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Promoting sustainable energy policy and practice

www.cse.org.uk

Wind turbines and wind power

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Kings Langley, 225 kW turbine

- 1980s – present-day: commercial turbines have increased from 75 kW to 2,000–3,000 kW (2–3 MW) capacity
- Largest typically 80–100 metres tall at hub height
- Onshore wind now sufficiently established to be viable means for near-term greenhouse gas mitigation

Little Cheyne Court
2.3 MW turbines

Wind power global installed capacity

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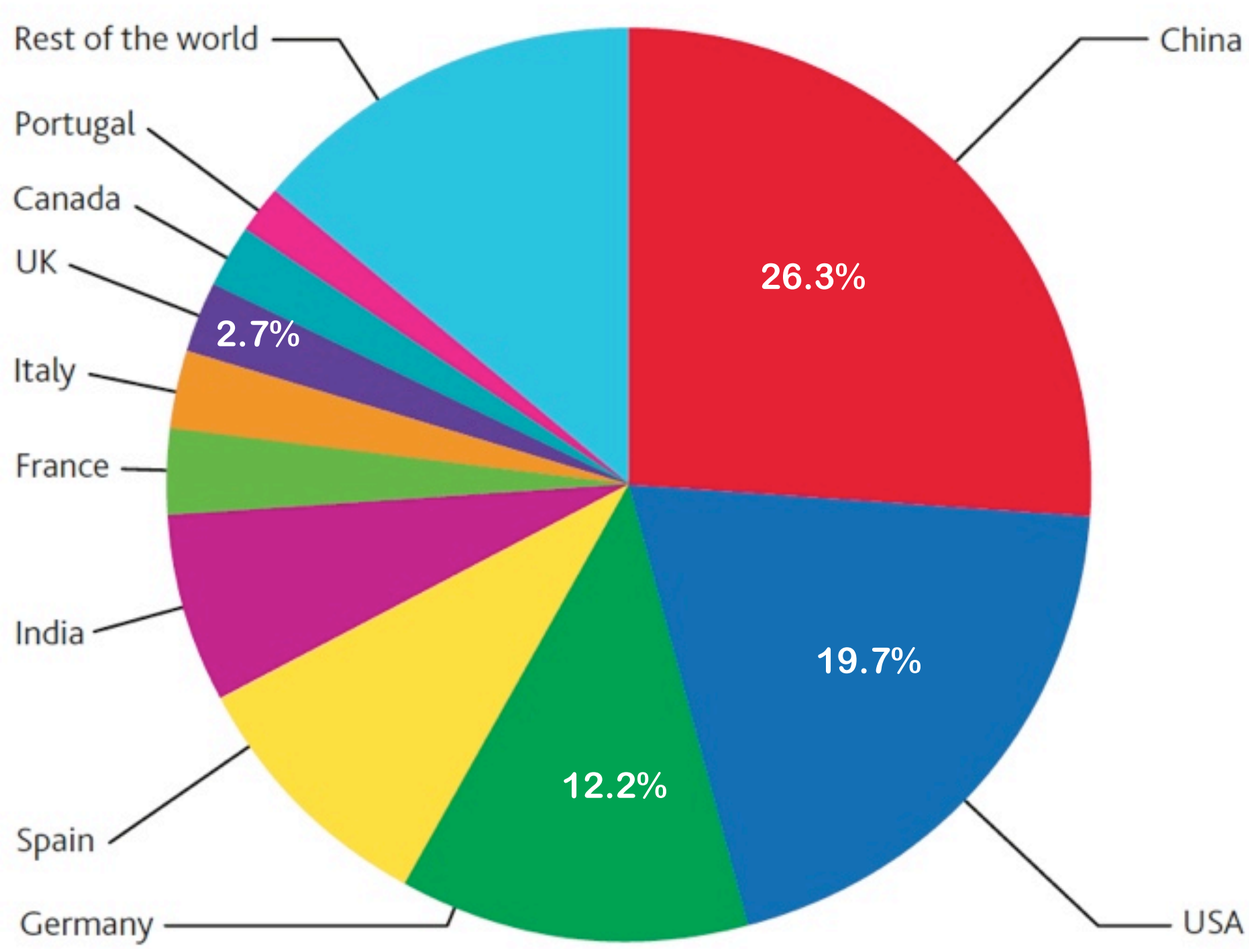
- Total cumulative installed capacity of wind power worldwide = 238 GW (238,000,000 kW)
- Expanded from just 14 GW in 1999
- Leading three countries (China, USA, Germany) have over 58% share
- Europe's combined share is 39%, down from 48% in 2009
- Regionally, EU can meet 6.3% of its electricity demand

