



IEA Greenhouse Gas R&D Programme

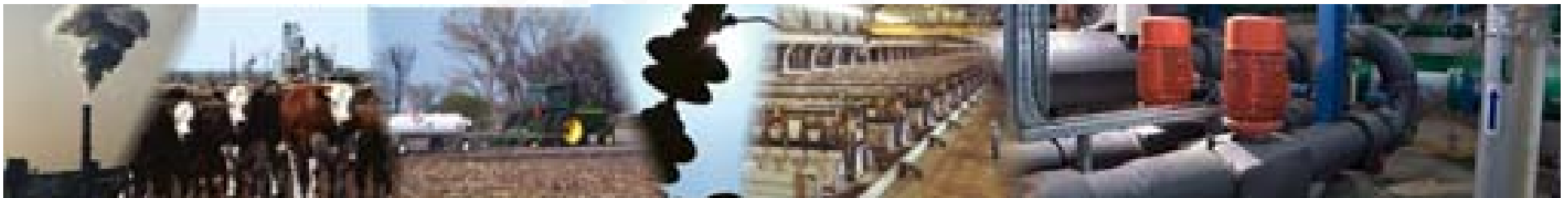


The Need for Flexibility in Power Plants with CCS

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IEA Greenhouse Gas R&D Programme

Workshop on operating flexibility of power plants with CCS
Imperial College, London, 11th-12th November 2009





Outline of the Presentation

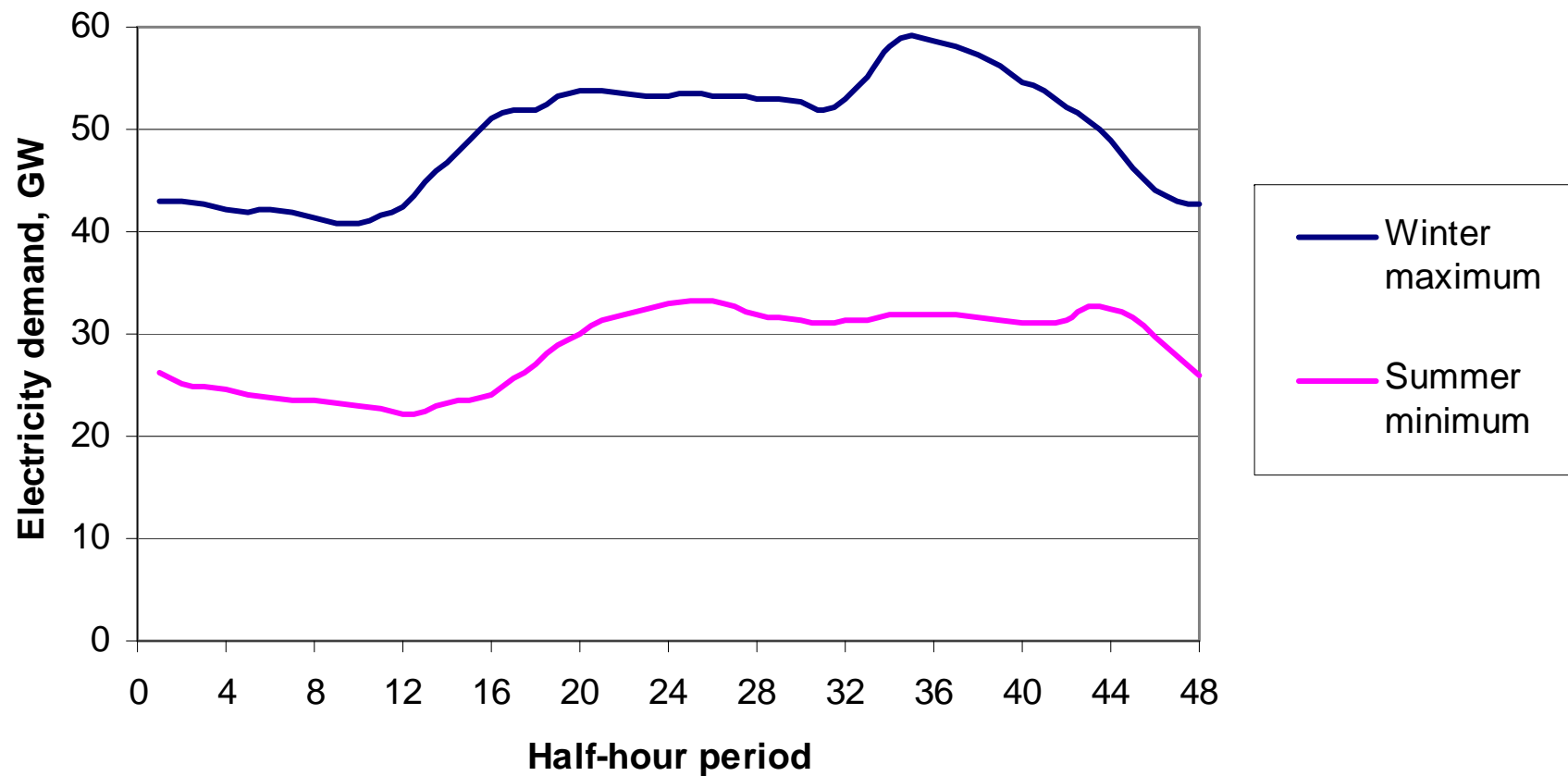
How flexible will CCS plants need to be?

