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# Challenges from Low-Carbon Energy

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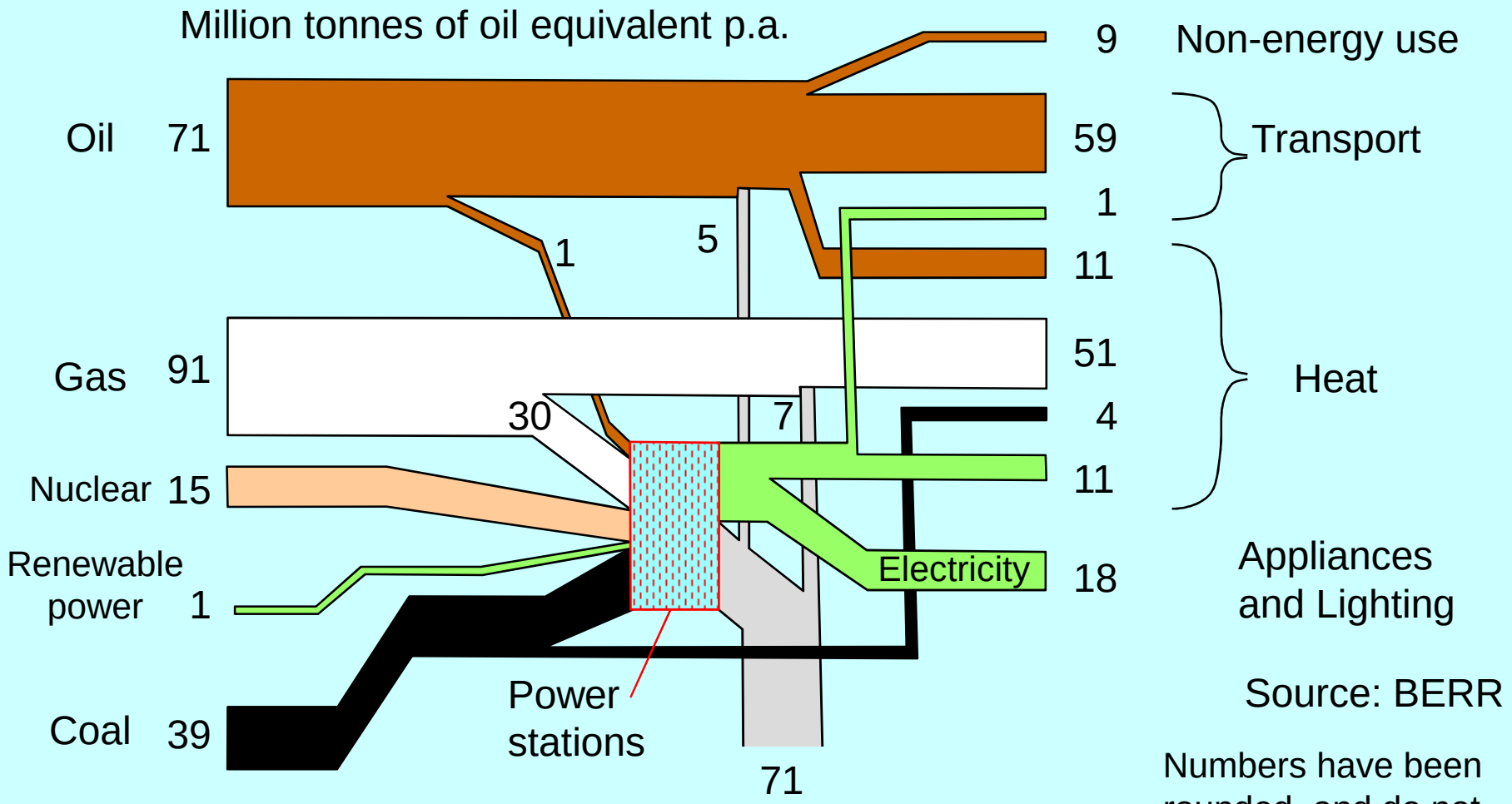
# UK Energy Flows (simplified), 2007

