Operational Flexibility of CCS

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Carbon Capture and Storage:

How is it Working and What Next?

IMechE, London, 13th-14th October 2010

IEA Greenhouse Gas Programme

- An Implementing Agreement established in 1991 by the International Energy Agency
- Aim is to:

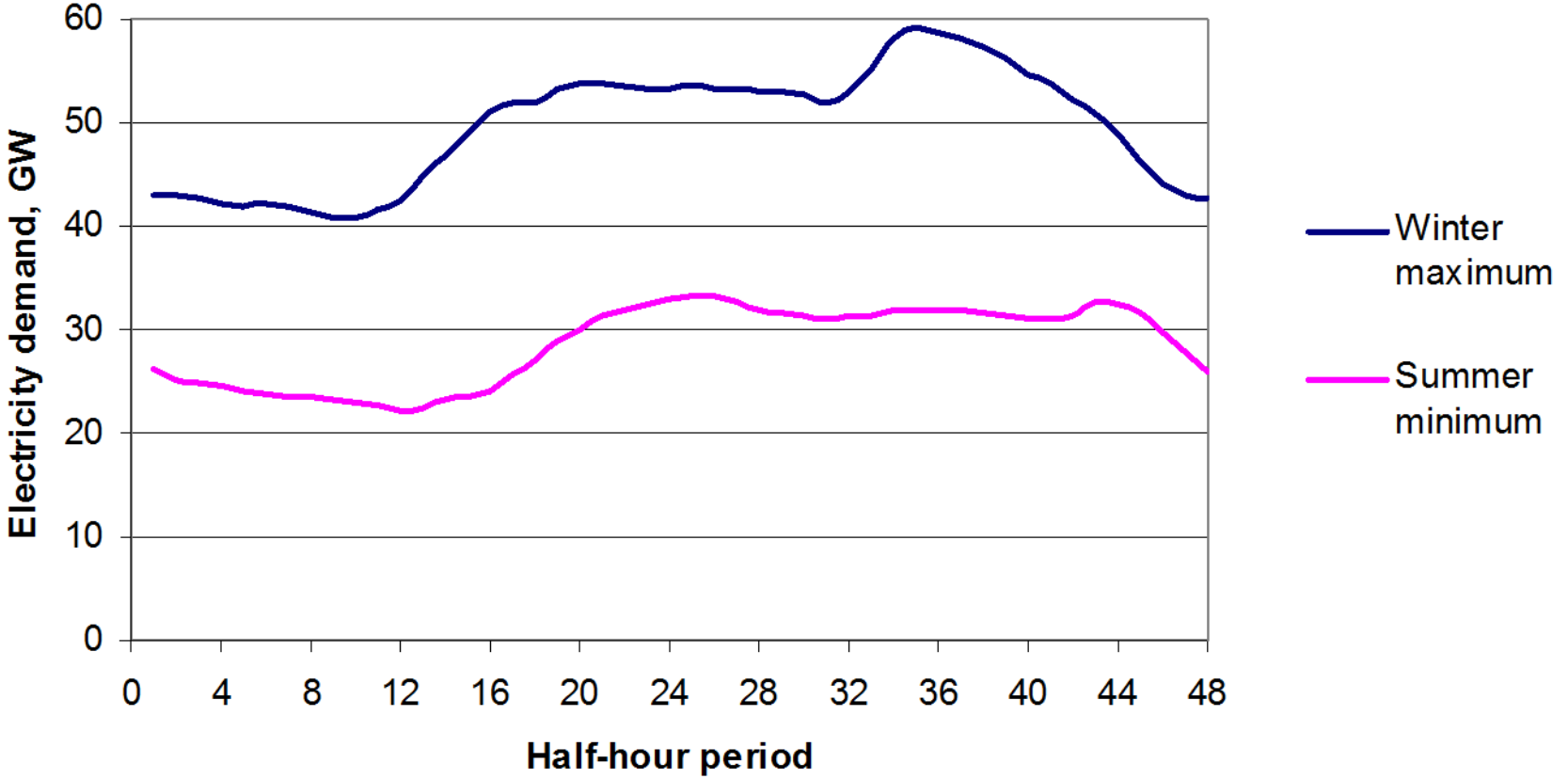
  Provide members with definitive information on the role that technology can play in reducing greenhouse gas emissions
- Emphasis on CO_2 Capture and Storage (CCS)
- About 20 country members and 20 industrial sponsors
- Based at Cheltenham, UK

Outline of Presentation

- Why will power plants with CCS need to operate flexibly?
- How to achieve flexibility in CCS power generation
- Costs and emissions of flexible CCS in an electricity system

