

**Imperial College
London**

**UKCCSC meeting,
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Ongoing work within the Mechanical
Engineering Department,
Imperial College, London

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WHAT WE'VE BEEN DOING

- **CAPTURE-READY**

- IEA GHG Report (2007-4) CO₂ Capture-ready plants has been released
- Peer-reviewed paper on Capture-Ready plants to be presented at
 - ASME International Mechanical Engineering Congress & Exposition, November 2007, Seattle, US

WHAT WE'VE BEEN DOING

- **PLANT FLEXIBILITY**

- 2 Conference papers on plant flexibility:
 - 3rd International Conference on Clean Coal Technologies for our Future, Cagliari, Italy, May 2007
 - 7th International Charles Parsons Turbine Conference Power Generation in an Era of Climate Change
- DTI 407: Coal-fired Advanced Supercritical Boiler/Turbine – Retrofit With CO₂ Capture Deliverable Db3: Economic Performance.
 - Includes assessment of plant flexibility

WHAT WE'VE BEEN DOING

- ONGOING WORK ON CCS IN CHINA/IGCC
 - Jon to complete tomorrow

PLANT FLEXIBILITY

- Potential for flexible operation of power plant

Electricity grid balancing mechanism

- In liberalised electricity markets like the UK electricity contracts are placed directly between suppliers and consumers (1/2h blocks of generation)
- **1h before real-time** positions must be notified to the system operator => **gate closure**.
- The system operator becomes the only purchaser of electricity.

Electricity grid balancing mechanism

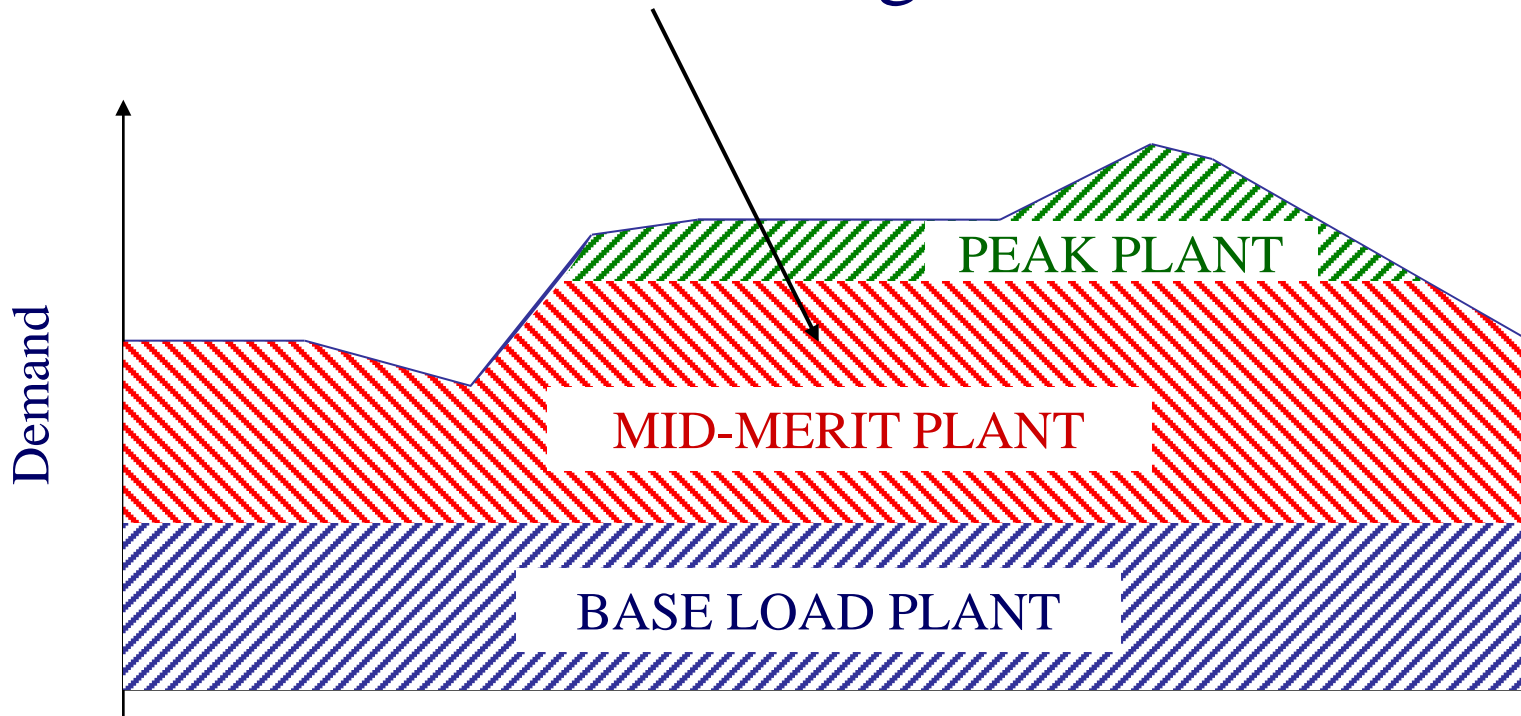
- The role of the system operator is to balance the grid
 1. If contracted positions are not met
 2. In case of an unexpected event (plant outage, sudden change in demand)
- The system contracts reserve generation to power generators

