CCS Plant Flexibility

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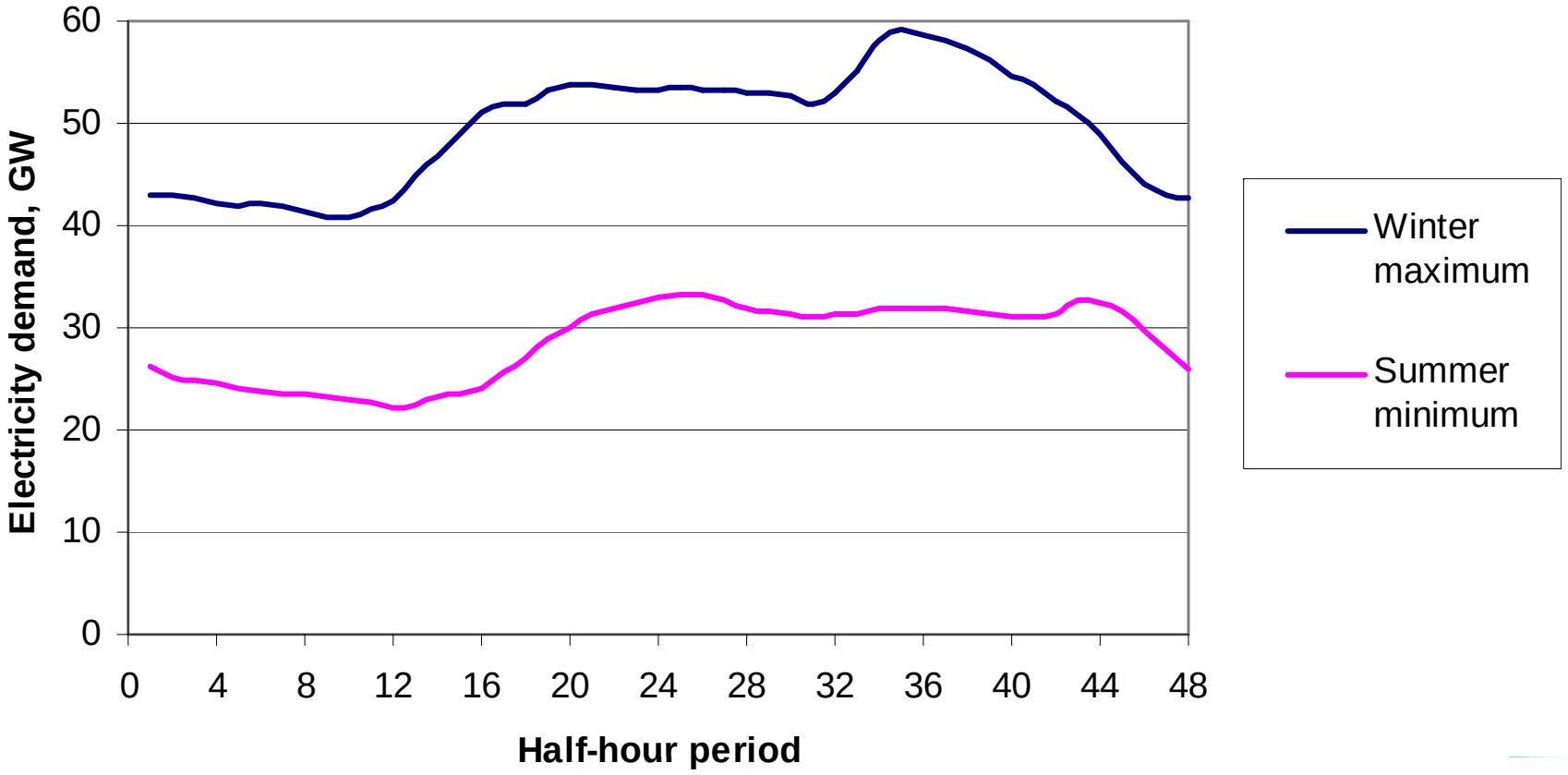
Power Demand Variability

Power plants have to operate flexibly



UK, 2008-9

Future Changes

- Need for more low-CO_2 power generation
- 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
- CCS will make a major contribution

The Role of CCS

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

- CCS plants may have to operate flexibly and at intermediate load
- CCS flexibility requirements depend on how much renewables and nuclear are used

IEAGHG Work on Flexibility

- Scoping study on CCS flexibility
  - University of Waterloo, Canada, 2008
  - Reviewed published work – very little at that time
  - Assessed work needed to model flexibility
- Workshop on CCS flexibility
  - Imperial College London, November 2009
  - 50 participants from 12 countries
  - Presentations and discussions on flexibility of CO_2 capture, transport and storage and electricity systems
  - Follow-on meeting in Norway, November 2010
- In-house work on system modelling and use of hydrogen storage in CCS plants
- Study on CCS flexibility and energy storage
  - Study scope being prepared