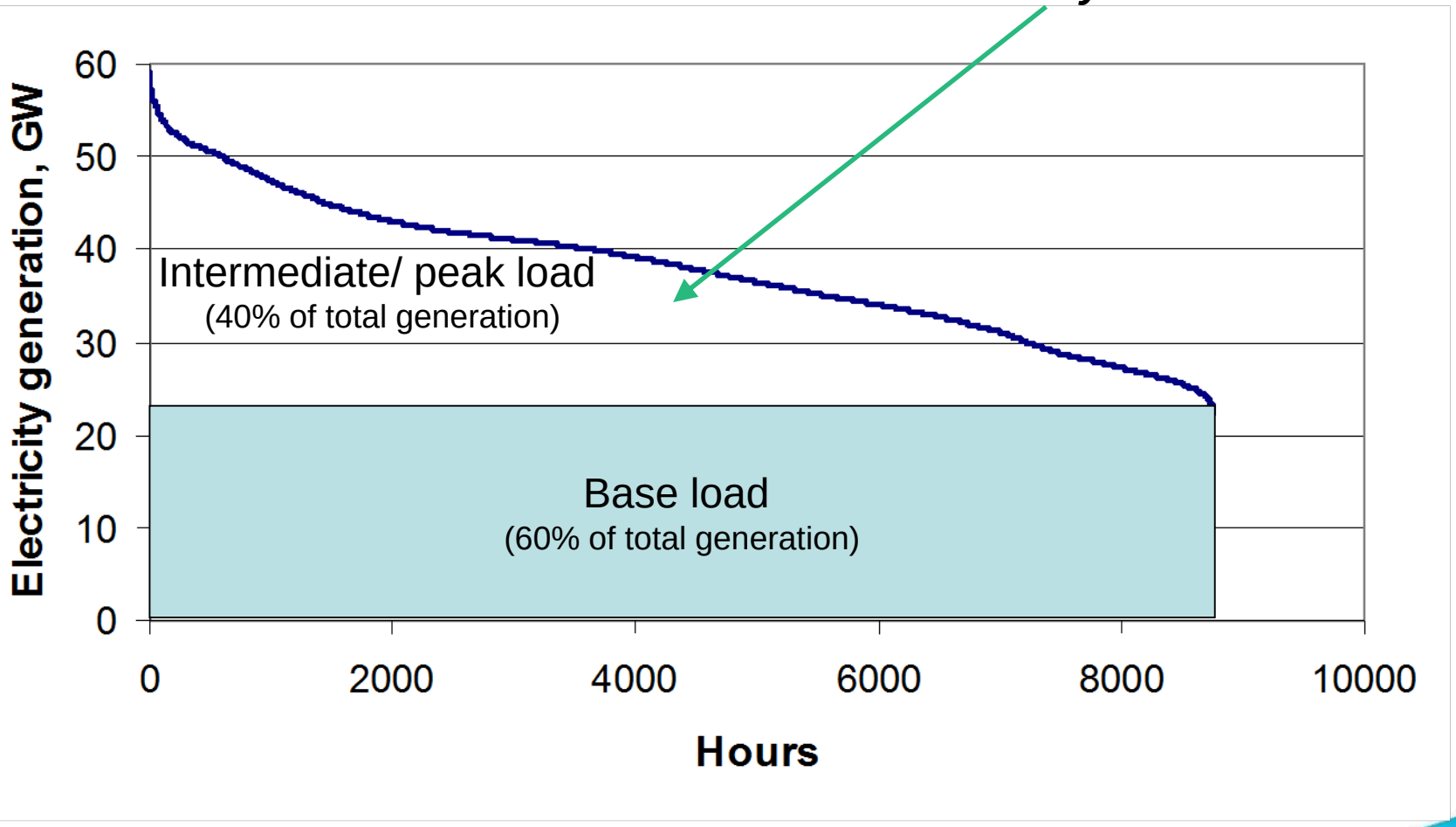
The Need for Flexibility

UK electricity demand, 2009

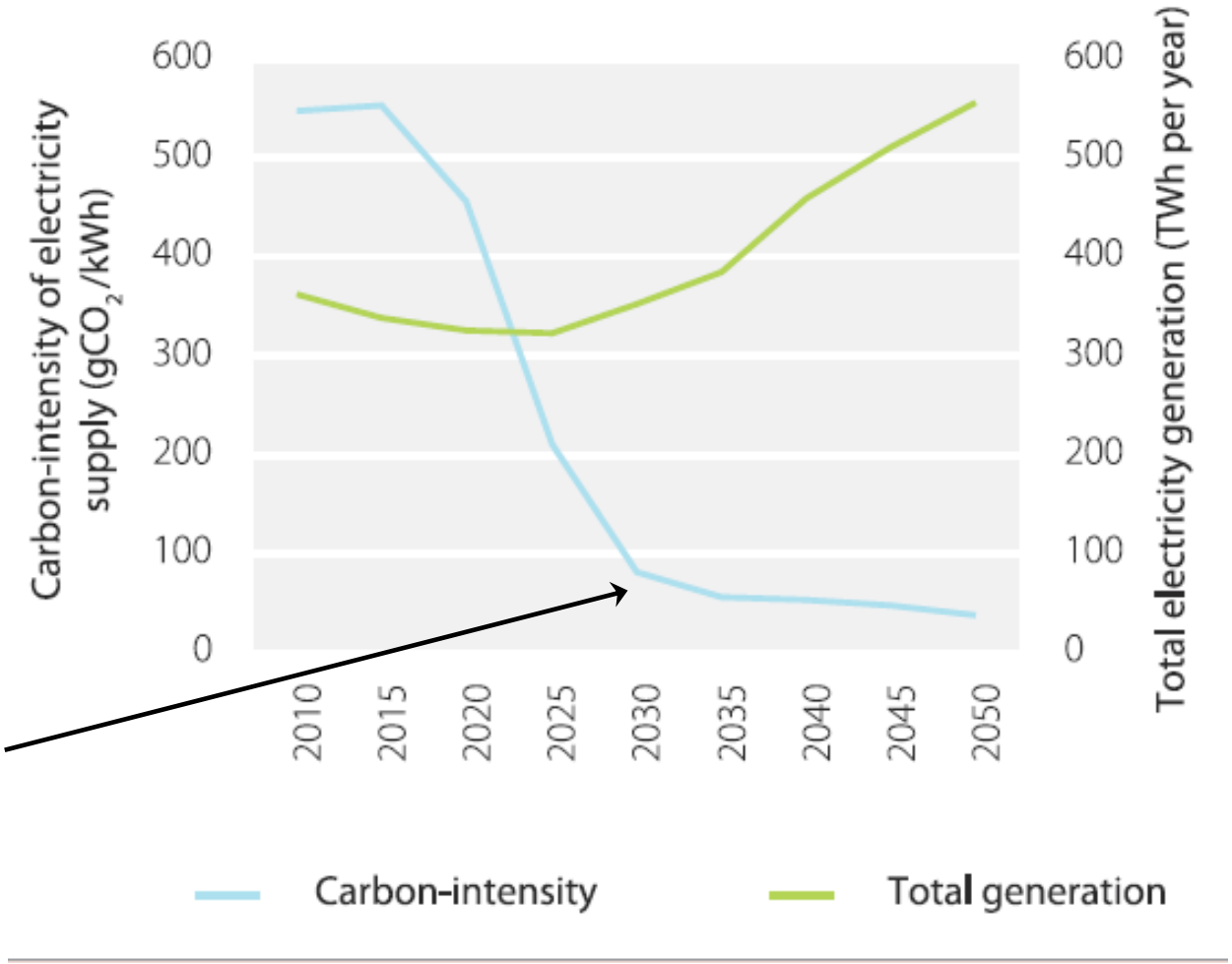


Electricity Demand

Do we need to decarbonise this electricity?



CO_2 Emission Projections



<100g/kWh by 2030

- UK Committee on Climate Change, 2009

The Role of CCS

- Power companies and national governments prefer diverse energy supplies to reduce risks
- CCS will operate in grids with other technologies
- Power plants are usually operated according to a merit order based on marginal operating costs