Top 10 countries by cumulative capacity

(GWEC Feb. 2012)



Wind power in global energy mix

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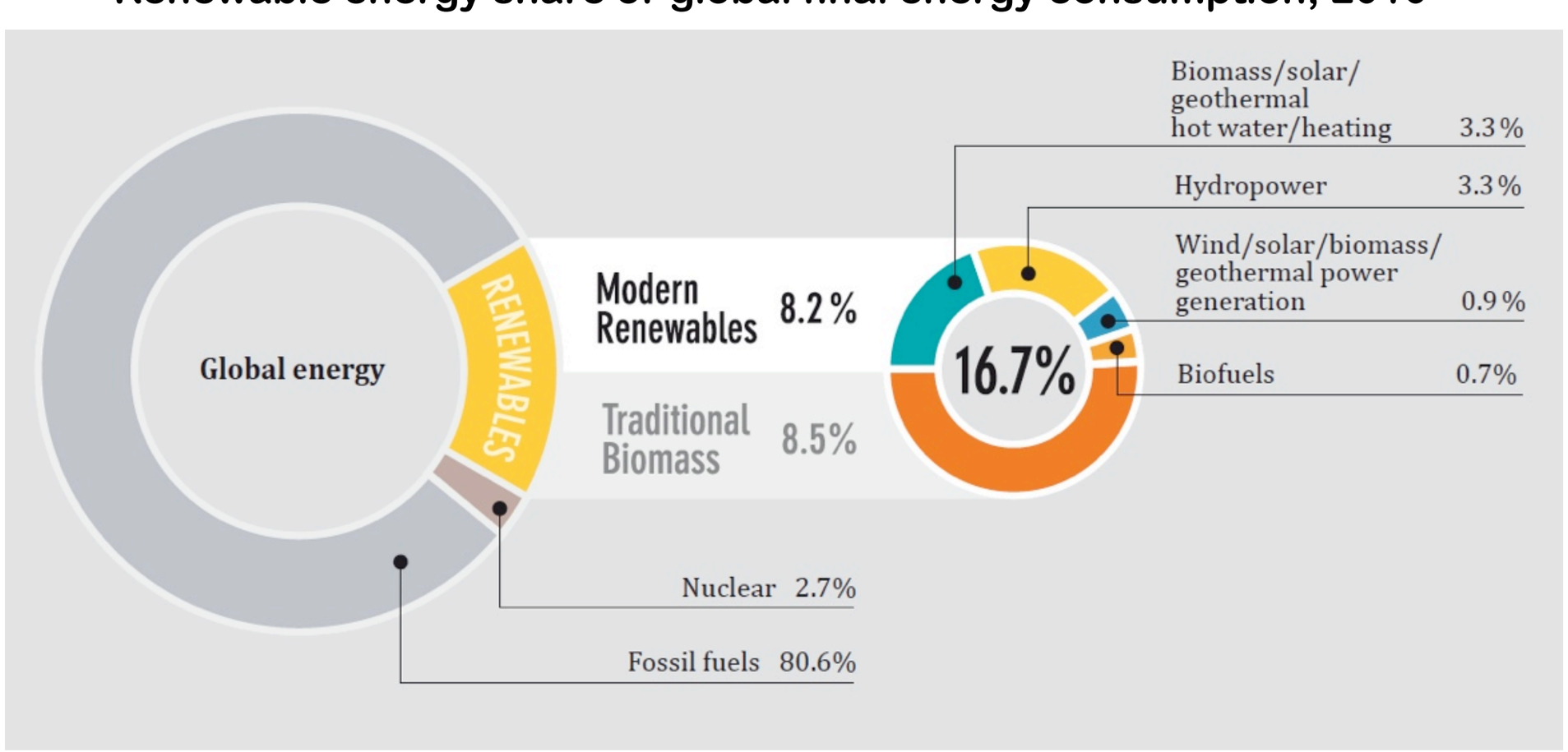
- *All* renewable energy sources supplied 20.3% global electricity in 2010
- Wind power generated 2.3% of global electricity
- Global wind power electrical generation in 2010 (based on 198 GW capacity) was estimated at 520 TWh