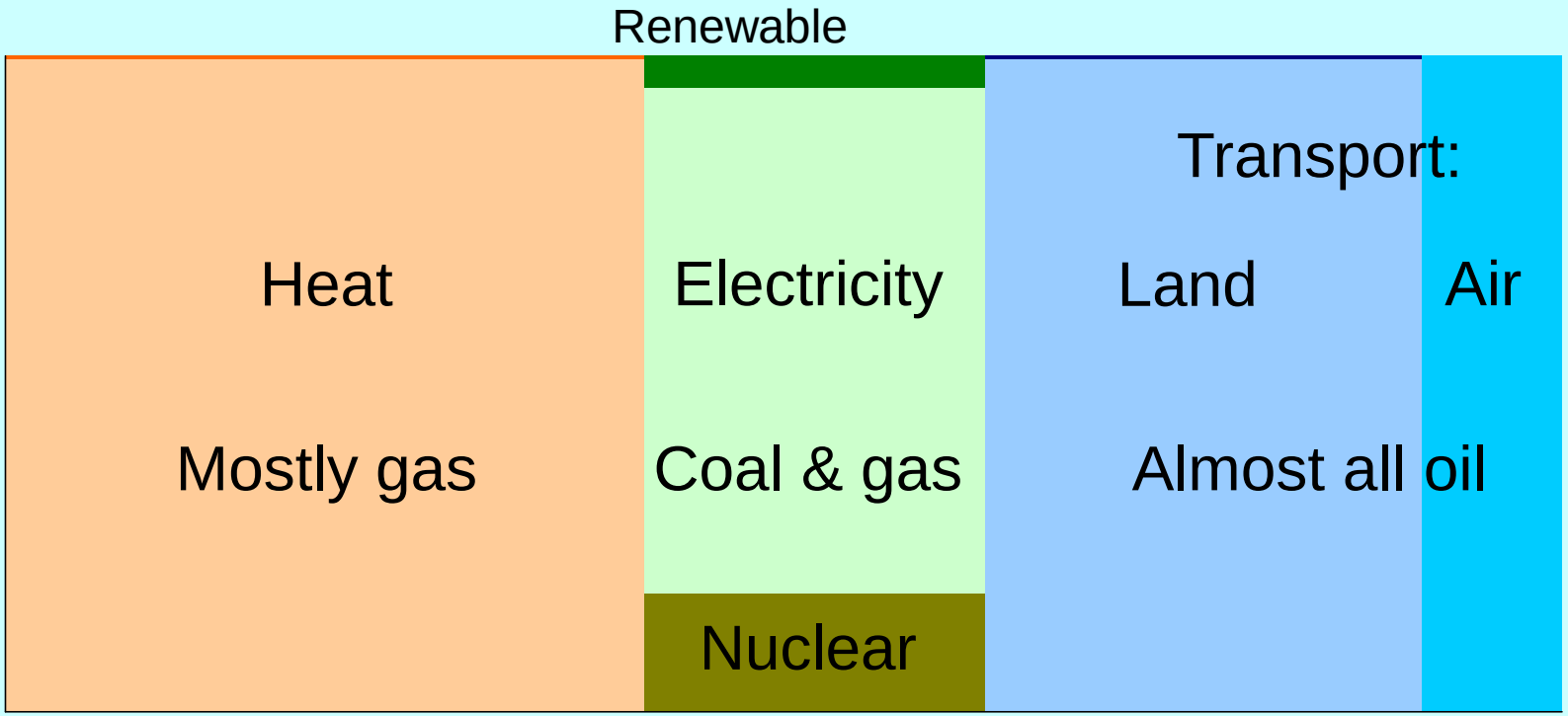



Lost in power stations & network, used by the energy industry

Source: BERR

Numbers have been rounded, and do not balance exactly in the source

# UK Energy in 2006




Source: BERR

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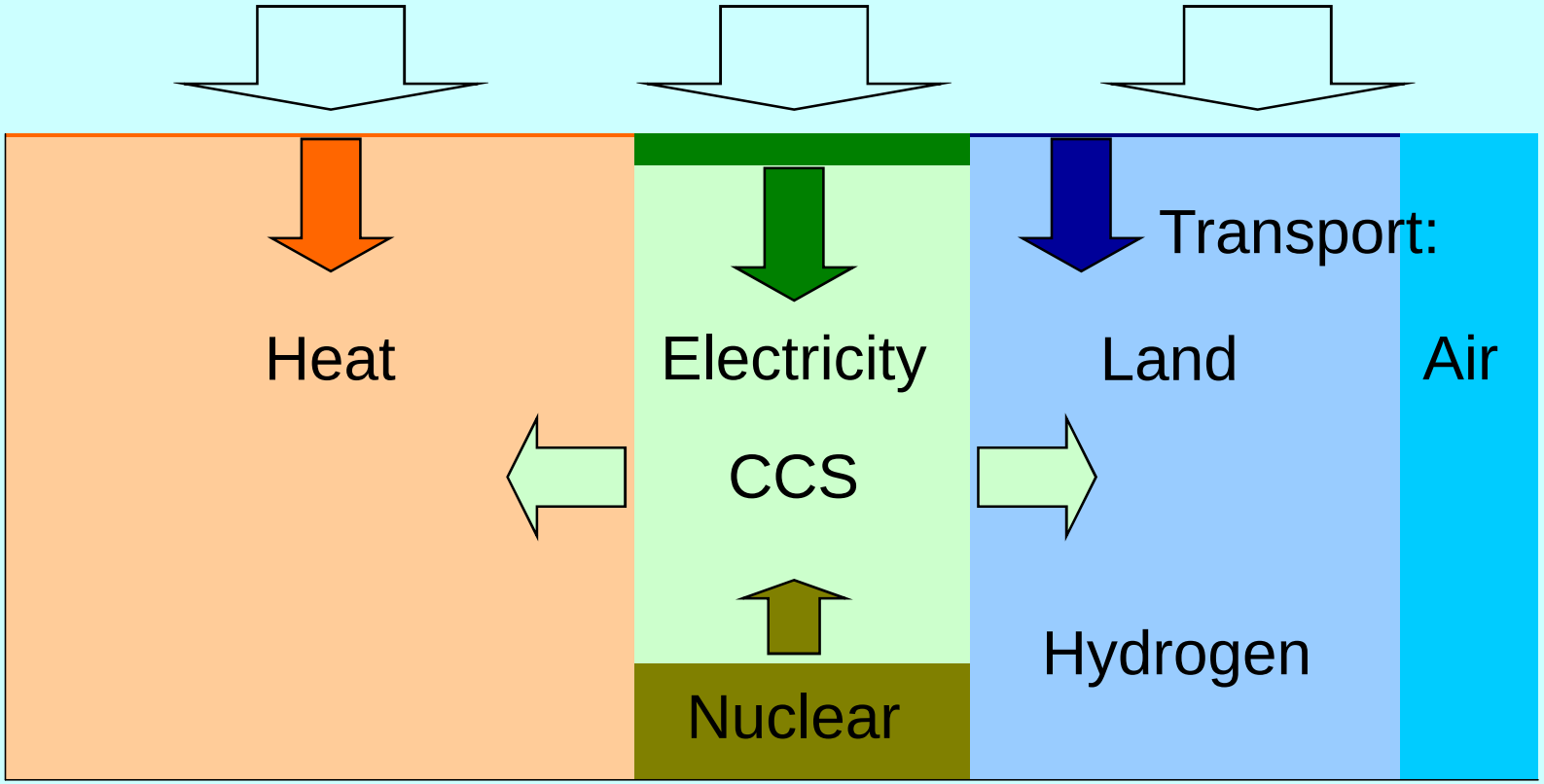
# UK Energy in 2050

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# Challenges for heat

- Reducing demand
- Supplying biomass sustainably
- Reinforcing the electricity network to cope with heat pumps