- Variability in electricity demand
- By how much will CO₂ emissions need to be reduced
- Characteristics of the other generation technologies that will be used to reduce CO₂ emissions

Can we avoid the need for CCS plant flexibility?



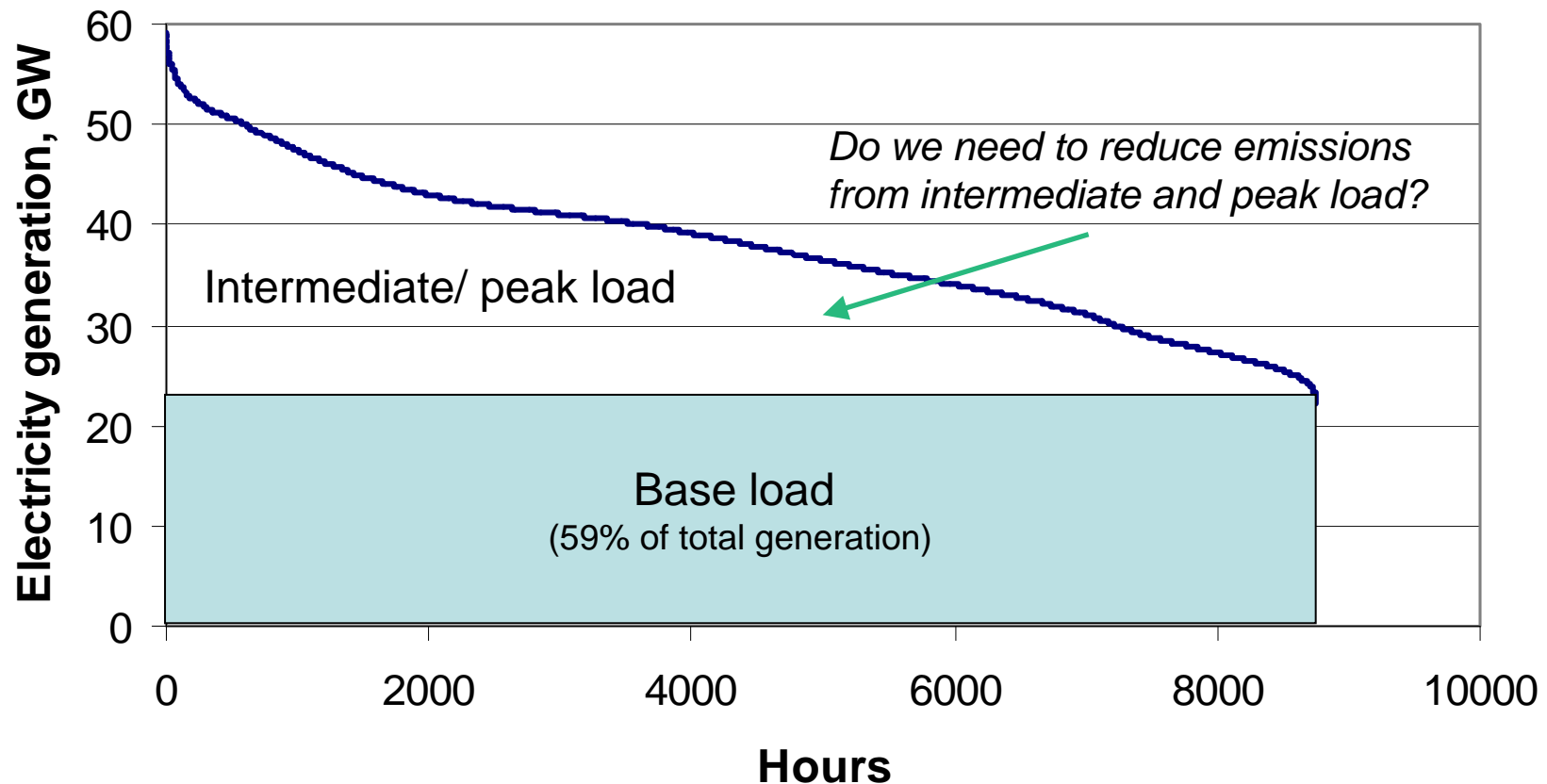
Electricity Demand



UK, 2008-9



Electricity generation



Data source: UK, 2008-9



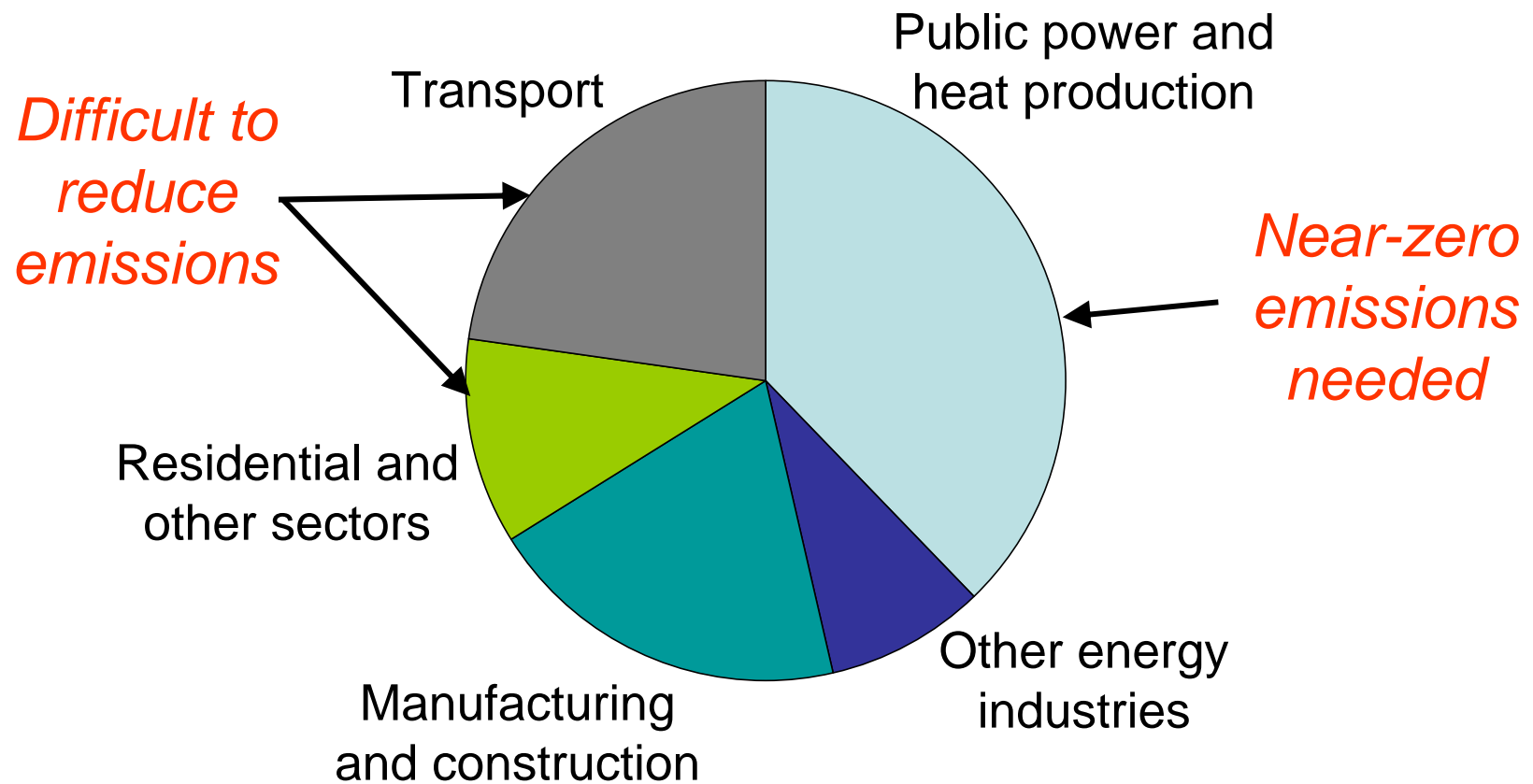
The Need for Deep Reductions in Emissions

G8 meeting, L'Aquila, Italy 2009:

- “The G8 countries have committed to reduce their greenhouse gas emissions by 80% or more by 2050 with reference to 1990 or more recent years.”
- “G8 countries committed to undertake significant comparable mid-term reductions, coherent with the long term objectives.”



CO₂ Emissions



IEA 2007 data, excludes land-use change



Techniques for Emission Reduction

- Energy efficiency improvements
- Land-use changes
- Changing to lower carbon fuels (coal to gas)
- Renewable energy
- Nuclear
- CCS



Impact of Renewable and Nuclear Energy

- Large increases in renewables are expected
 - EU's Renewable Energy Directive commits to 20% of overall energy from renewable sources by 2020.
 - For electricity a greater fraction may be required
 - E.g. ~35% in the UK
 - Wind, solar, tides etc have variable outputs
- Use of nuclear is expected to increase in some countries, decrease in others
 - Nuclear plants are relatively inflexible



Impact of Renewable and Nuclear Energy

Marginal operating cost merit order

- Wind / solar etc
- Nuclear
- Fossil fuels with CCS / Biomass
- Fossil fuels without CCS