Renewable energy share of global final energy consumption, 2010



REN21. Renewables 2012 Global Status Report

Wind power in the UK

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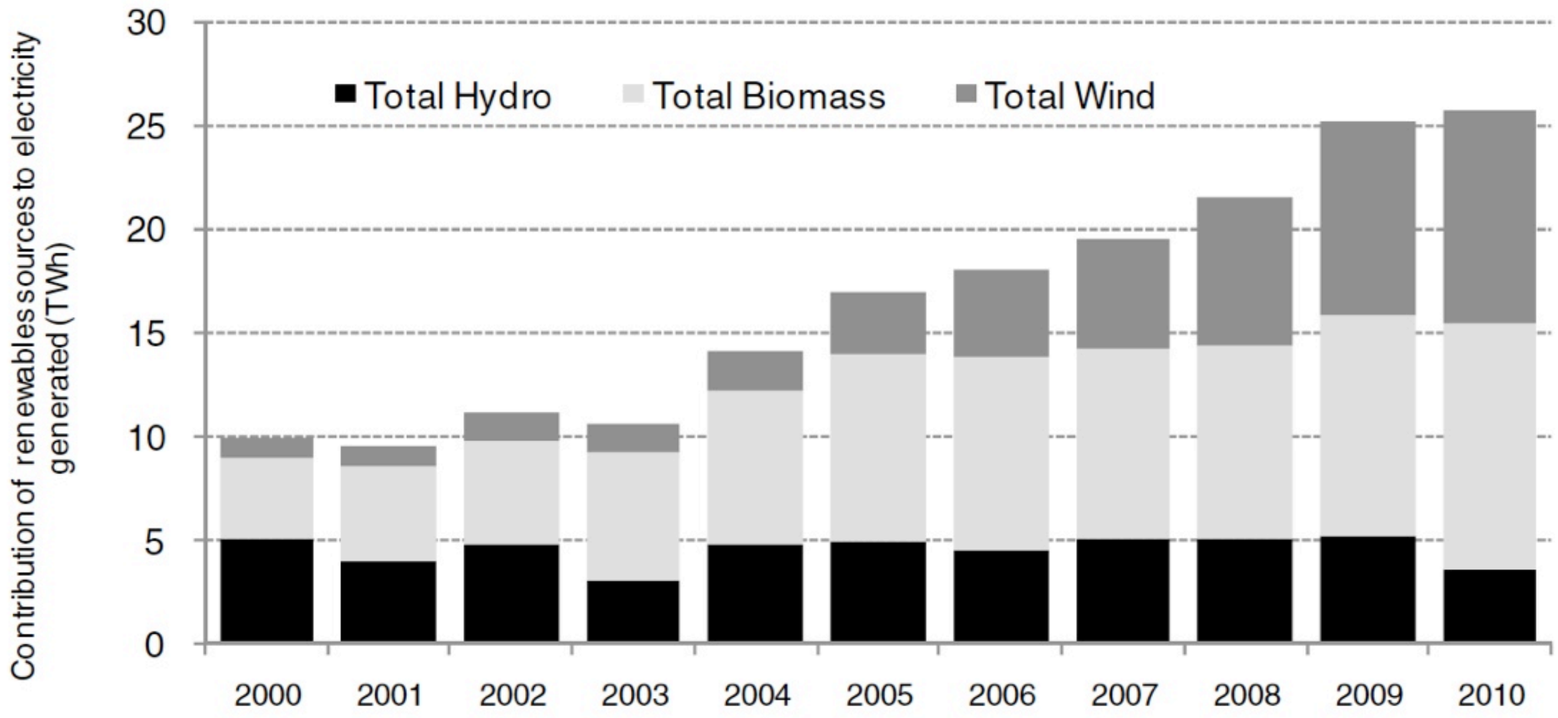
- Renewable energy inputs just over 3% of all energy inputs
- Two-thirds of these inputs went towards electricity generation



Electricity generation by main renewable sources since 2000

Digest UK Energy Statistics 2011.
© Crown Copyright

- In UK in 2010 wind power capacity stood at 5.2 GW:¶
  - contributed 11.4% of total renewable energy inputs
  - contributed 40% of total renewable electricity supplied
    - 7.13 TWh onshore | 3.04 TWh offshore

¶ Increased to 6.5 GW by end 2011

UK Carbon Emissions (2010)