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# Challenges for transport

- Reducing demand
- Supplying biofuels sustainably
- Reinforcing the electricity network to cope with vehicle charging

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# Challenges for hydrogen

- Producing low-cost, clean, hydrogen
- Moving it to users
- Storing it in vehicles
- Using it in a long-lived fuel cell

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# Hydrogen filling station


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# Fuel cell “microcab”


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# Fuel cell “microcab”


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# The Ross Barlow

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# Metal hydride store

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# Challenges for electricity

- Electricity must be produced at the moment it is consumed
- Nuclear cannot easily adjust output
- Carbon capture may reduce output flexibility
- Many renewable sources can only produce when nature allows
- Transmission limits must be respected

# Or else…


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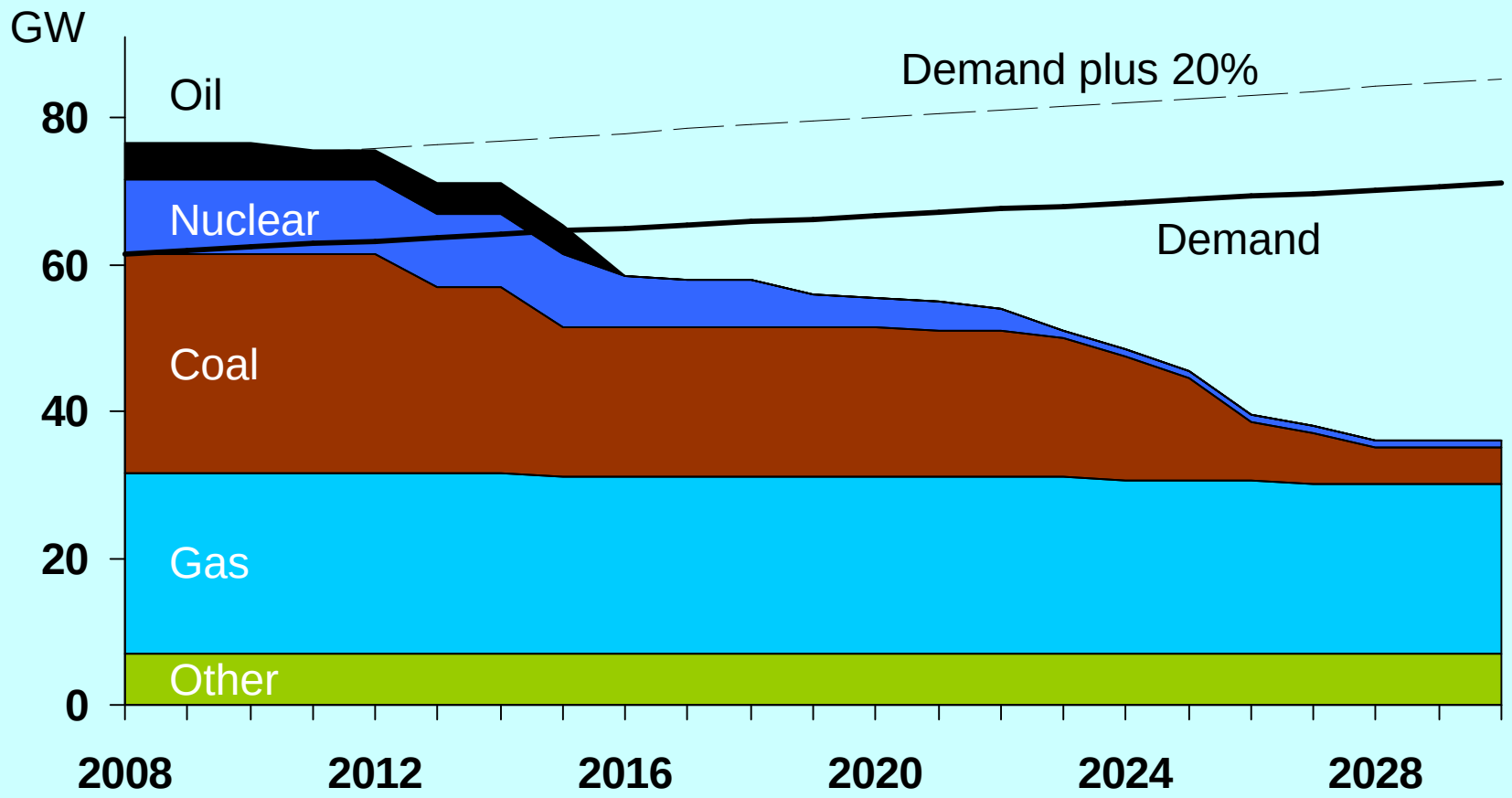
# Variable output at the peak

- We need enough capacity to meet the expected peak demand…
  - even if some of it is not available
  - and even if demand is unusually high
- In the past, a 20% “planning margin” has usually been sufficient