Electricity grid balancing mechanism

- Operating reserve:
 - Primary response: very quick response to variation of demand (a few minutes). Allows for the secondary response to react
 - Secondary response: Quick response. Allow the primary response to resume to normal condition. Can sustain load.
- Standing reserve:
 - provide cover for unavailable plant over a period of hours. Contracted 24h in advance.

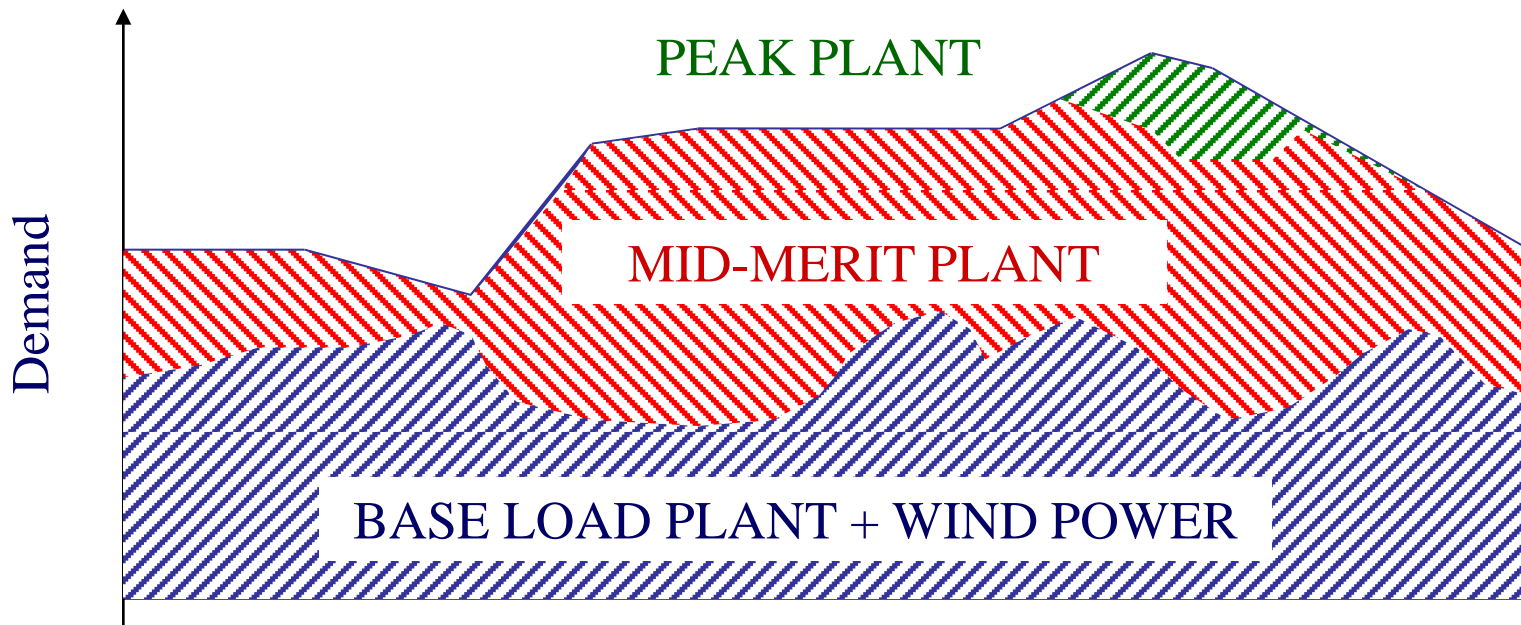
Electricity system balancing mechanism

- Large fossil fuel plants already provide some of these services to the grid



Electricity system balancing mechanism

- Wind power level of penetration of the grid will increase in future (Renewable target)



INTRODUCTION

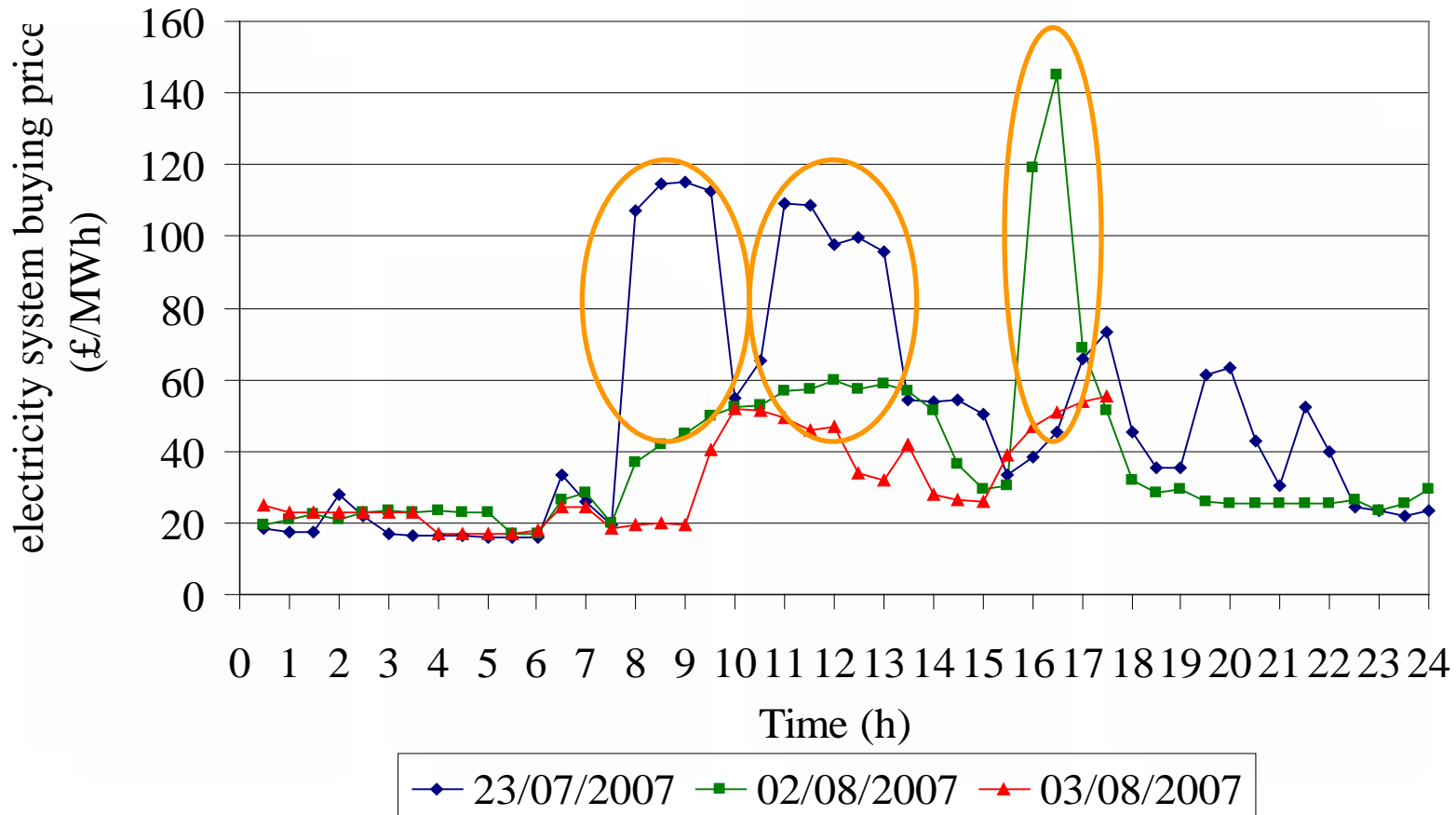
- Flexible operation of pulverised coal power plants with CO₂ Capture