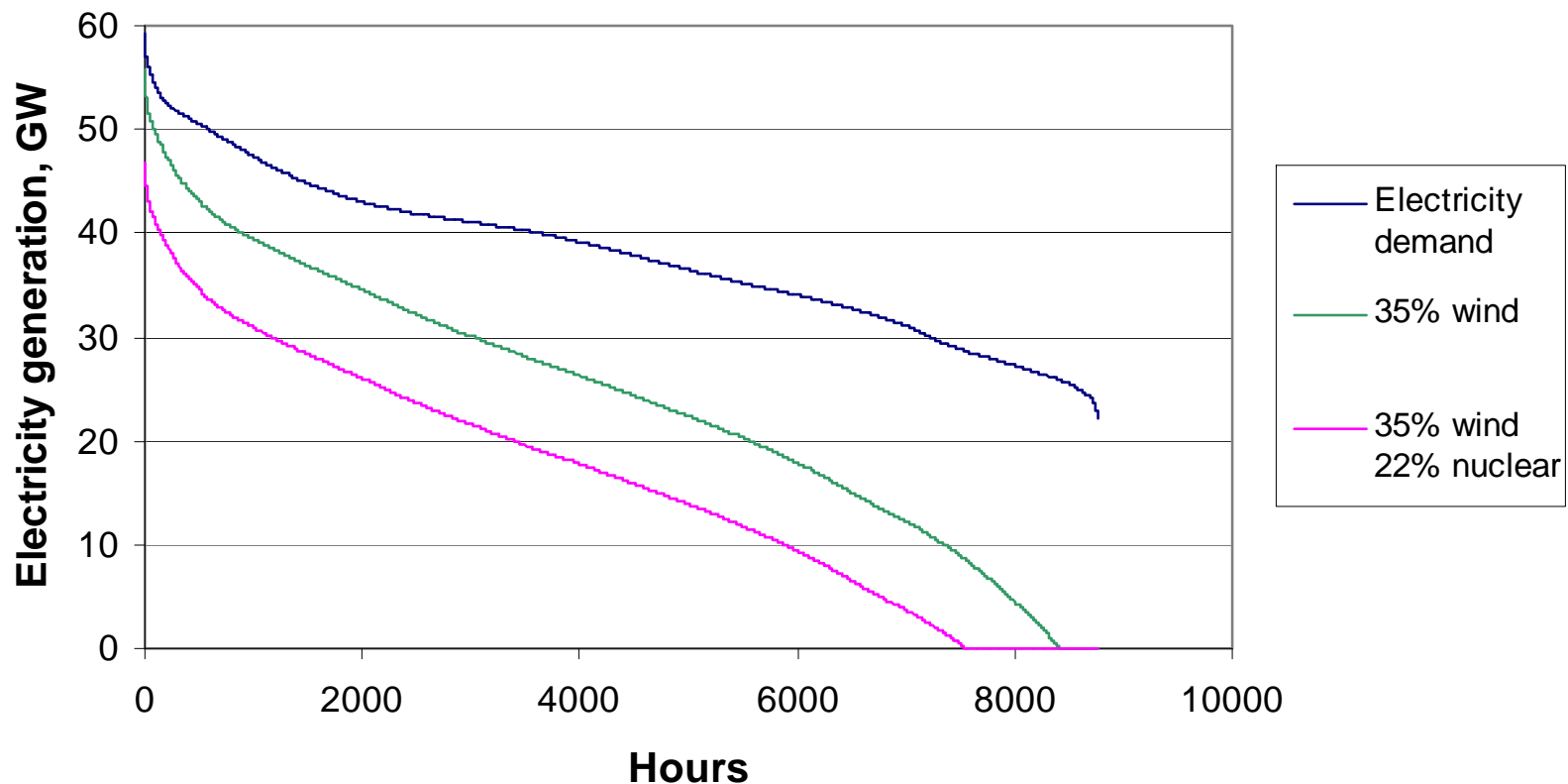
Low marginal cost,
operate whenever
available