# Plant closures

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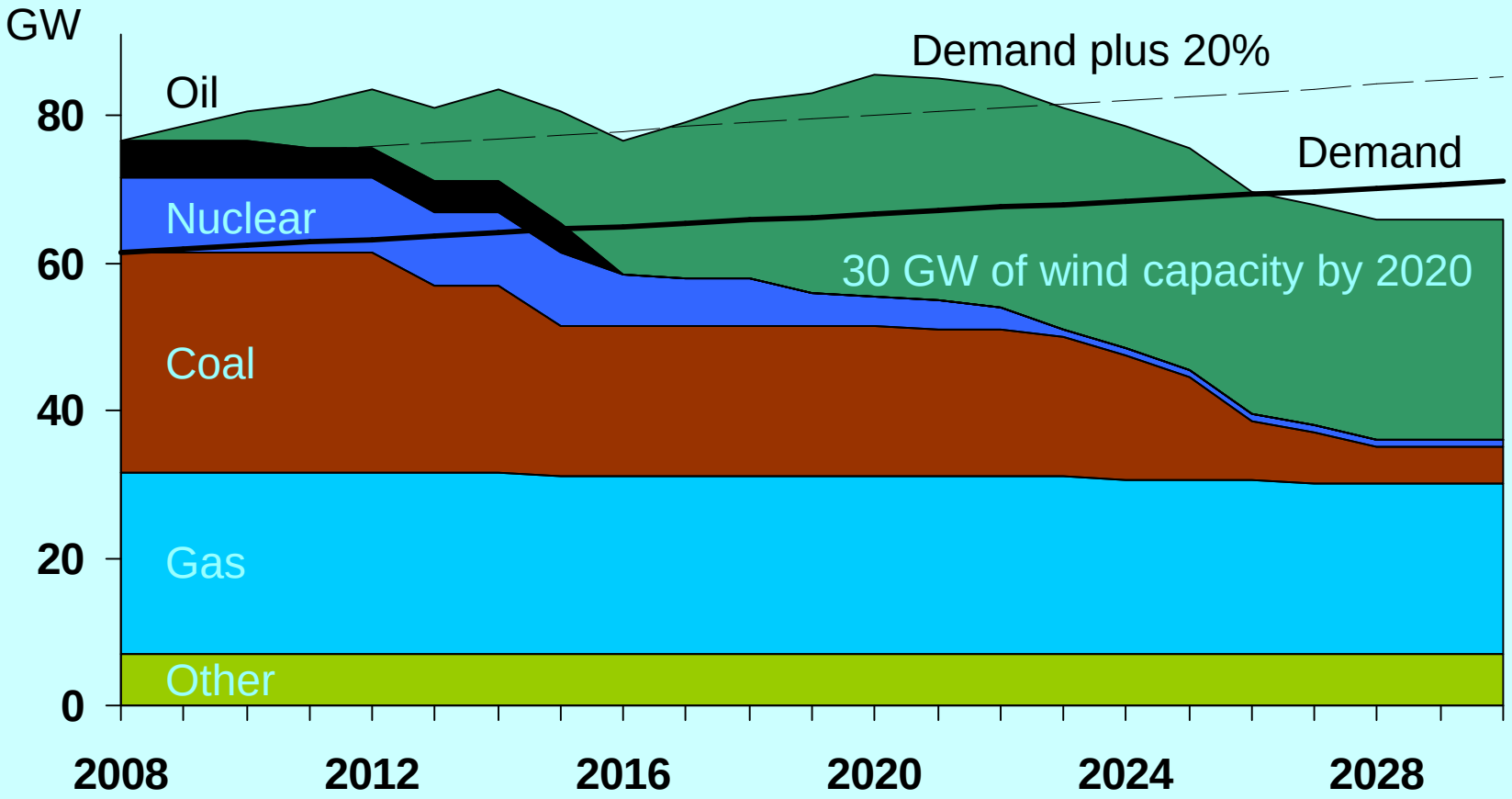
# The growth of wind capacity

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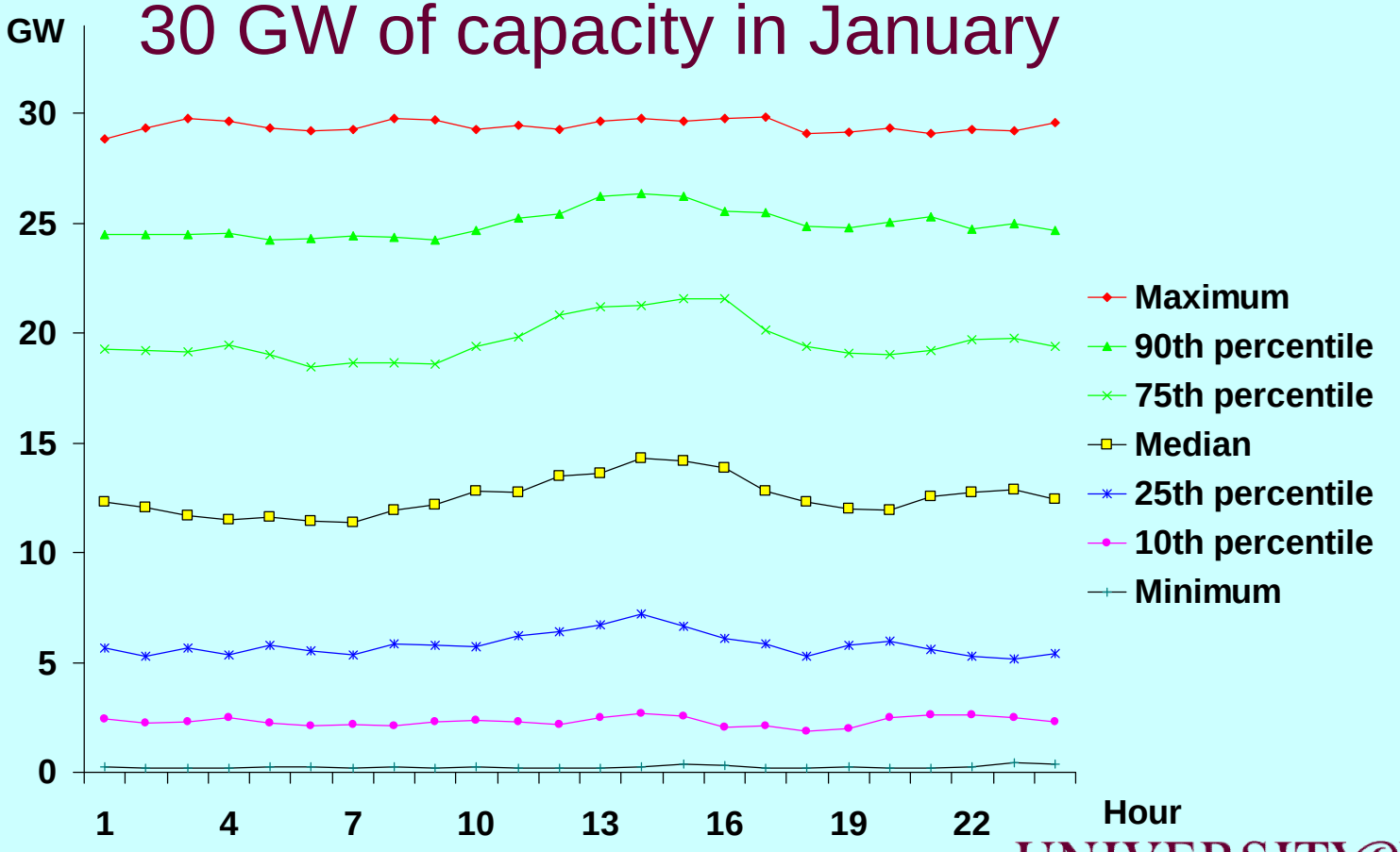
# Wind Output - Probability distribution