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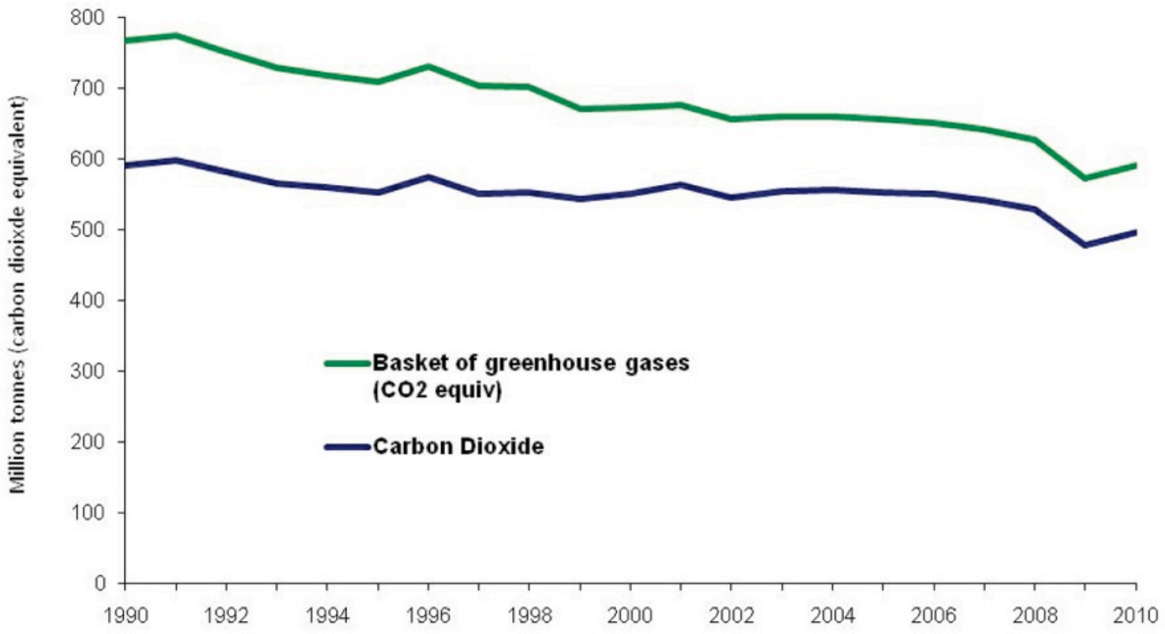
- Total UK carbon dioxide emissions in 2010 were **496 $MtCO_2$**
  - Total greenhouse gas emissions came to 590 $MtCO_2$ equivalent, meaning direct CO_2 emissions by far most significant fraction (84%)



DECC Statistical Release, 2010 . © Department of Energy & Climate Change.

- Fossil fuel electricity generation emitted 171 Mt CO_2:
  - coal = 98 Mt CO_2
  - gas = 70 Mt CO_2
  - oil = 3 Mt CO_2
- This is more than 87% of energy sector

- Estimated contribution of wind (onshore & offshore) was 0.07 $MtCO_2$
  - 0.04% of CO_2 emissions whilst generating 1.4% electricity

Carbon Life Cycle Assessment

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- Life Cycle Assessment (LCA)
- Lifetime carbon emissions in grammes CO_2 equivalent per kilowatt hour produced at power plant – i.e. $gCO_2eq/kWh_{elec.}$

Energy source	$gCO_2eq/kWh_{elec.}$	Comments
natural gas	443	Various combined cycle turbines
coal	960	Various generator types with scrubbing
heavy oil & diesel	778	
nuclear	66	Various reactors
solar thermal	13	80 MW parabolic trough
solar PV	32	
biomass SRC	23	SRC = short rotation coppice (usually co-fired with coal at present)
onshore wind	**10**	Typical values for 1.5 MW onshore turbine

Data from Sovacool et al. (2008) and Pehnt (2006).

Efficiency of wind power

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- Efficiency of turbines ultimately limited by what energy can be extracted from kinetic energy of wind – Lanchester-Betz limit = 0.593
  - modern turbines have coefficient of performance = **0.500**
- Load factor:
  - average hourly quantity of electricity supplied during the year, expressed as a percentage of the average output capability at the beginning and the end of year
- Load factor is *not* measure of efficiency
- Wind turbines generate electricity **80–85%** of the time
- Data collected worldwide through 2008 demonstrates onshore wind installations can achieve availability of more than **97%**

Efficiency of wind power

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- Load factors for various types of thermal power plant and wind turbine capacities in UK reported over 2008 to 2010

	2008		2009		2010	
Source of electricity generated	**Installed capacity (MW)**	**Load factor (%)**	**Installed capacity (MW)**	**Load factor (%)**	**Installed capacity (MW)**	**Load factor (%)**
Conventional thermal stations * of which coal-fired	35,145 * 23,069	40.0 * **45.8**	35,244 * 23,077	33.8 * **39.3**	35,196 * 23,085	35.1 * **40.9**
Nuclear stations	10,979	49.4	10,858	65.6	10,865	59.4
Onshore wind ⁋ unchanged configuration	2,820	**27.0** ⁋ 29.4	3,483	**27.4** ⁋ 26.9	4,037	**21.7** ⁋ 21.5