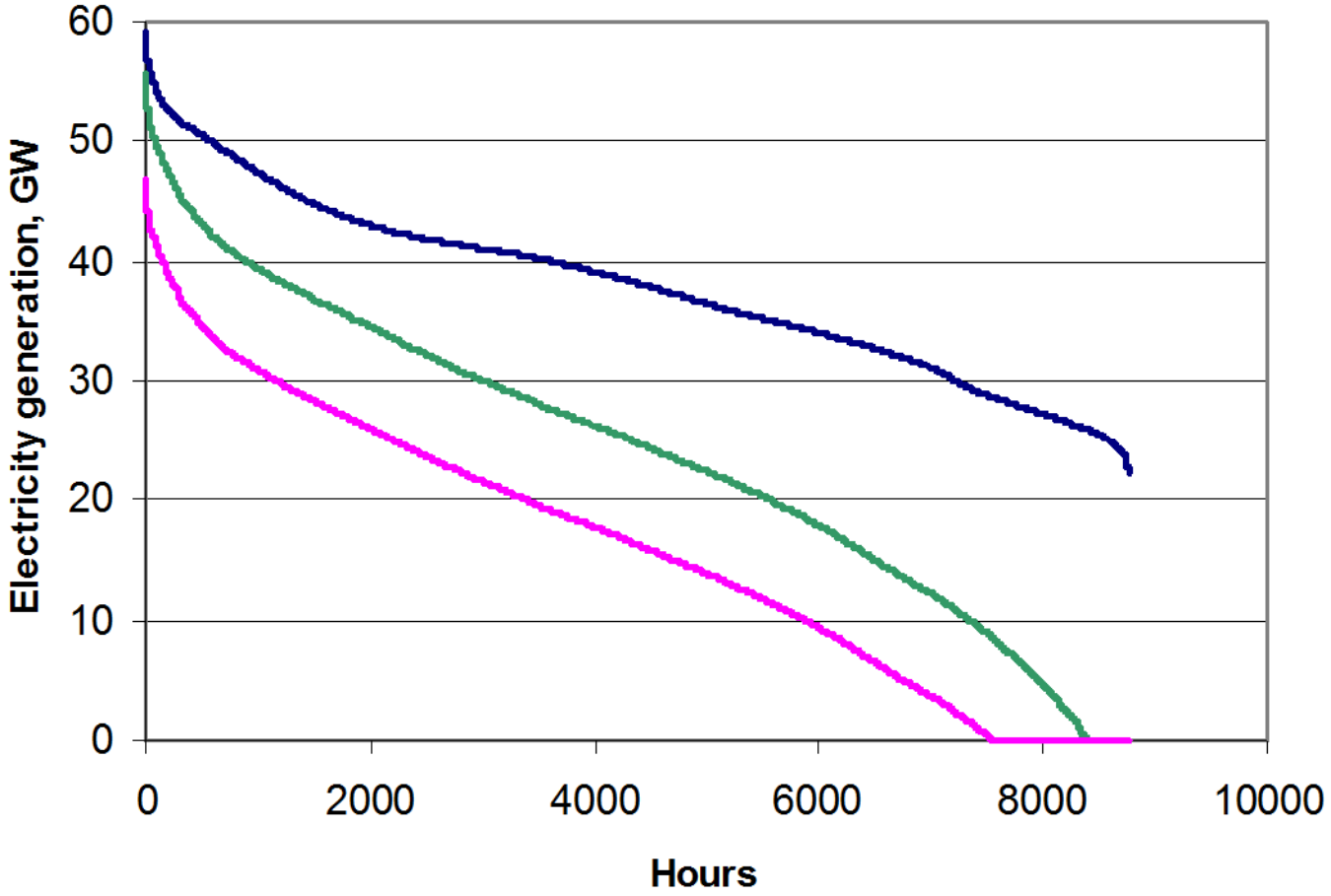
  - Wind / solar / marine energy
  - Nuclear
  - Fossil fuels with CCS / Biomass
  - Fossil fuels without CCS

Lower marginal cost - operate whenever available

Higher marginal cost - operate at lower load factor

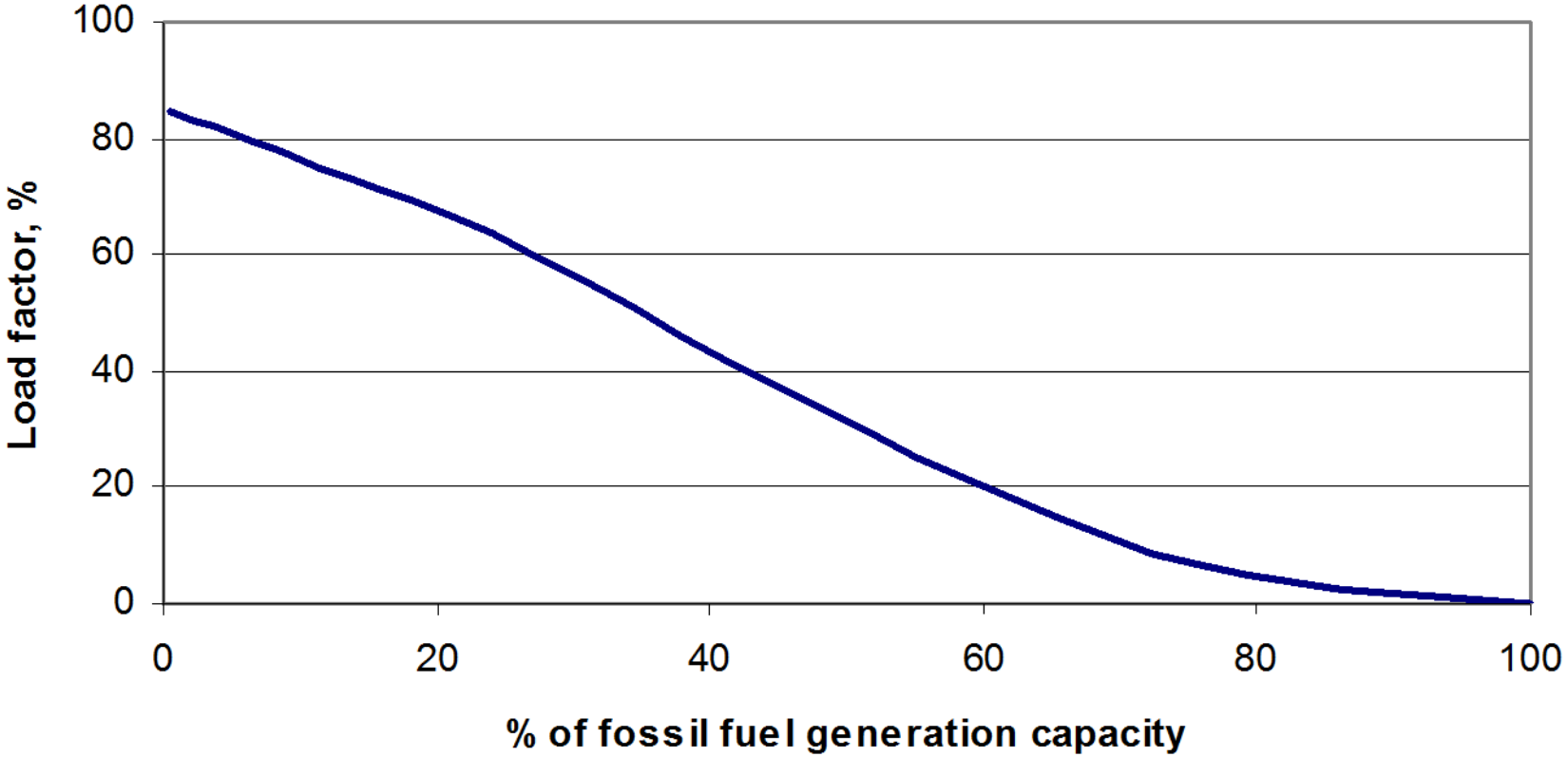
Note: Renewable plants rather than nuclear plants may be turned down to cope with short term demand variations because they incur lower costs for changing load