Source: Green and Vasilakos (2008)

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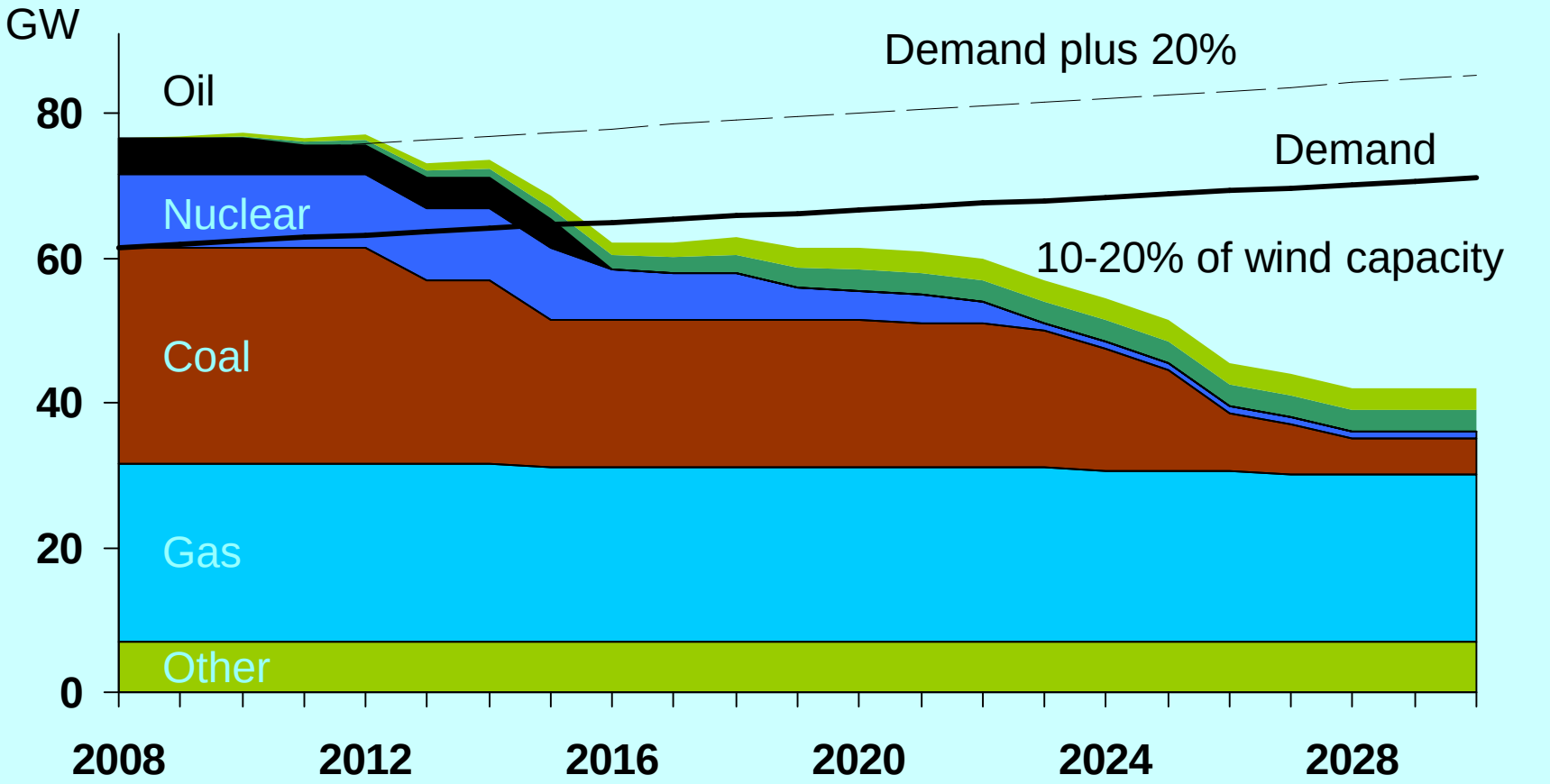
# The wind capacity credit