Dealing with intermittent supply

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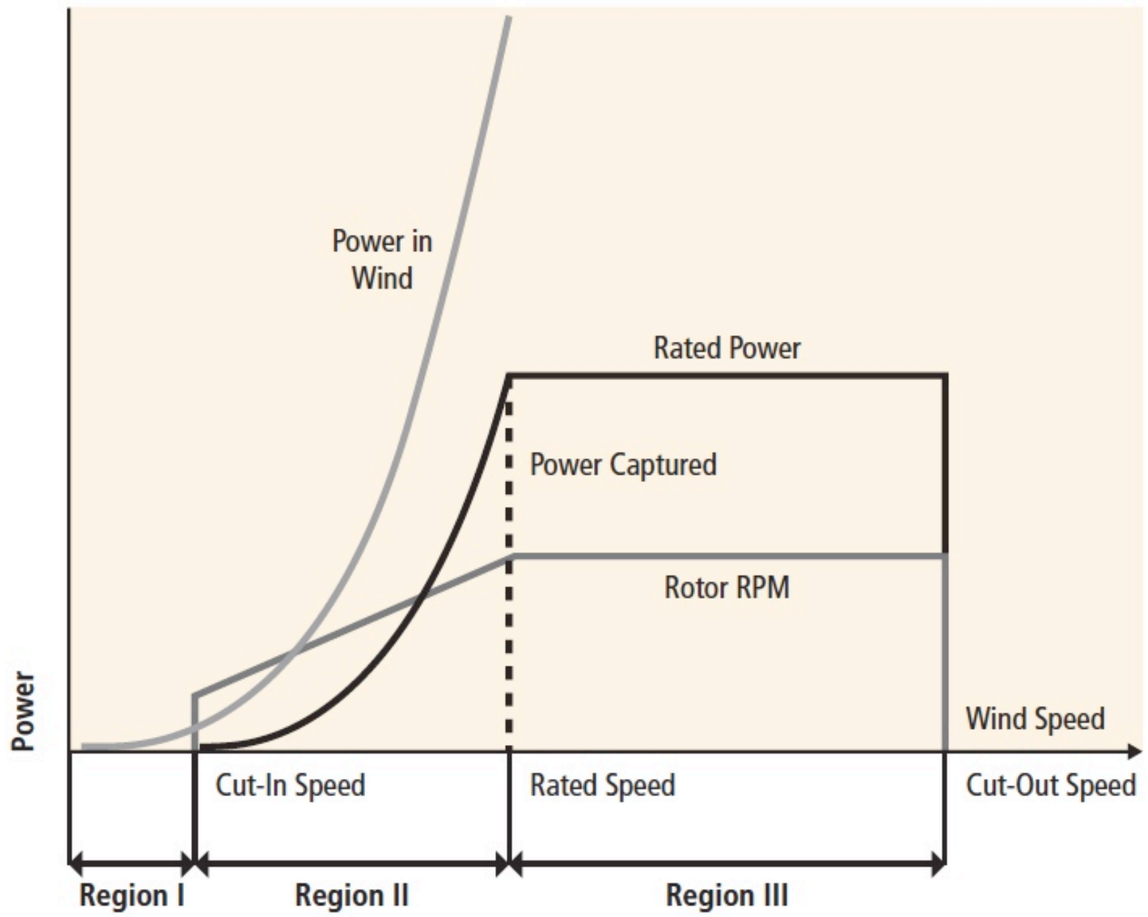
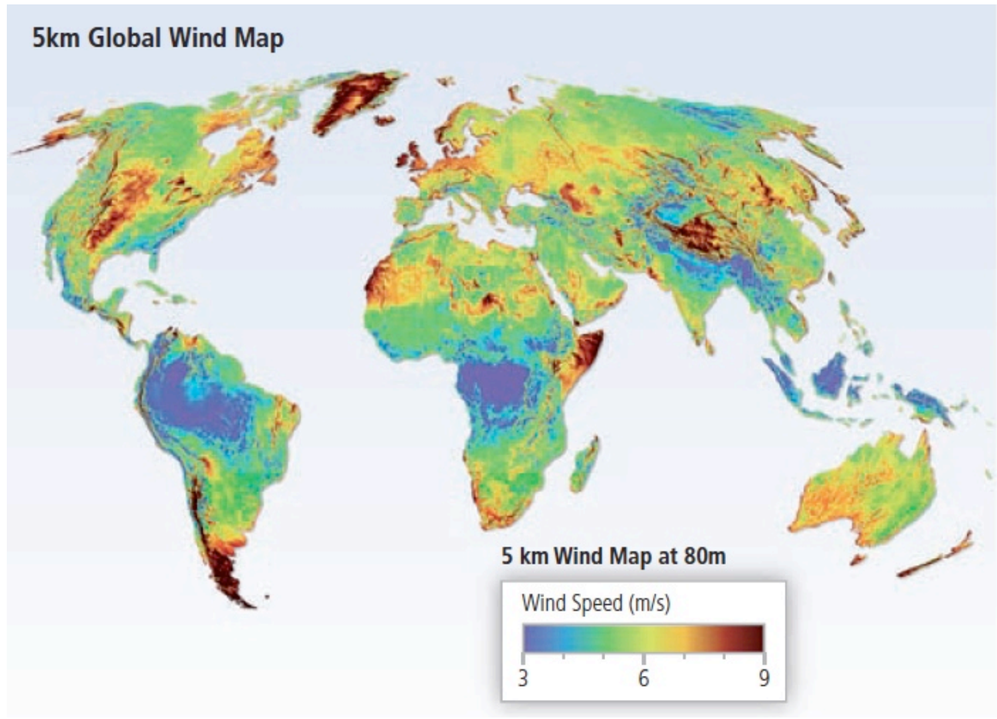
- UK has one of best wind profiles in Europe and even the world