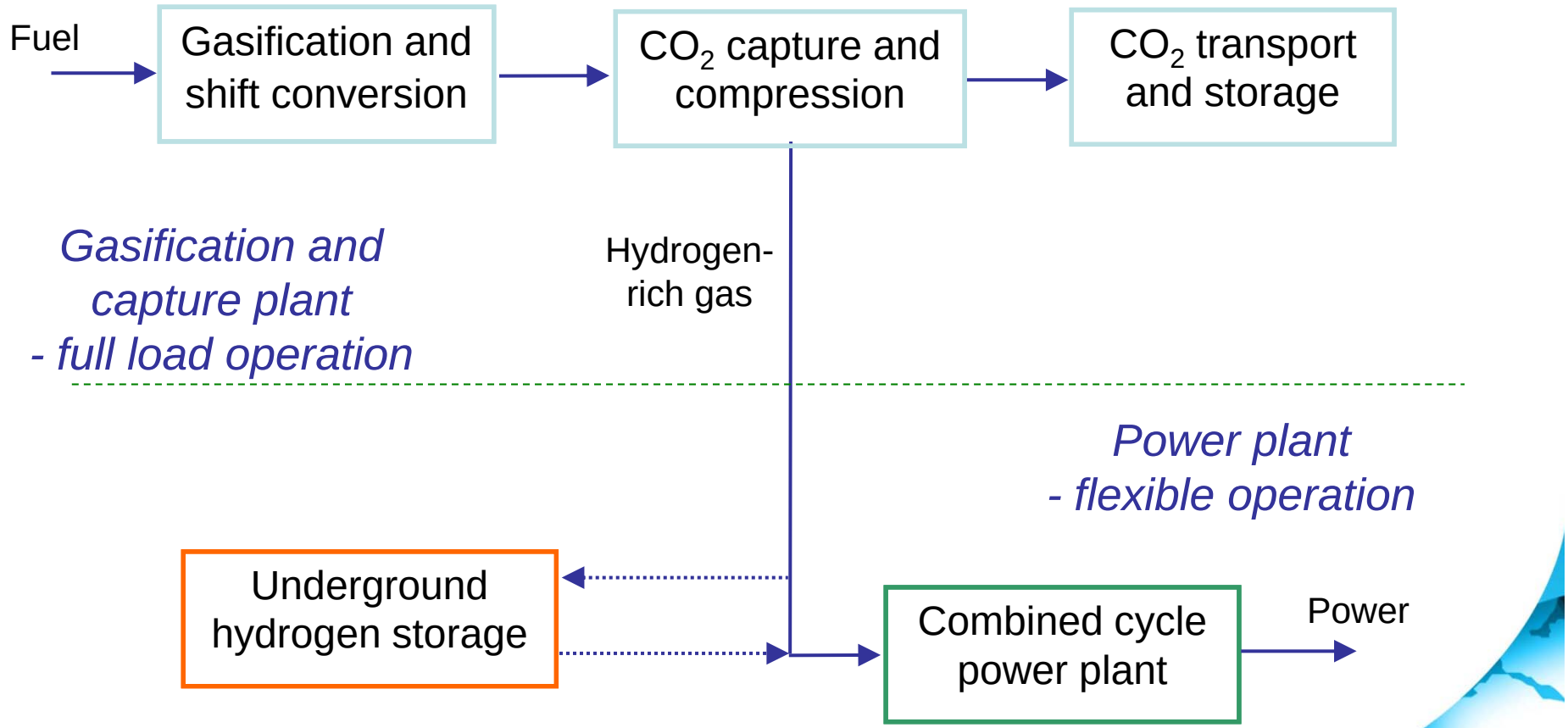
Can CCS Plants Operate Flexibly?

- Little information available in the public domain
- Modelling and pilot plant work is underway
- Results for post combustion capture are encouraging but it is early days
- Capture technology suppliers are starting to consider flexibility
- Suppliers can include more flexibility but market needs and economic benefits of flexibility are uncertain
- CO_2 storage appears to be flexible but results from more sites would be helpful
- Need to ensure regulations do not add unnecessary constraints
  - Will high percentage capture be required even during rapid load changes?