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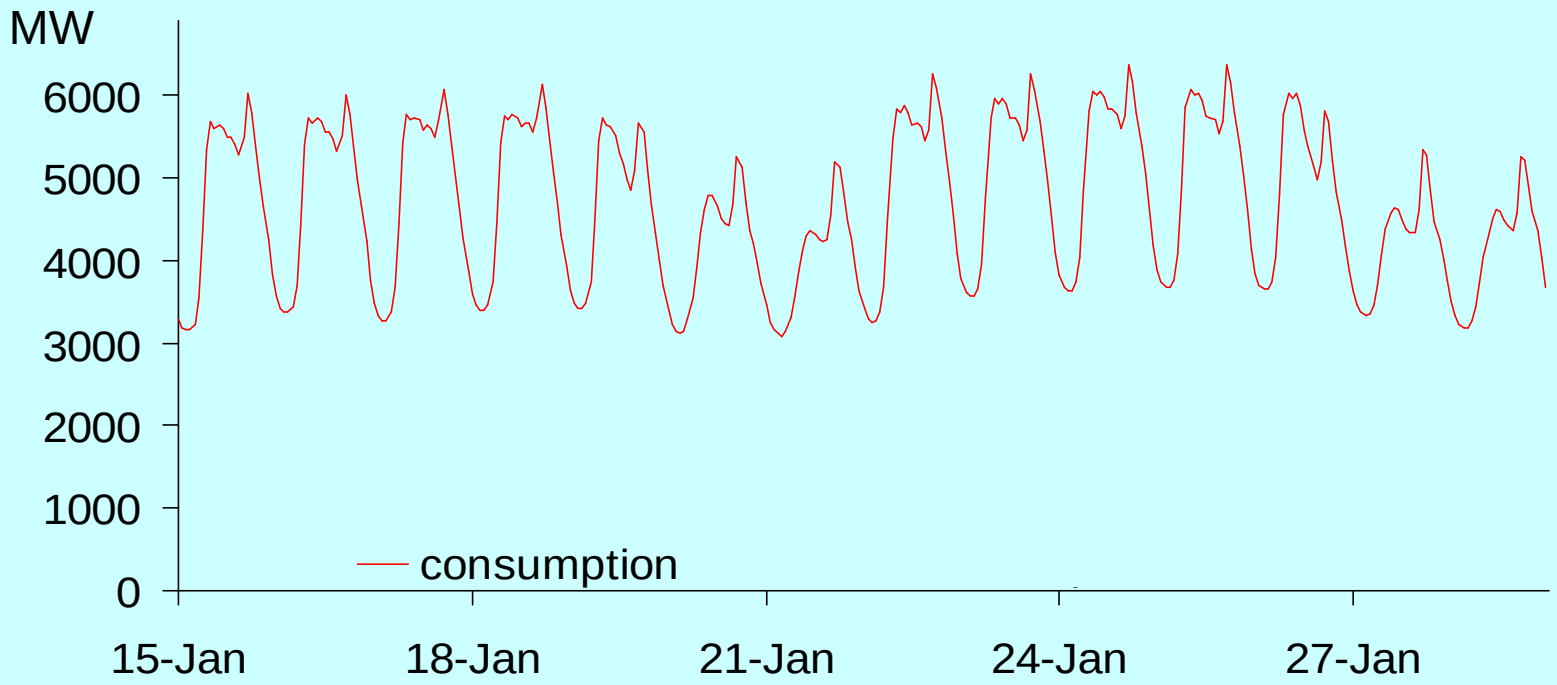
# Variable output from day to day

- Denmark currently has a greater share of wind power than any other country…
  - This makes it a good case study
- It has strong transmission links to large neighbours with different generation
  - This might make it a poor case study

# Denmark, January 2007

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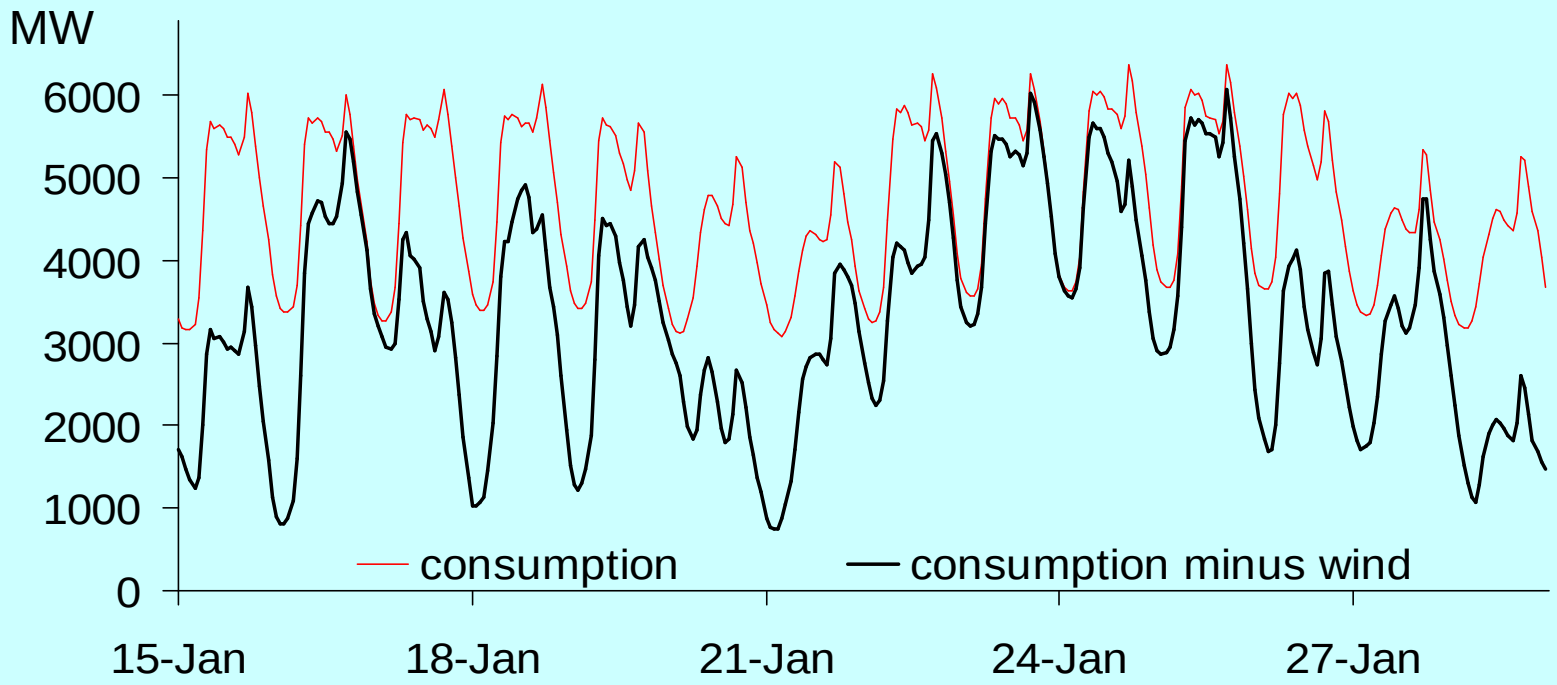
# Denmark, January 2007