Higher marginal cost,
operate at lower load
factor





Fossil Fuel Power Generation



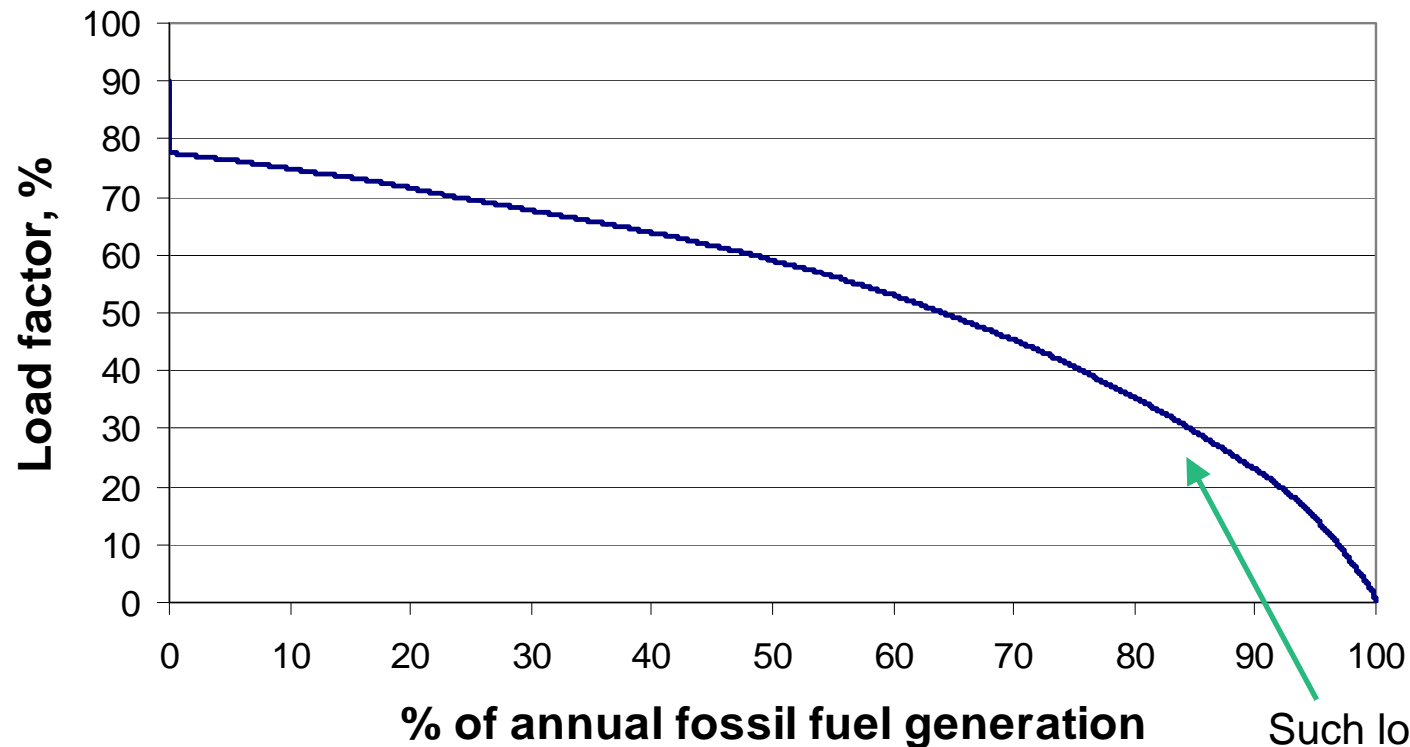
Data sources: UK power demand 2008-9

Wind energy scaled from current UK output



Fossil Fuel Plant Load Factors

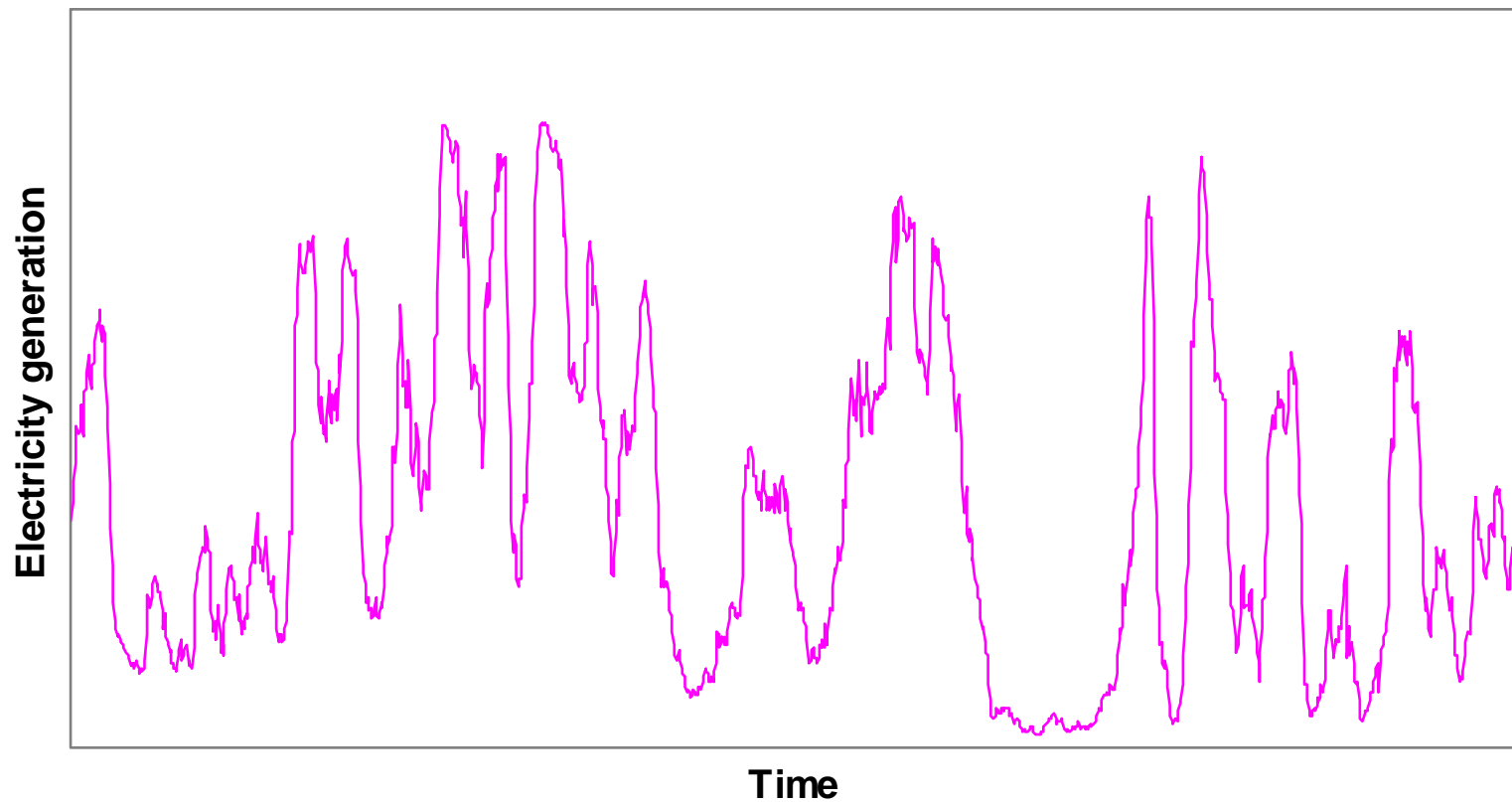
35% wind, 22% inflexible nuclear generation



Such low load factors would only be required for CCS plants in very low emission scenarios