Impact of Renewables/Nuclear on Fossil Fuel Plant Operation



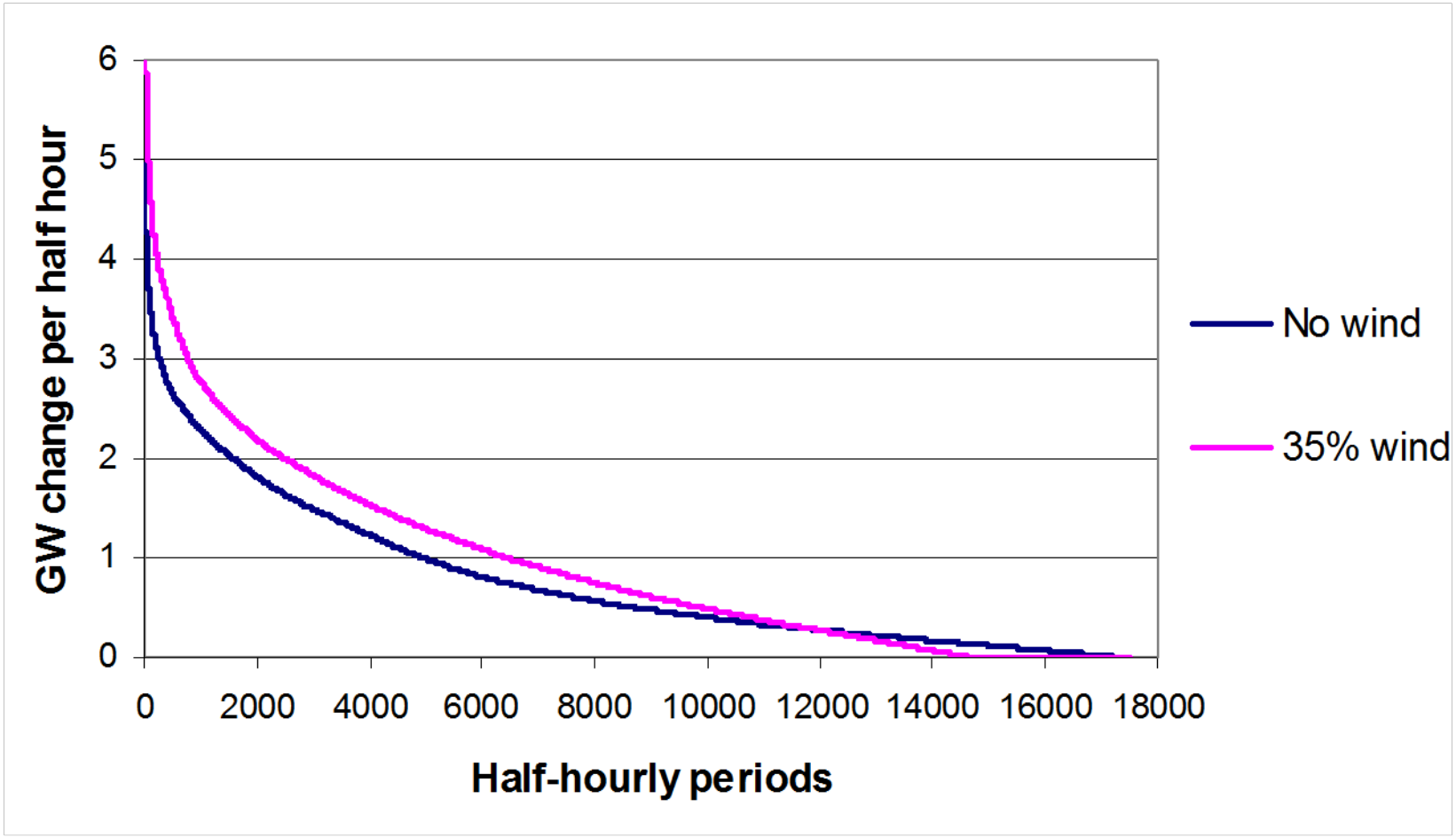
35% wind, 25% nuclear

Plant Load Factors



Load factor of fossil fuel plants: % of plant availability
35% wind, 25% nuclear

Rate of Change of Load for Fossil Fuel Power Plants

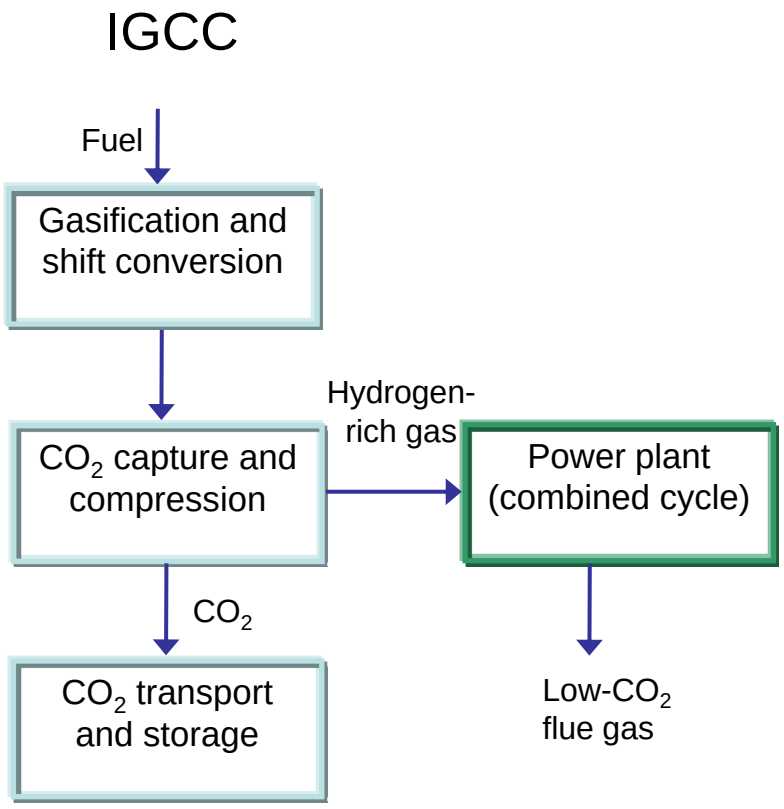


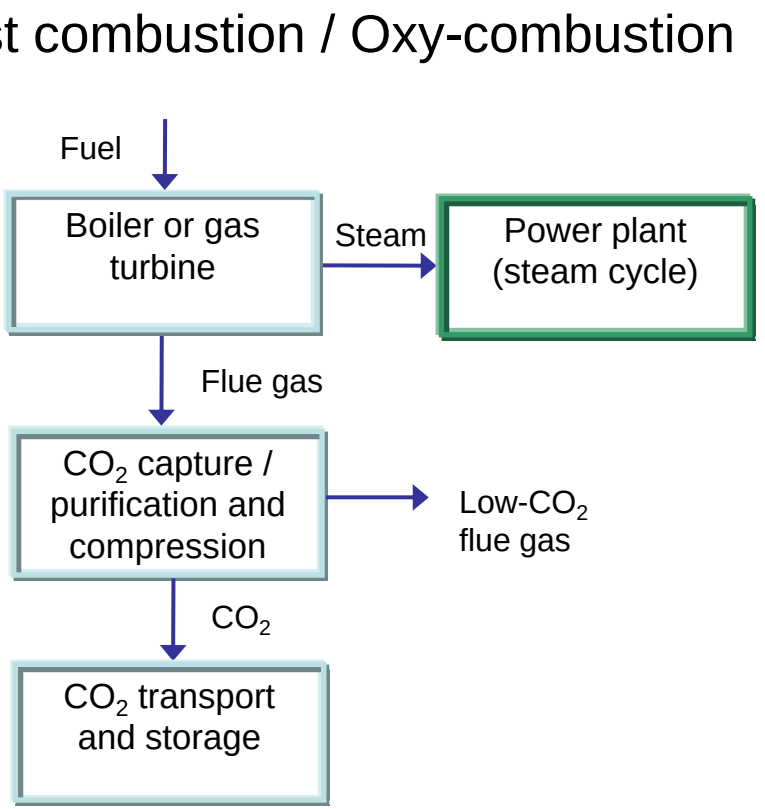
Assuming 35% of generation from wind, 25% nuclear
Based on 2009 UK power demand (half-hourly periods)
Wind power output scaled from 2009 NETA data