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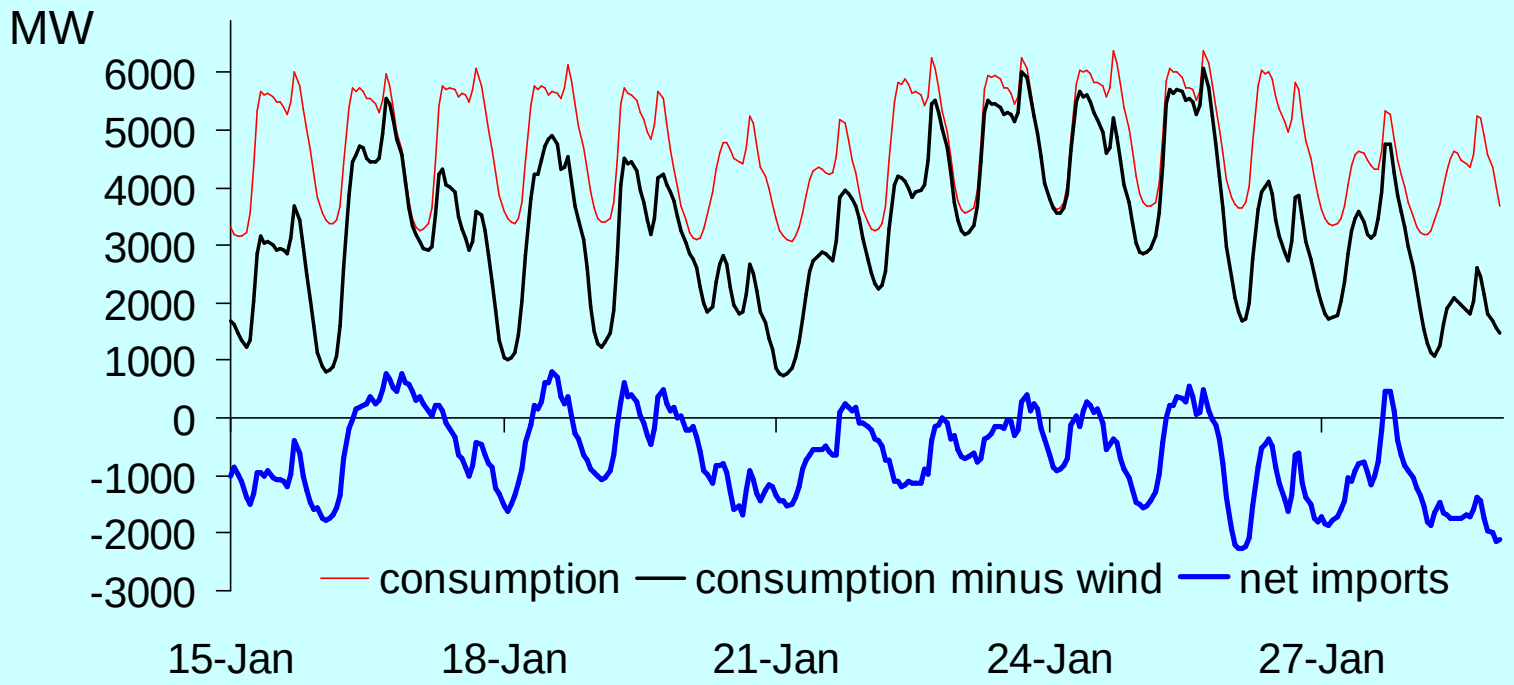
# Market volatility

- More variation in the load of thermal plant
  - Greater variation in prices
- More times when this load changes rapidly
  - Greater variation in prices
- More chances to trade power

# Denmark, January 2007

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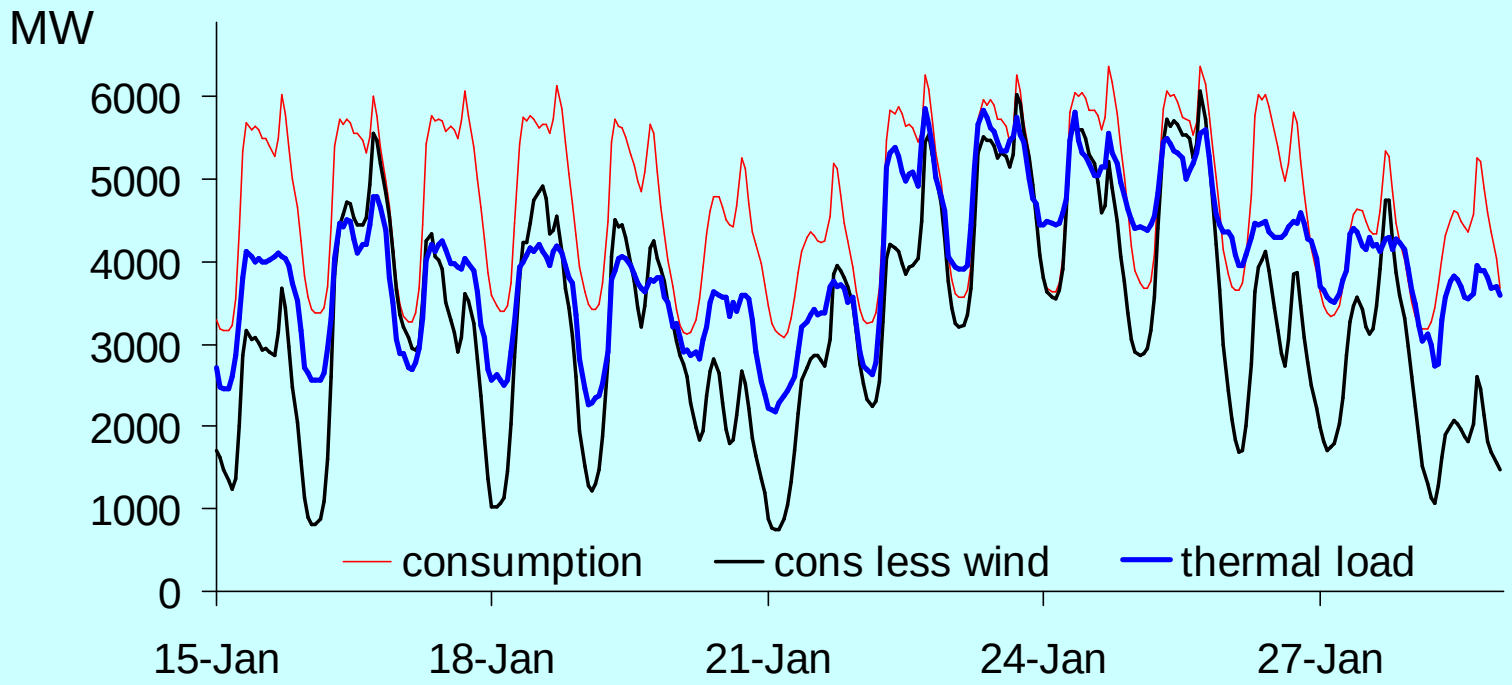
# Denmark, January 2007