- Wind turbine design maximises energy capture over range of wind speeds – cut-in speed 4 m/s

Conceptual power curve for modern variable-speed wind turbine.



Wind resource map (3TIER).

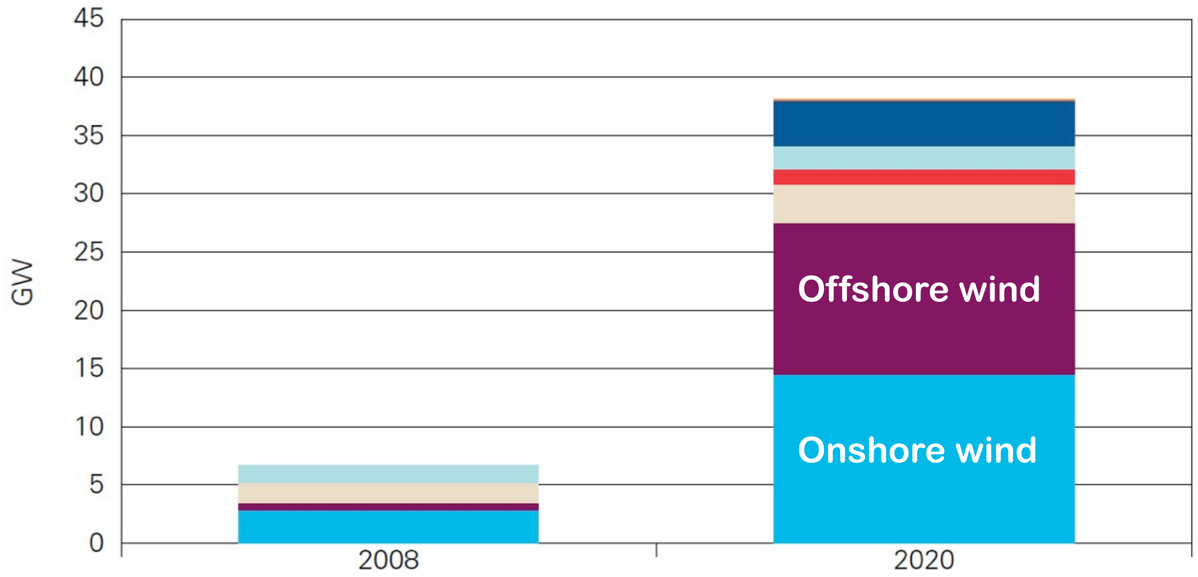


- Larger rotor diameters & improved aerodynamics yield better energy capture at lower wind speeds (Region II)

- Increased generator capacity allows greater energy capture when operating at rated power (typically 12 m/s; Region III)

Dealing with intermittent supply

- By 2020, UK electricity demand expected to be 390,000 GWh
- The UK Government targets set electricity generation from renewables to be 30% of total (117,000 GWh), comprising 38 GW installed capacity
  - includes approx. 15 GW onshore wind and 12 GW offshore wind installed capacity



<u>Example:</u>

- Wind-powered grid of 10 GW has forecast error of 0.37
- Requires reserve of 3 times s.d. (3 × 0.37)
  - 1.14 GW across ½ h
  - Approx. 3 GW across 4 h

How safe is wind power?