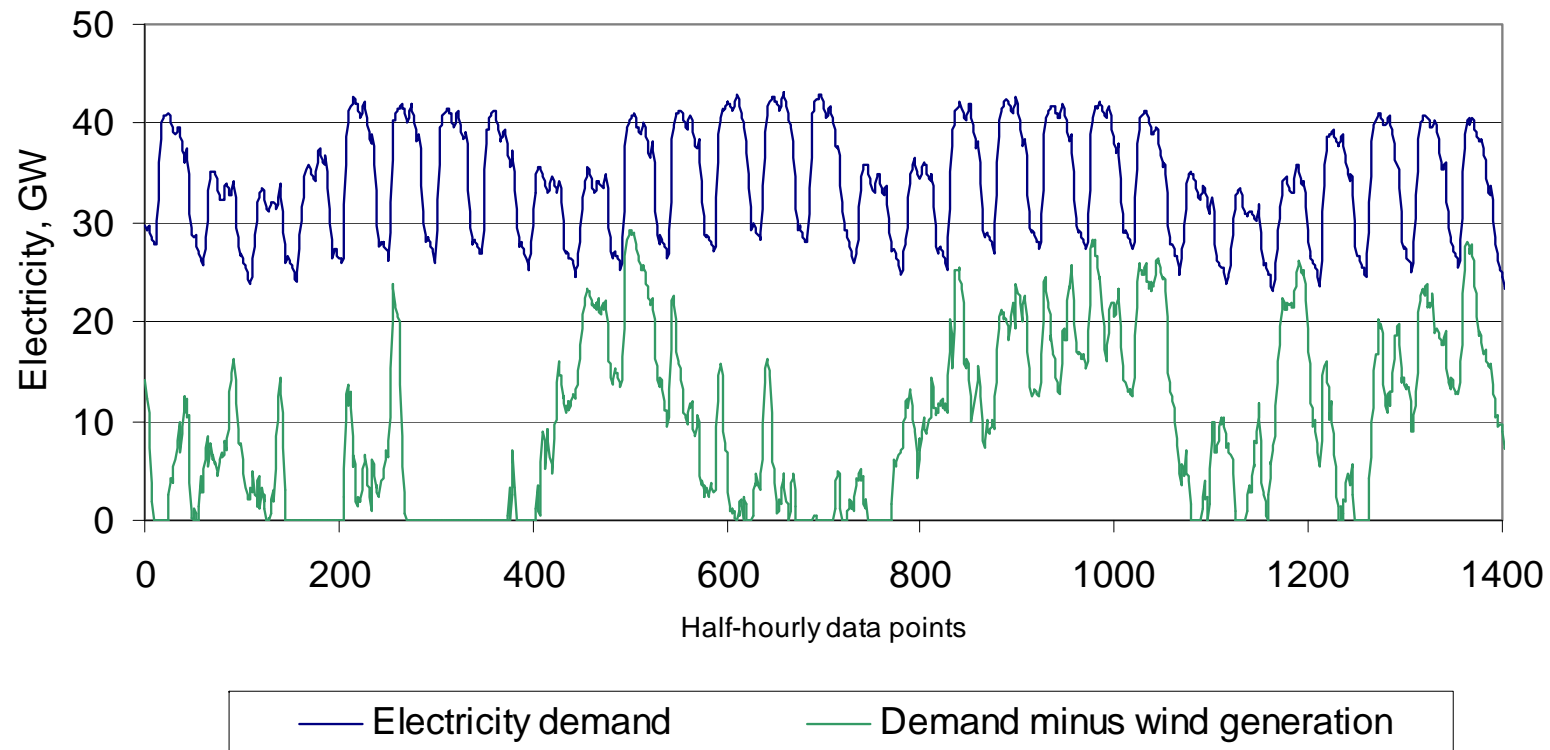
Variability of Wind Generation



HV grid connected wind in the UK, May 2009



Electricity Supply from Non-Wind Plant

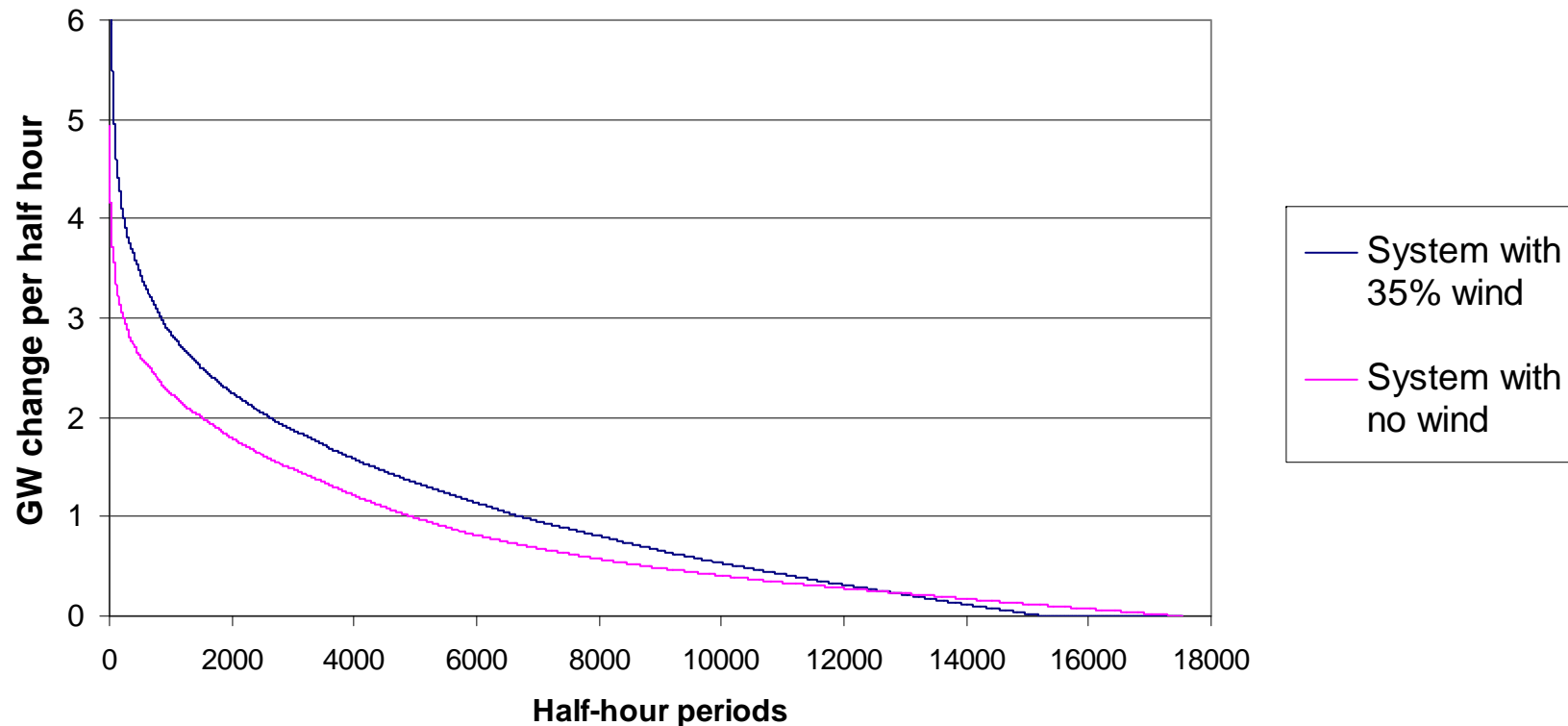


Basis: UK, May 2009, wind scaled to 35% of total generation



Rate of Change of Load

Impact of wind generation on fossil fuel power plants



Basis: UK power demand (maximum 59GW)
22% of generation from 'inflexible' plants
Wind output scaled from current system output



