if lower grade ores are used, but will only rise to level of other 'low carbon' technologies, not as large as current fossil fuelled electricity generation

All:
- Can reduce future carbon footprint if high CO_2 life cycle phases are fuelled by low carbon energy sources







Conclusions

- All electricity generation technologies emit CO_2 at some point during their life cycle
- None of these technologies are entirely 'carbon free'
- Fossil fuelled electricity generation has the largest carbon footprint (>1,000gCO_{2eq}/kWh)
- 'Low carbon' technologies have low carbon footprints (<100gCO_{2eq}/kWh)
- Future carbon footprints can be reduced for all electricitiy generation technologies if the high CO_2 emission phases are fuelled by low carbon energy sources

Thank You!

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