How to Achieve Flexibility

- Integrated power generation and CCS plants
  - CCS needs to operate flexibly
- Non-integrated CCS and power generation plants
  - Avoids the need for CCS flexibility

Integrated CCS Power Plant





- CCS operates at the same load factor as the power plant
- Utilisation of CCS plant is low at low power plant load factors
- Flexible CO_2 capture, transport and storage is needed

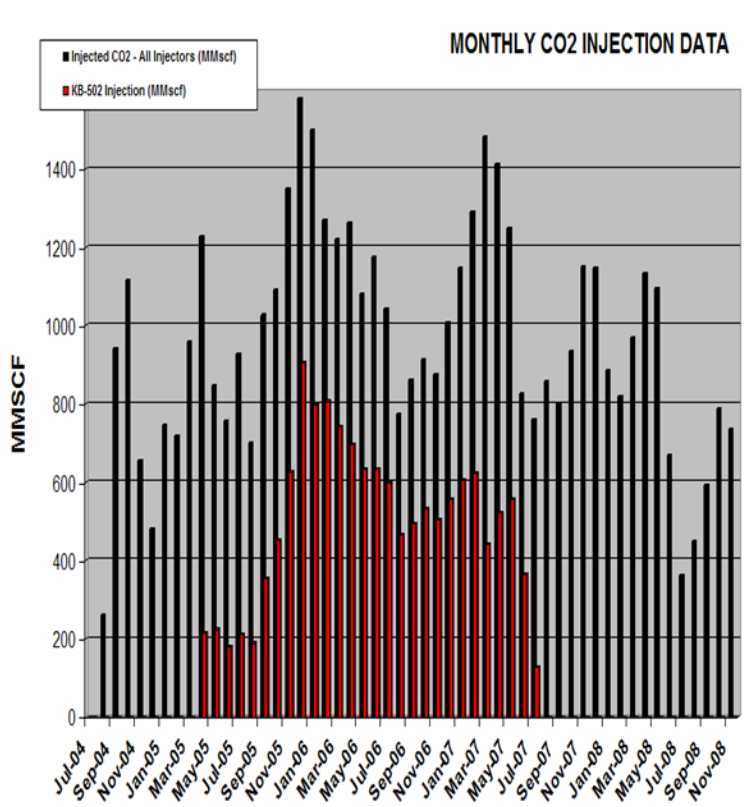
Flexibility of Integrated CCS

- Potential constraints on flexible operation of capture plants
  - Thermal cycling of equipment
  - Liquid distribution in columns
  - Process materials reaching steady state
  - Constraints imposed by energy integration for improved efficiency
  - CO_2 compressor turndown
- Process developers are working on flexibility
- Little information in the public domain
- CASTOR/CESAR pilot plant experience:
  - "The capture plant will be as flexible as the power plant"
  - Small scale: 1t/h CO_2
- Further work needed to demonstrate flexible operation
- Some constraints may be overcome by accepting lower percentage capture of CO_2 during load changes
  - Impact on overall annual emissions needs to be assessed
  - Regulations need to allow it

CO_2 Transport and Storage

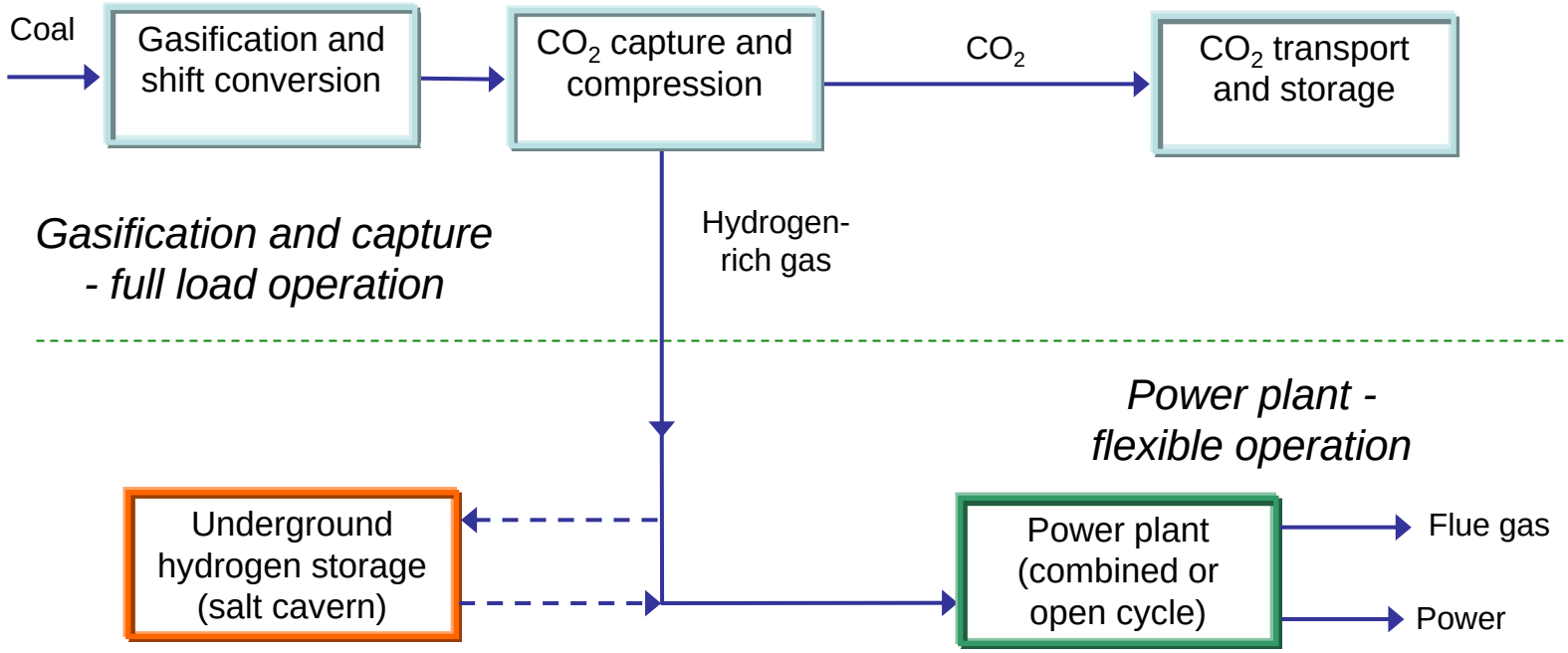
- Potential constraints on flexible operation
  - CO_2 pipeline operation
    - CO_2 normally piped in the dense phase – different to natural gas
  - CO_2 underground storage reservoirs
    - Encouraging experience of flexibility at In Salah
    - Experience at more storage sites is needed
    - Some concerns about impact of intermittent operation on long term storage capacity
- Little information in the public domain

Flexibility of CO_2 Storage
Information from In Salah



J Forsyth, BP. CCS operating experience from InSalah, IEAGHG report 2010/1, January 2010