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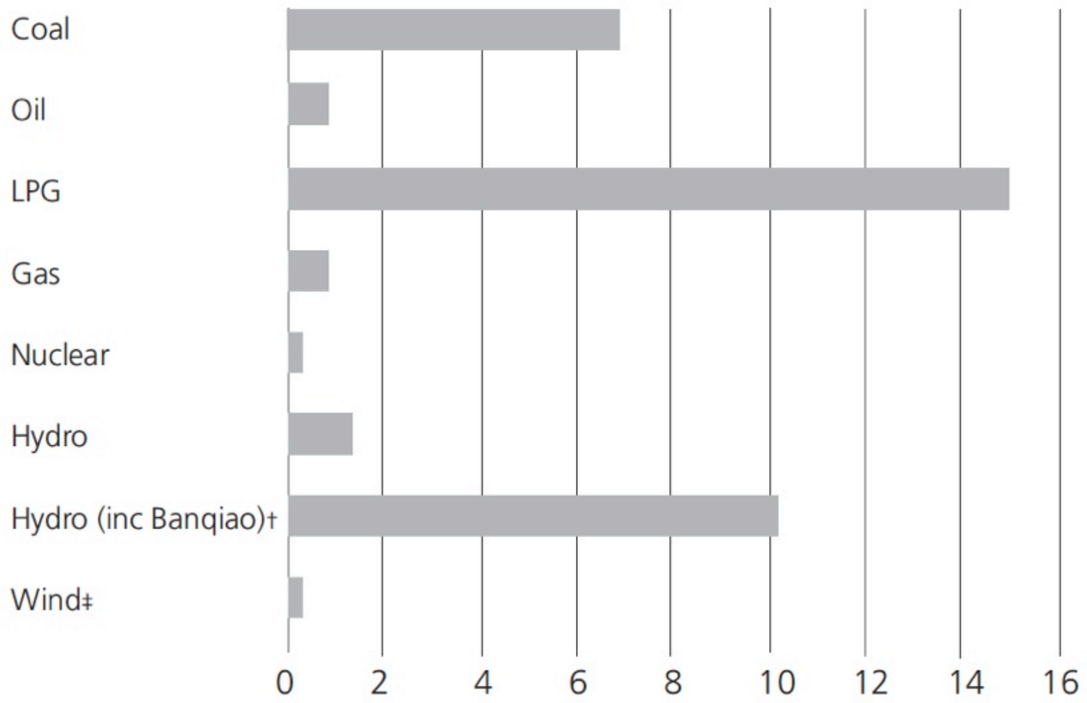
- Risks to life and health occur at all points in supply chain, not just at point of generation
- Fatalities frequently used as benchmark because data is typically the most reliable, accurate and complete
  - Energy-Related Severe Accident Database (ENSAD)
- Figures normalised to Gigawatt-electric-year (GW_eY)



Cumulative fatalities per GW_eY.
Data from Burgherr & Hirschberg (2008) and Gipe (2010).

- Note ENSAD data records *severe* accidents, i.e. with 5 fatalities or more
- Fatalities for wind record *all* incidents (44 as of Dec. 2010)
- Nuclear modern Gen. II reactors only and excludes latent fatalities from Chernobyl
- Regional disparities will distort figures, e.g. coal:
  EU-27 1970–2008 = 989 deaths
  China 1994–1999 = 11,032 deaths

Wind turbine safety: Other issues

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- Wind turbines can shed parts of or whole blades as a result of an accident or icing – ‘blade throw’
- In addition, turbines can shed ice that has built up on blades
- Data is, unfortunately, limited

  - The Netherlands Agency for Energy handbook – this analysed large databases from Germany & Denmark covering turbine operation from 1980s to 2001:
    - Reported operating blade failure rate approx. **4 in 10,000**
    - Max. distance recorded: 150m whole blade, 500m fragment
  - Vestas managing engineer testified in 2003:
    - Experienced **1 blade failure** across 10,000 units over 12 years

Impacts on local residents

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- Proximal ‘nuisance’ effects – noise and shadow flicker
- Noise
  - Impacts can be audible or subaudible (infrasound)
    - **Despite many studies and reports, little evidence to support theory of health impacts caused by infrasound (‘Wind Turbine Syndrome’)**
- Audible noise generally compensated by environmental noise regulations that inform siting requirements
  - Note, in the UK sound intensity (45dB) is used as limit, not fixed distance
- Local topography and weather patterns can contribute to conditions (e.g. high wind shear) that result in negative impacts due to audible noise
  - Evidence suggests this is often correlated to local residents’ general attitudes to nearby wind turbines
- Shadow flicker – siting and operating of turbines can be controlled
  - **No risk to photosensitive epileptics**