Economic Implications

- CCS plants are capital intensive
- Operation at low load factors increases costs
- This may not be a significant problem
 - There is limited competition to CCS for intermediate load generation with low-CO₂ emissions
 - Hydro and biomass have major resource constraints
 - Prices of intermediate load power will be higher in a carbon-constrained world

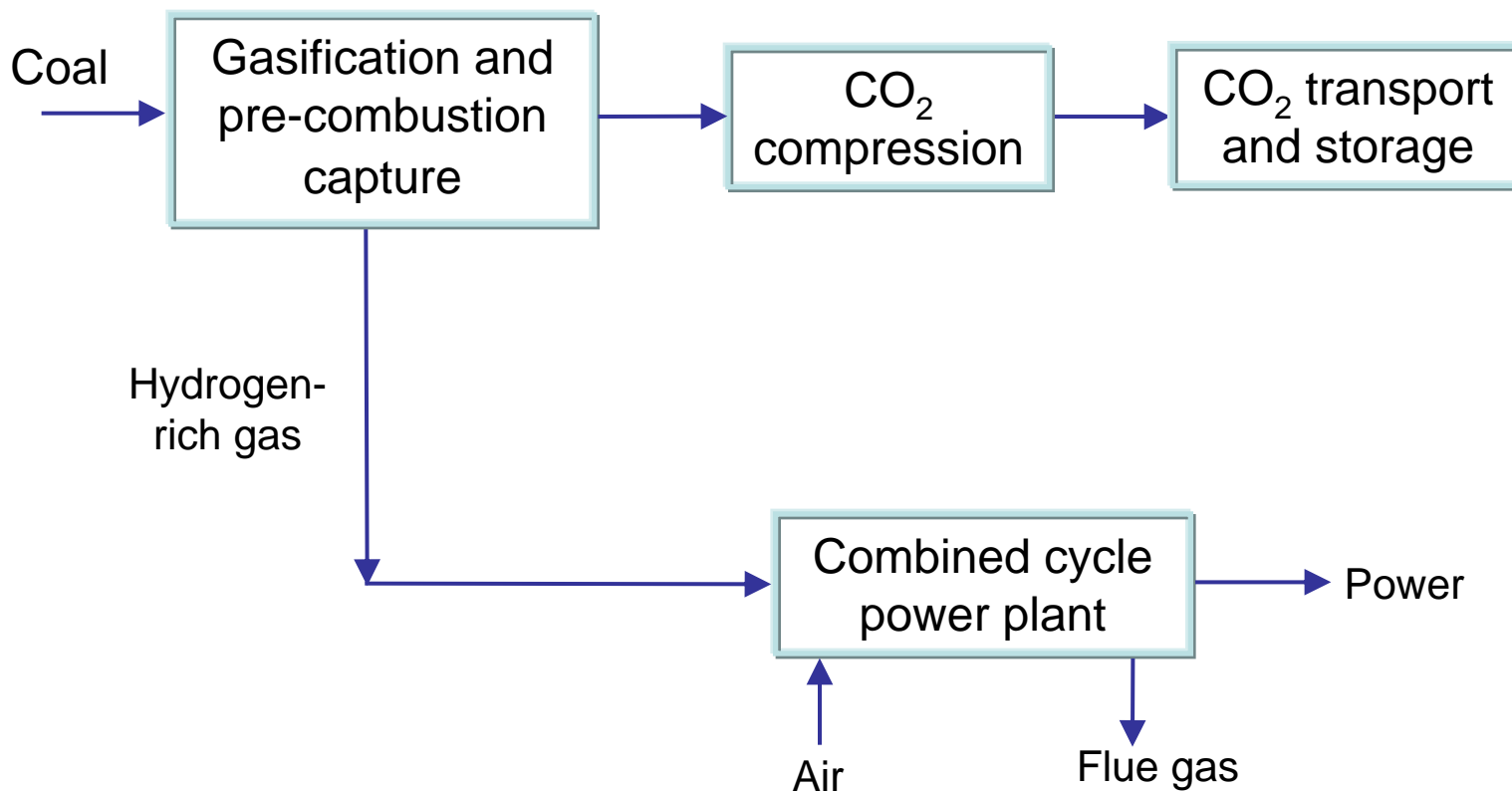


Can the Need for Flexibility be Avoided?