Non-Integrated CCS

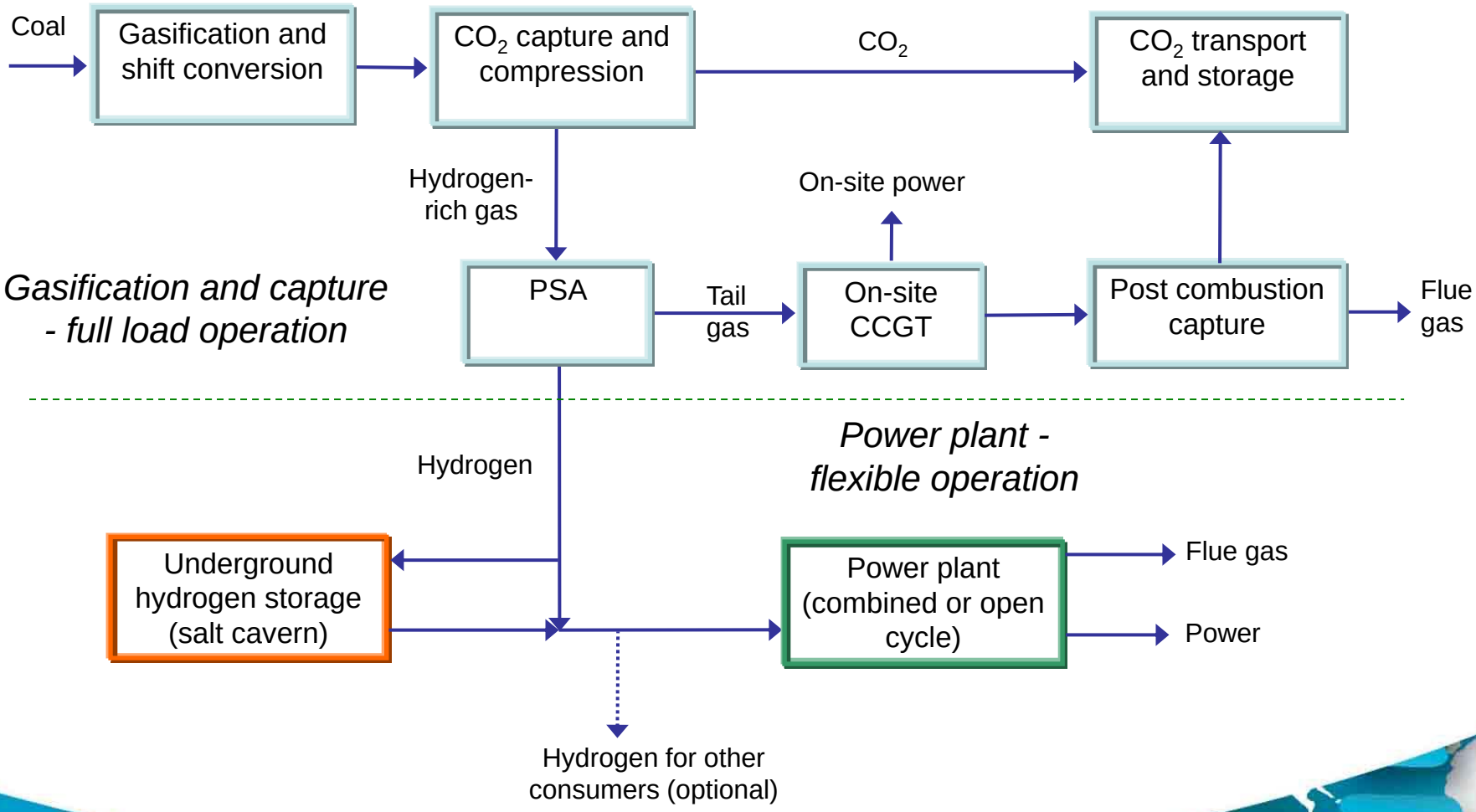


- Only the power plant has to operate flexibly
- CCS can operate continuously, no need for flexibility
- High utilisation of CCS equipment