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)

Non-Integrated Plants with Hydrogen Storage



CCS Plants in Future Grids

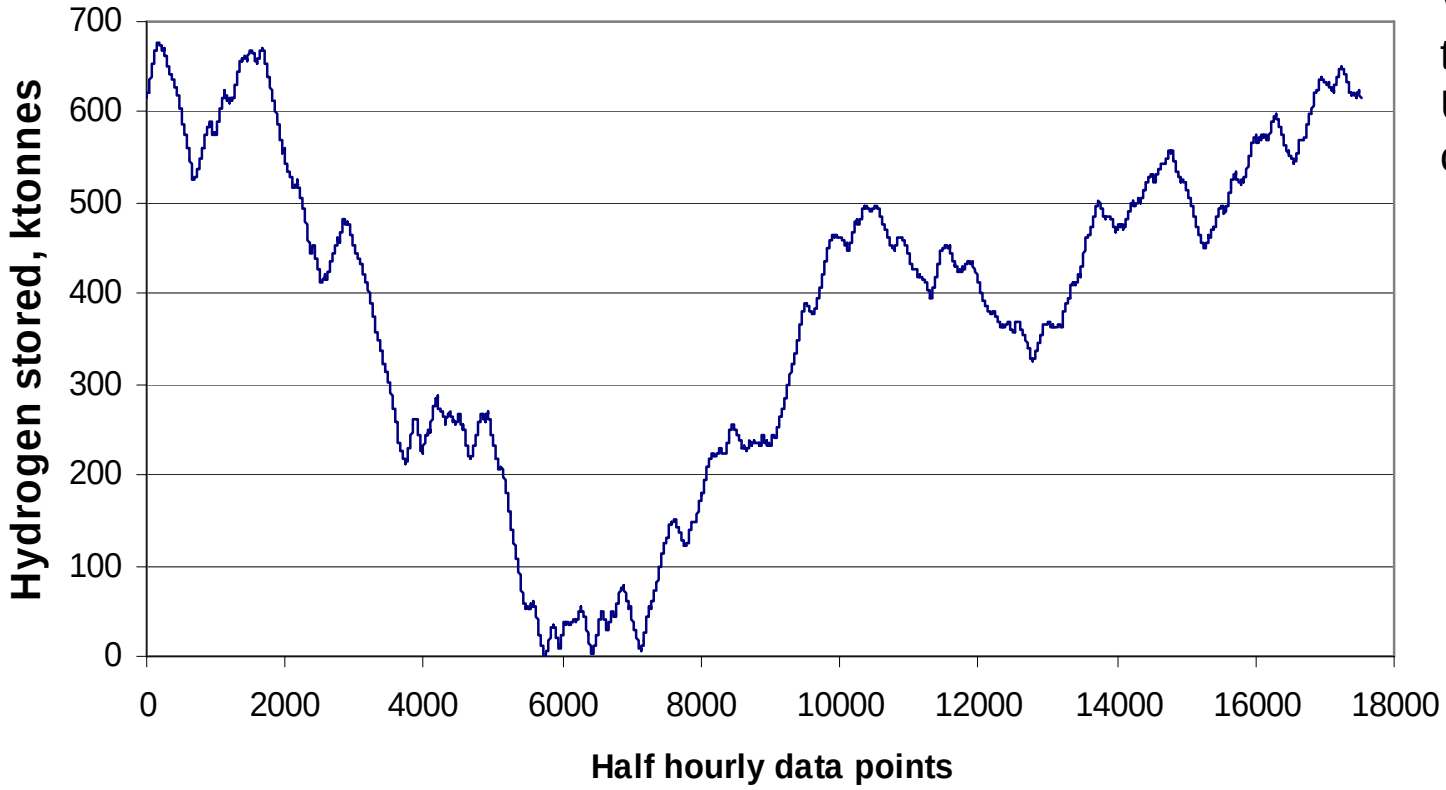
- IEAGHG modelled operation of fossil fuel CCS plants in a future electricity system
  - Based on current UK electricity demand and variability of wind electricity generation
  - Half hourly data points
  - Wind output directly scaled to larger capacities
    - » Actual variability is likely to be lower due to greater geographical spread and more offshore wind
- Analysis focussed on post combustion capture and coal gasification hydrogen production with pre-combustion capture

Ref: Davison, International Journal of Greenhouse Gas Control 3 (2009) 683-692

Hydrogen Storage

- Salt cavern storage
  - Solution mined
  - Widely used for natural gas storage
- Hydrogen storage is proven
  - UK (Teesside)
    - » 3 caverns, 200-300 tonnes H_2 each
    - » Operated for many years, no discernable leakage
  - USA (Texas)
    - » 8,000 tonne cavern = 270 GWh (thermal, LHV)