Avian and bat mortality

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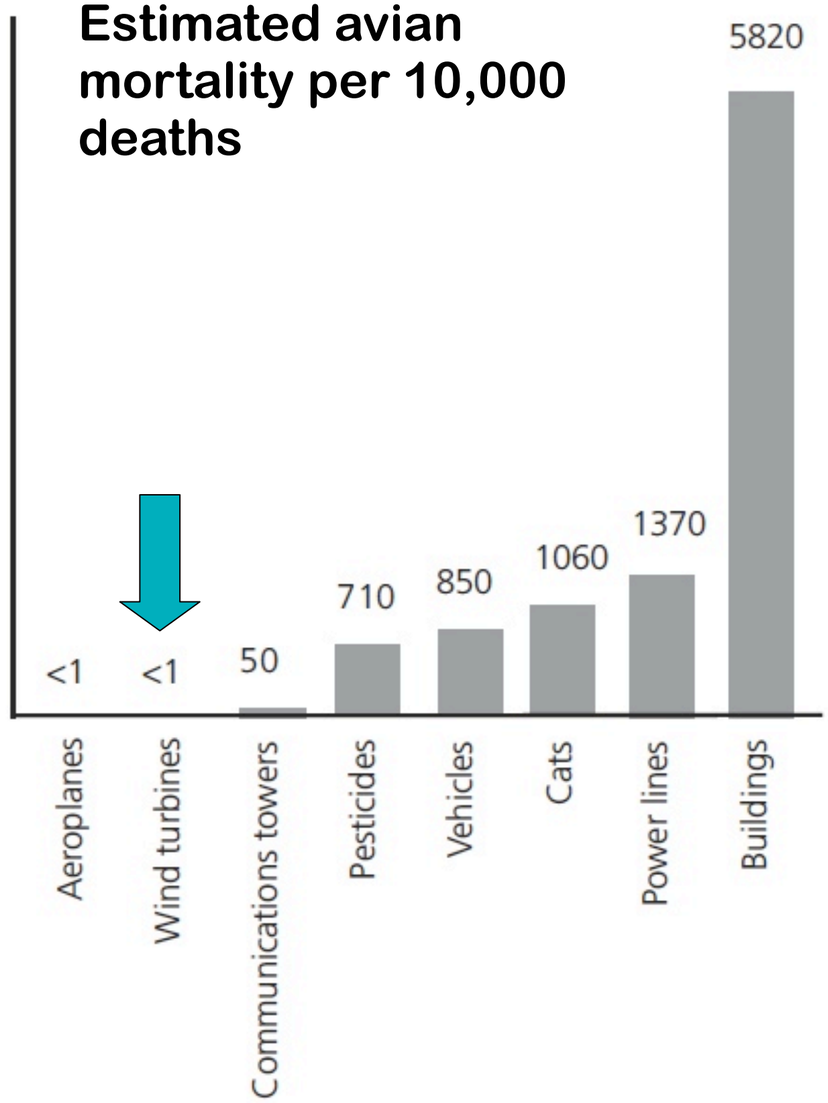
- Significant impacts are very site- and population specific
- Overall, bird deaths caused by wind turbines are negligible compared with other human causes (**less than 1 in 10,000**)
- Songbirds are main victims due to greater abundance in most ecosystems
  - High-profile concern is a result of raptor deaths in ecologically sensitive populations in Spain and USA
- **No evidence that turbines cause any meaningful decline in UK bird populations**
- Some uncertainty regarding impact on bat populations – extreme variations in sites across N. America
  - Reducing operation of turbines in low wind conditions ('feathering') shown some success



Wind power and the ‘social gap’

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- The ‘social gap’ – dichotomy between public acceptance and local resistance
- Large-scale adoption and visibility of onshore wind power contributes to its high profile within this issue
  - Similar public attitudes can be found to offshore wind and other renewable projects
- Attitude of local residents can be shaped by several factors:
  - Lack of perception of wider issues relating to climate change and energy supply (public good vs. minimising local impacts)
  - Visceral dislike of wind turbines, especially visible impact on local landscapes
  - Lack of community initiatives (‘imposition’ of top-down energy projects) and adversarial planning process
    - This trend is being reversed in many countries, incl. UK