- Smart grids, load shifting etc to smooth demand
- Electricity storage
 - Pumped hydro, compressed air storage, flow batteries etc
 - Electrolysis to produce hydrogen – an expensive option
- Include energy storage in CCS processes
 - Solvent storage in post combustion capture (short term)
 - Oxygen storage in IGCC and oxy-combustion (short term)
 - Hydrogen storage in gasification combined cycles (short and long term)

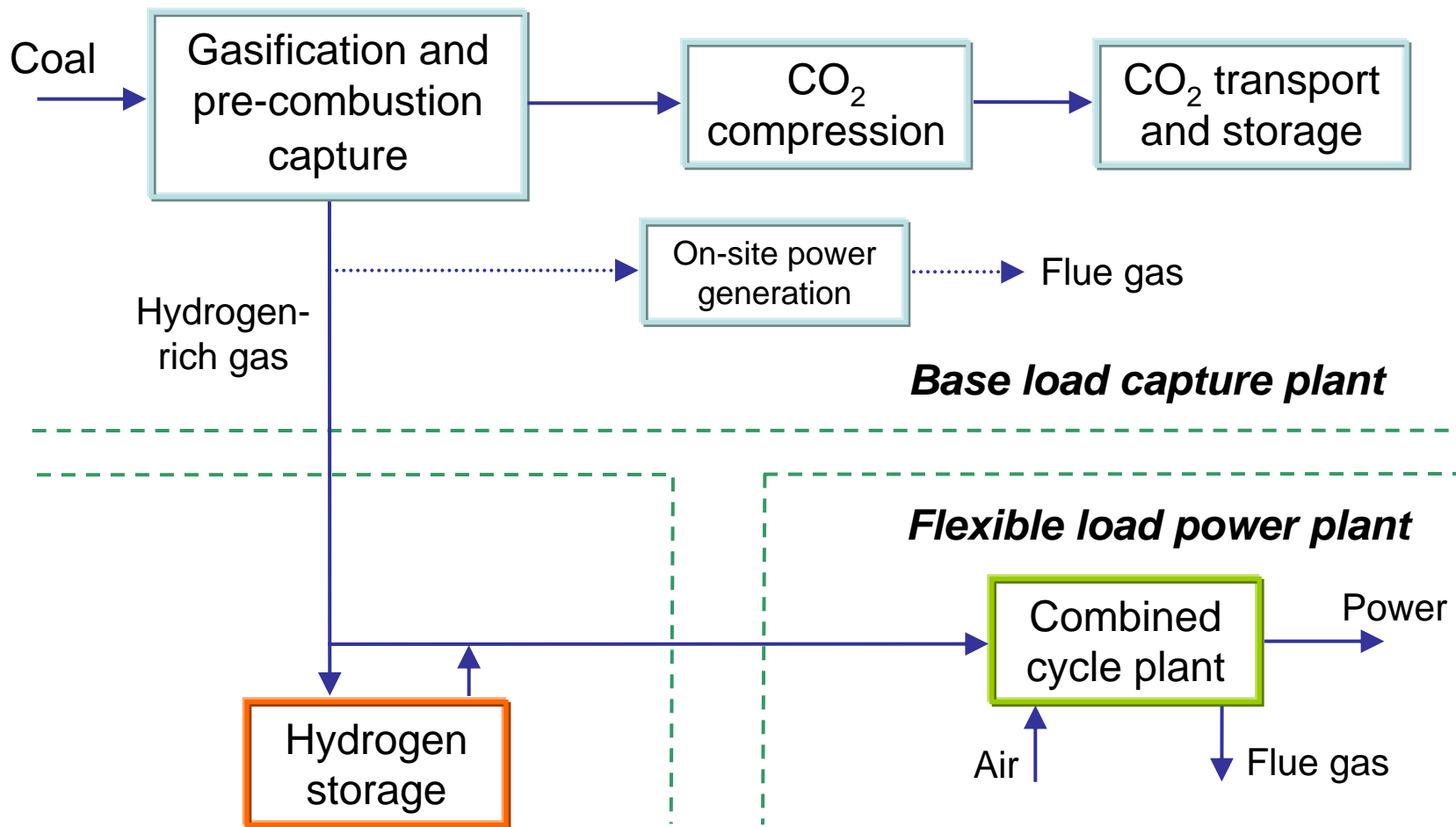


Integrated Gasification Combined Cycle





Gasification Combined Cycle with H₂ Storage





Gasification Combined Cycle with H₂ Storage

- Gasification, capture and storage can operate at base load – no need for flexibility
- Only the combined cycle plant has to operate flexibly
- High utilisation of capital investment
- Underground hydrogen storage is proven technology, e.g. in salt caverns in Texas and UK
- Small cost and efficiency penalties for non-integrated base load plants
- Large cost advantage for intermediate load plants
- 99% CO₂ capture is possible



Conclusions

- CCS flexibility requirements depend on external factors:
 - Variability of electricity demand
 - The overall GHG abatement requirement
 - The amount of wind and nuclear in the system
 - Developments in electricity system load management
- Some CCS plants will be able to operate at base load if there is a modest CO₂ abatement requirement, little wind and nuclear or high load management
- Most CCS plants will probably have to operate flexibly
- Including energy storage in some CCS processes can be an effective way to reduce the need for flexible operation