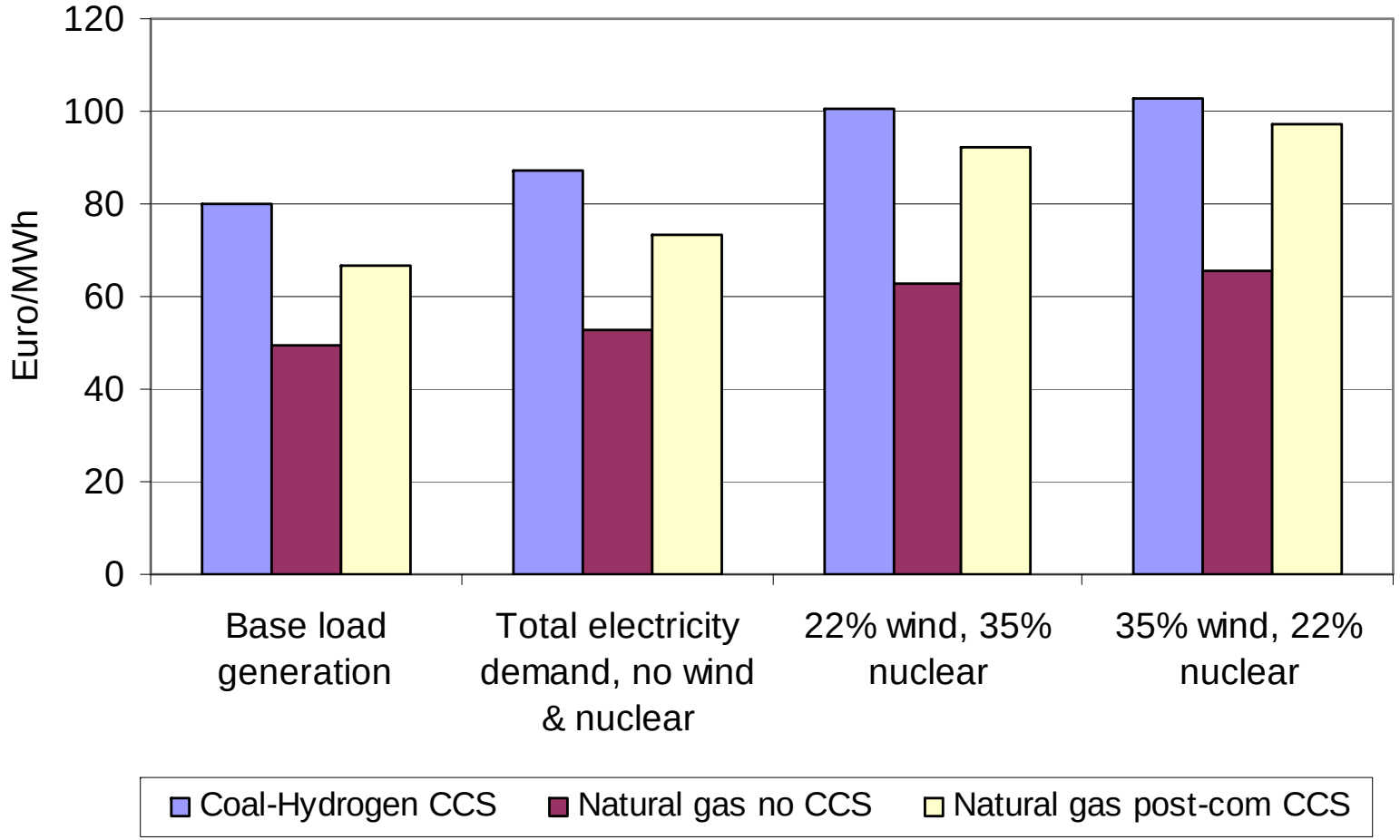
Hydrogen Storage Quantities



Volume equal to 27 days of UK natural gas consumption

Current UK electricity demand
Future generation mix: 35% wind, 22% nuclear, 43% coal-hydrogen-CCS

Fossil Fuel Generation Costs



2007 costs, coal €2/GJ, gas €6/GJ, 8% DCF, 25 year plant life, €5/t CO_2 storage cost
CO_2 emissions: Coal-H_2 plant 16g/kWh, Natural gas post combustion plant 64g/kWh

CCS with Hydrogen Storage - Advantages

- Gasification and CCS plant can operate at full load
  - Practical advantages for gasification, capture, CO_2 transport & storage
  - Economic advantage – best use of the capital investment
- Only the gas turbine power plant has to operate flexibly
- Option of near-zero emissions (≤16g/kWh)
- Suitable for retrofit of CCGTs
  - No additional area or CO_2 pipeline needed at the power plant
- H_2 is made available for de-carbonisation of small scale energy users

CCS with Hydrogen Storage - Disadvantages

- Hydrogen-burning gas turbines are needed
- Geology for hydrogen storage may be a constraint in some places
- Hydrogen pipelines would be needed if power plants and hydrogen stores cannot be located together

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
- In some countries CCS plants will be able to operate at base load
  - If there is a modest CO_2 abatement requirement, little wind and nuclear or high load management
- In some countries most CCS plants will probably have to operate flexibly
- Little information in the public domain on CCS plant flexibility
- Including energy storage in some CCS processes can be an effective way to reduce the need for flexible operation