Non-Integrated CCS

emissions: 98.5-99% capture

Near-zero

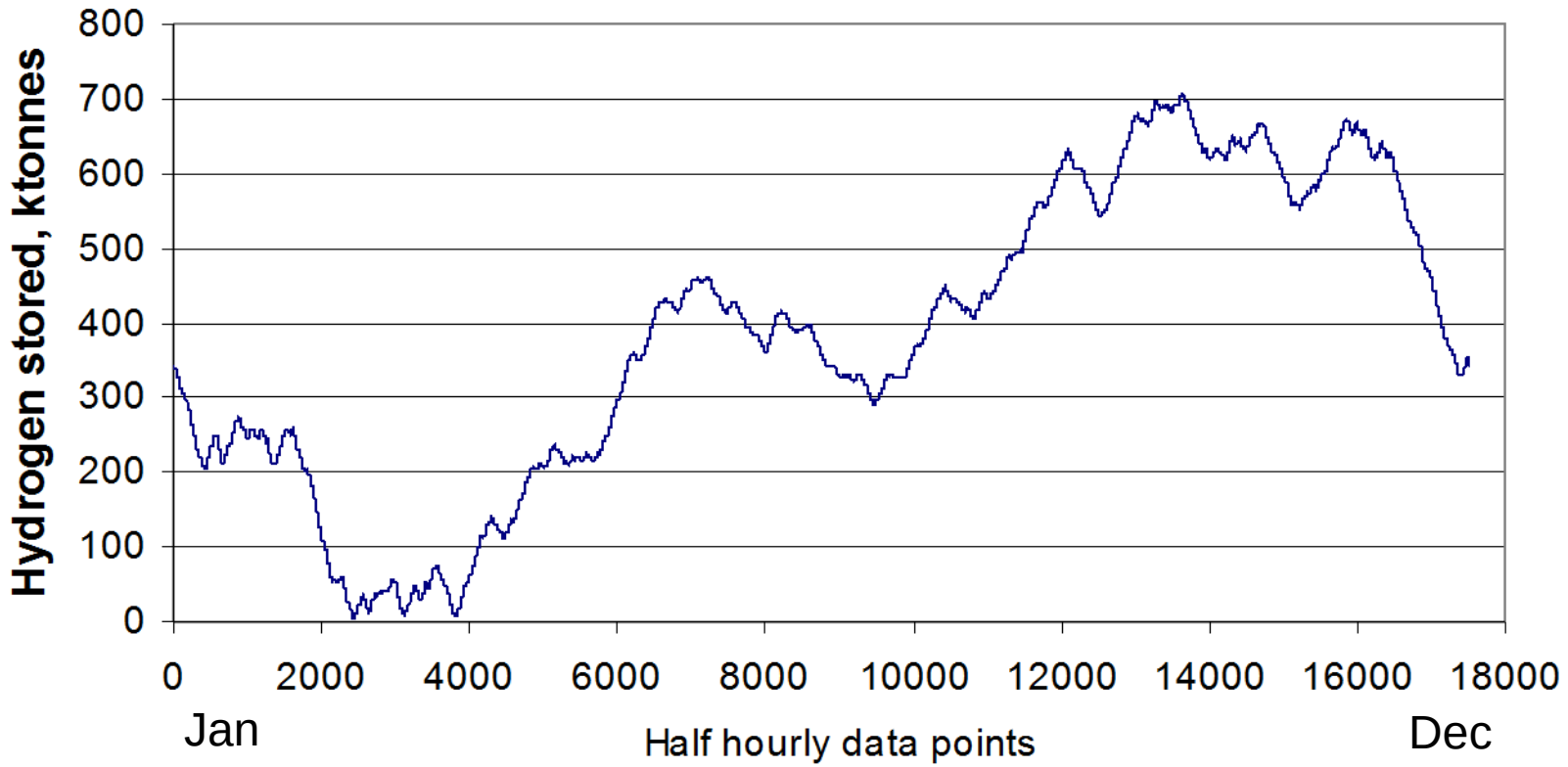


Hydrogen Storage

- Solution mined salt caverns, widely used for natural gas storage
- Commercial experience of hydrogen storage in salt caverns
  - UK
    - Former ICI chemical complex, Teesside
    - Caverns now operated by SABIC
    - 3 caverns, 200-300 tonnes H_2 each
    - Operated for many years, no discernable leakage
  - USA
    - Air Liquide, Texas
    - Cavern 250 feet diameter, 1500 feet long
    - 93 million Nm^3 working capacity (8,000 tonne)
    - No scale up required for CCS

Hydrogen Storage

Modelling of UK electricity system with 35% wind and 25% nuclear

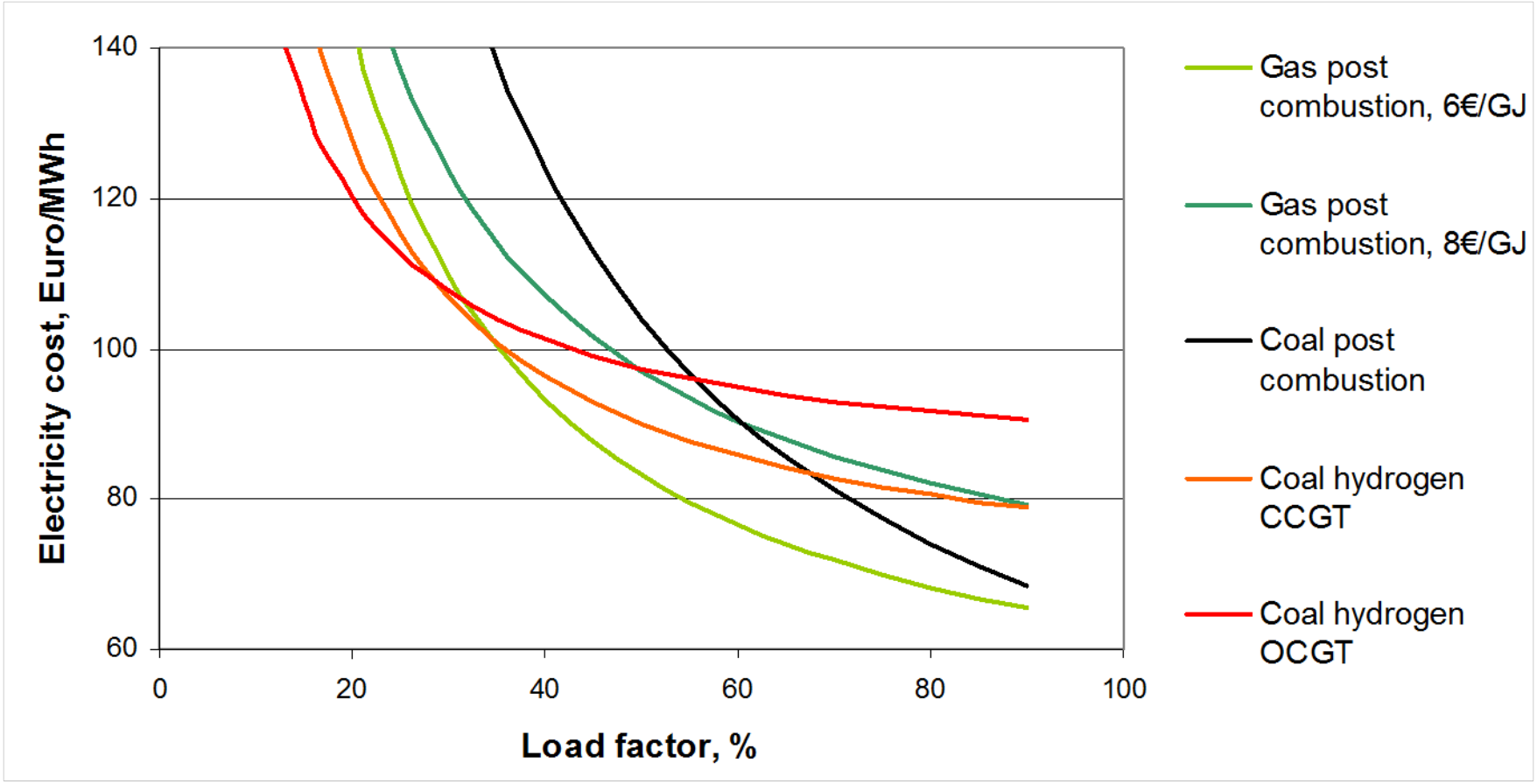


Total storage volume to enable gasification/CCS plants to operate at full load is equivalent to 27 days of UK natural gas consumption

Non-Integrated CCS

- Issues to be considered for flexible operation
  - Hydrogen combustion in gas turbines
  - Availability of salt strata suitable for hydrogen storage
  - Hydrogen storage in geological structures other than salt caverns

Costs of Electricity with CCS
(Individual plants)