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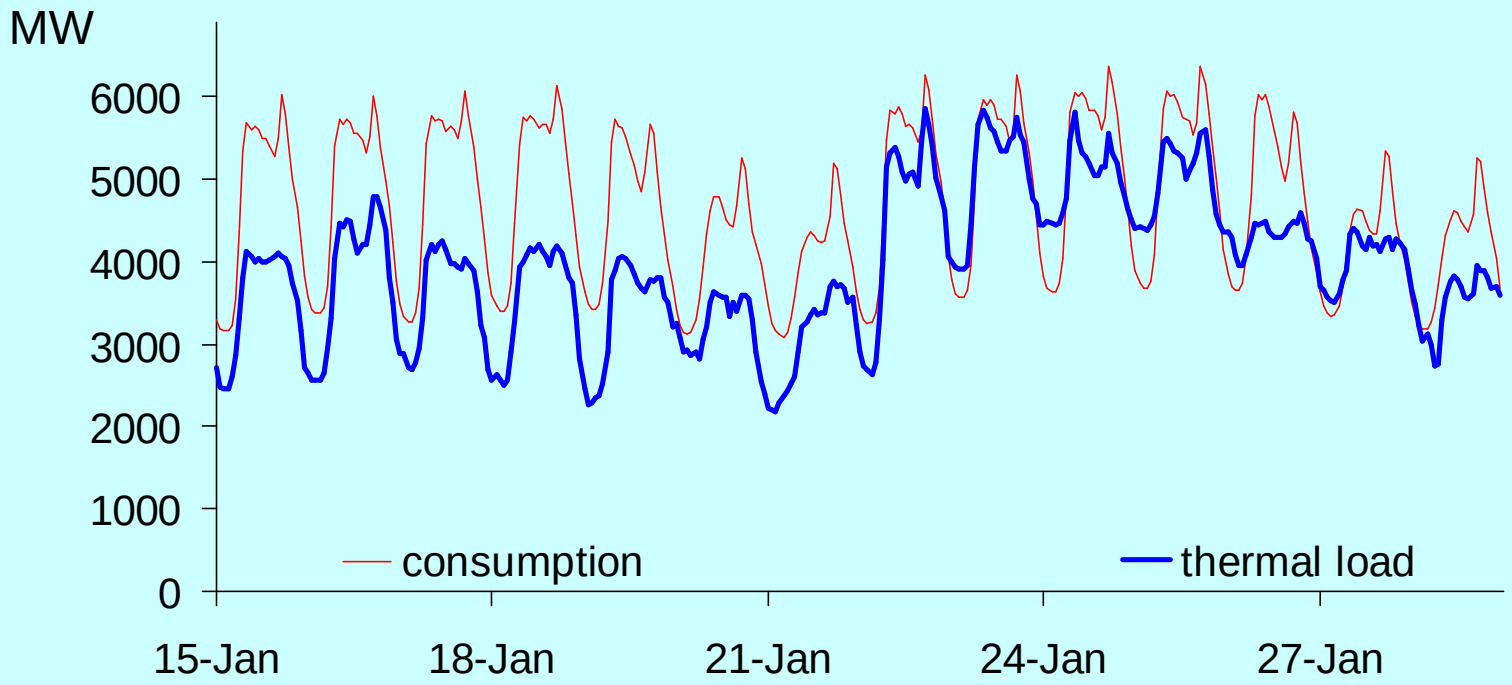
# Denmark, January 2007

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# Electricity Transmission

- Transmission between different power or weather systems reduces cost of variability
- Transmission to connect remote generators will be essential
- Rising ratio of generation capacity to output
- Must transmission capacity match generators' capacity or their output?
  - How would they share it?

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# Market mechanisms

- Value of electricity varies over space and time
  - Losses in transmission

    (<2% on average; up to 10% at margin)
  - Constrained transmission cannot accept power from some distant sources
- Prices that reflect this send better signals
  - and guide people to make better choices

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# Market mechanisms

- Two ways to reflect this in prices
- Uniform national price for electricity, plus separate price for moving power
  - Ofgem favours tradable Transmission Access Rights
- Locational Marginal Prices set by System Operator based on participants' bids

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# Locational Marginal Pricing

- Companies may trade bilaterally
- Voluntary price offers to system operator to generate / adjust generation
- System operator ensures a stable dispatch
  - Uses adjustment bids as needed
  - Calculates marginal cost of power at each node from these bids

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# Locational Marginal Pricing

- LMPs are paid for all power in the system operator's market(s)
- Bilateral trades between nodes pay the difference in LMPs as a transmission charge
- Financial Transmission Rights hedge these charges (for both grid owner and users)

# Energy storage

- Norway “stores” electricity for Denmark as water
- Danish CHP plants can use electric water heating
- Hydrogen production via electrolysis might be timed to use surplus power
- Plug-in vehicles might offer “free” storage

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# Conclusions

- A low-carbon energy system can be built
- Operating it effectively needs coordination
- Market mechanisms already exist that could help with this

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