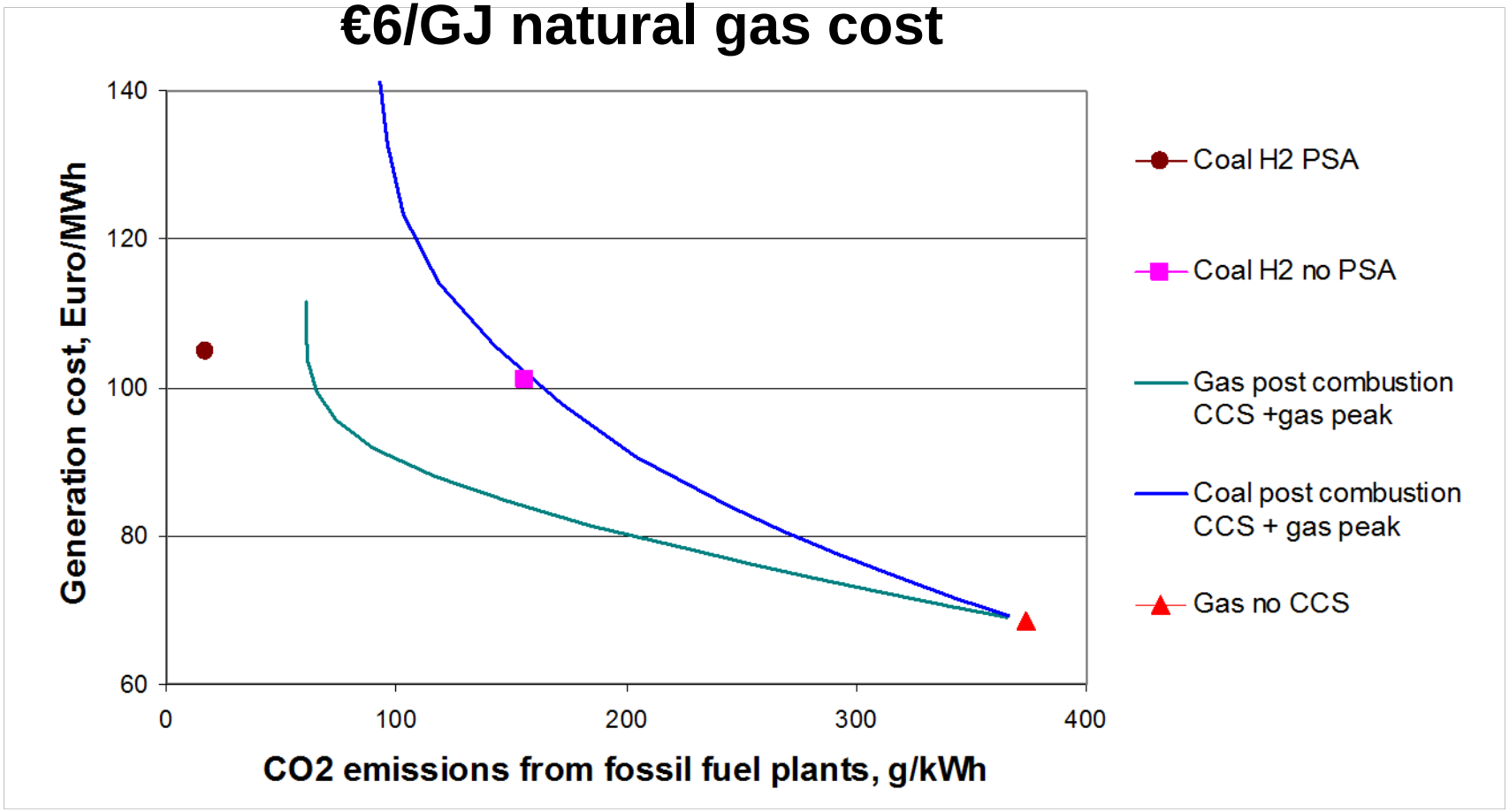


Coal: €2/GJ, Gas: €6-8/GJ, Discount rate: 8%, Plant life: 25 years,
O+M cost: 4%/y of capital, CO_2 transport and storage: €5/tonne

Electricity costs

plants in an overall system

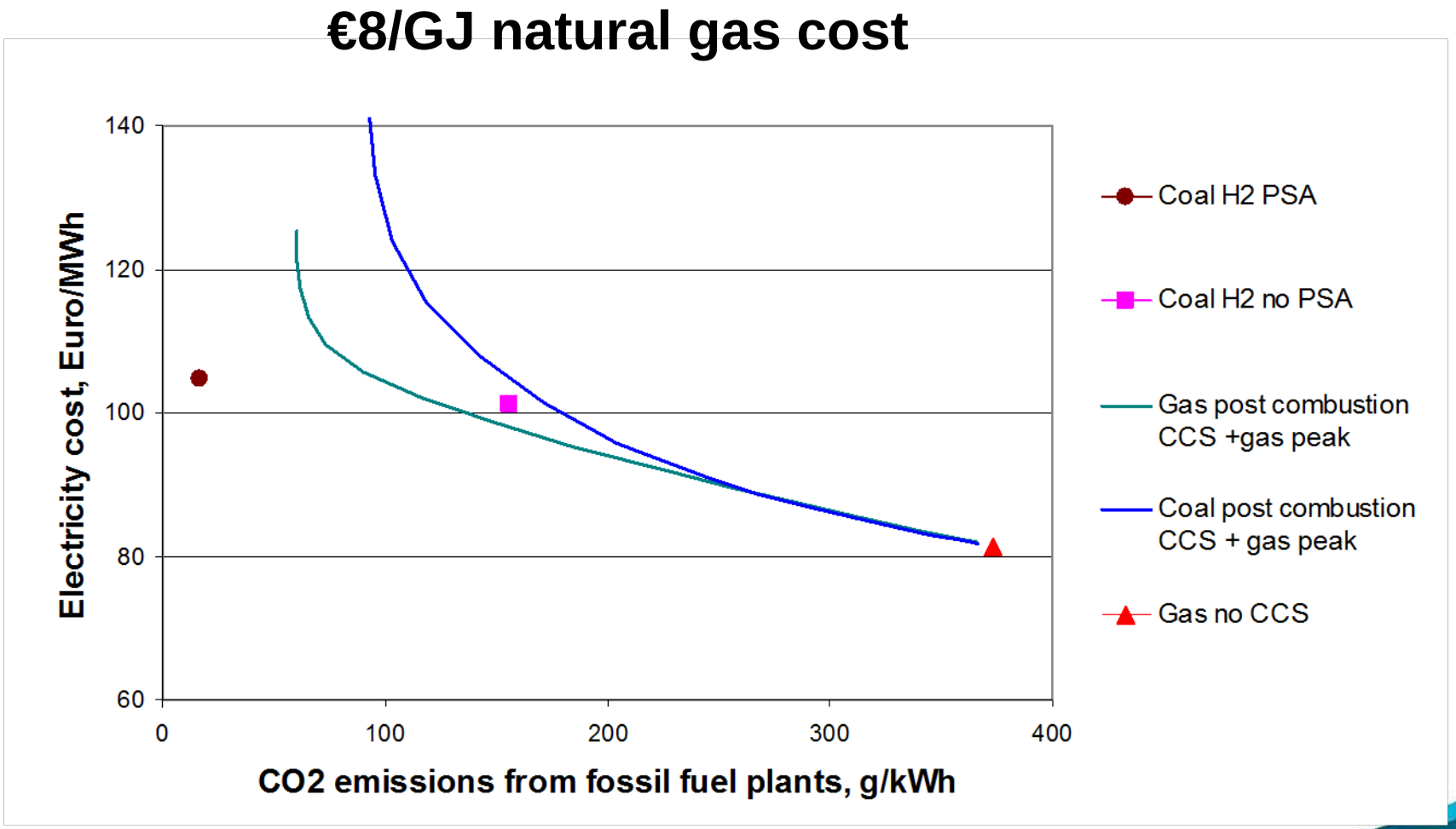
Fossil fuel



- Fraction of fossil fuel plants with CCS is increased to reduce emissions
- CCS plants operate at the highest load factors
- Open cycle gas turbines used for lowest load factors

Electricity costs

Fossil fuel plants in an overall system



Conclusions

- CCS operational flexibility requirement depends on:
  - The variability of power demand
  - The amount of renewables and nuclear in the grid
  - The overall CO_2 emissions target
- Two approaches for flexible fossil fuel power generation:
  - Integrated power generation with CCS
    - CCS has to operate flexibly
  - Non-integrated CCS and power generation
    - CCS flexibility is not necessary
- Further work is need to demonstrate flexible operation of CCS plants
- Optimum combination of flexible CCS power plants depends strongly on fuel prices and emission limits

Thank you

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