Temporary additional plant output – CO₂ venting in flue gas

- Alter the penalty efficiency to generate more power at times when electricity value is high.

Flexibility

Variation in electricity prices between gate closure and real-time on a daily basis



CO2 venting/ Solvent storage

Operating choice will depend on electricity price

but also CO2 price !!!

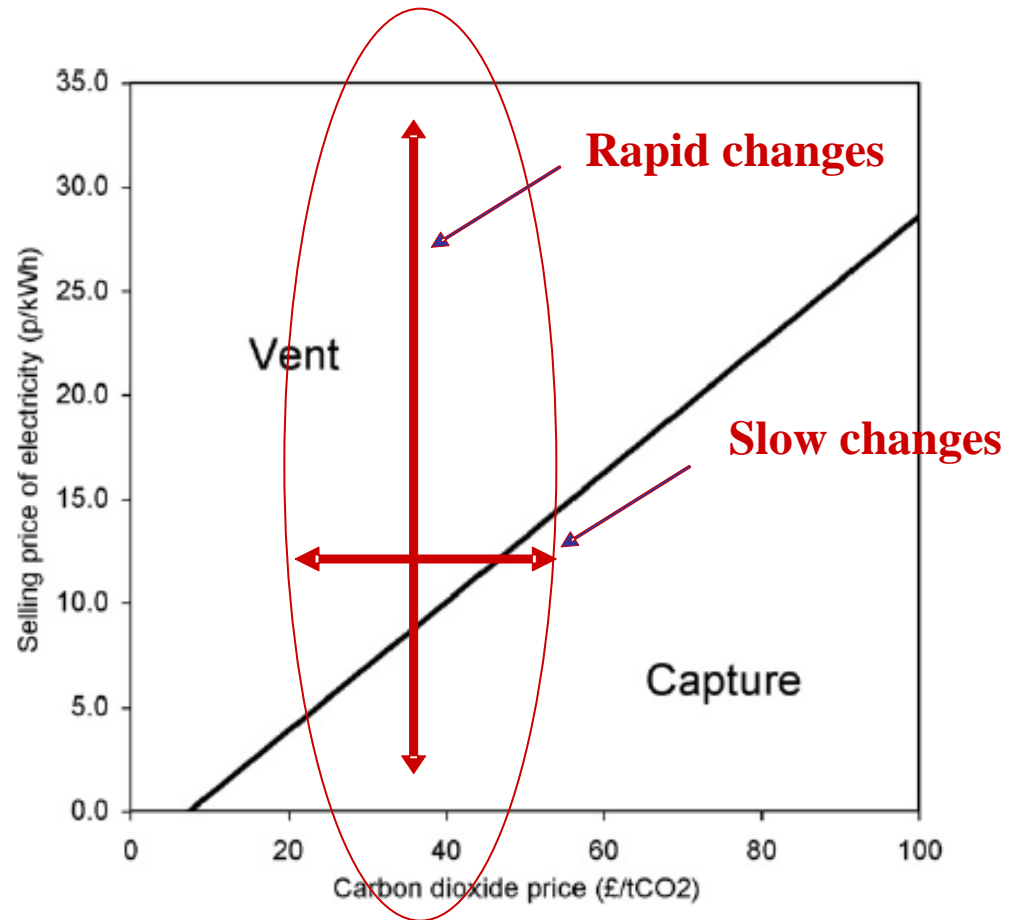


Figure from Chalmers and Gibbins (2007) Initial evaluation of the impact of post combustion capture of carbon dioxide on supercritical pulverised coal power plant part load performance, Fuel, in-press

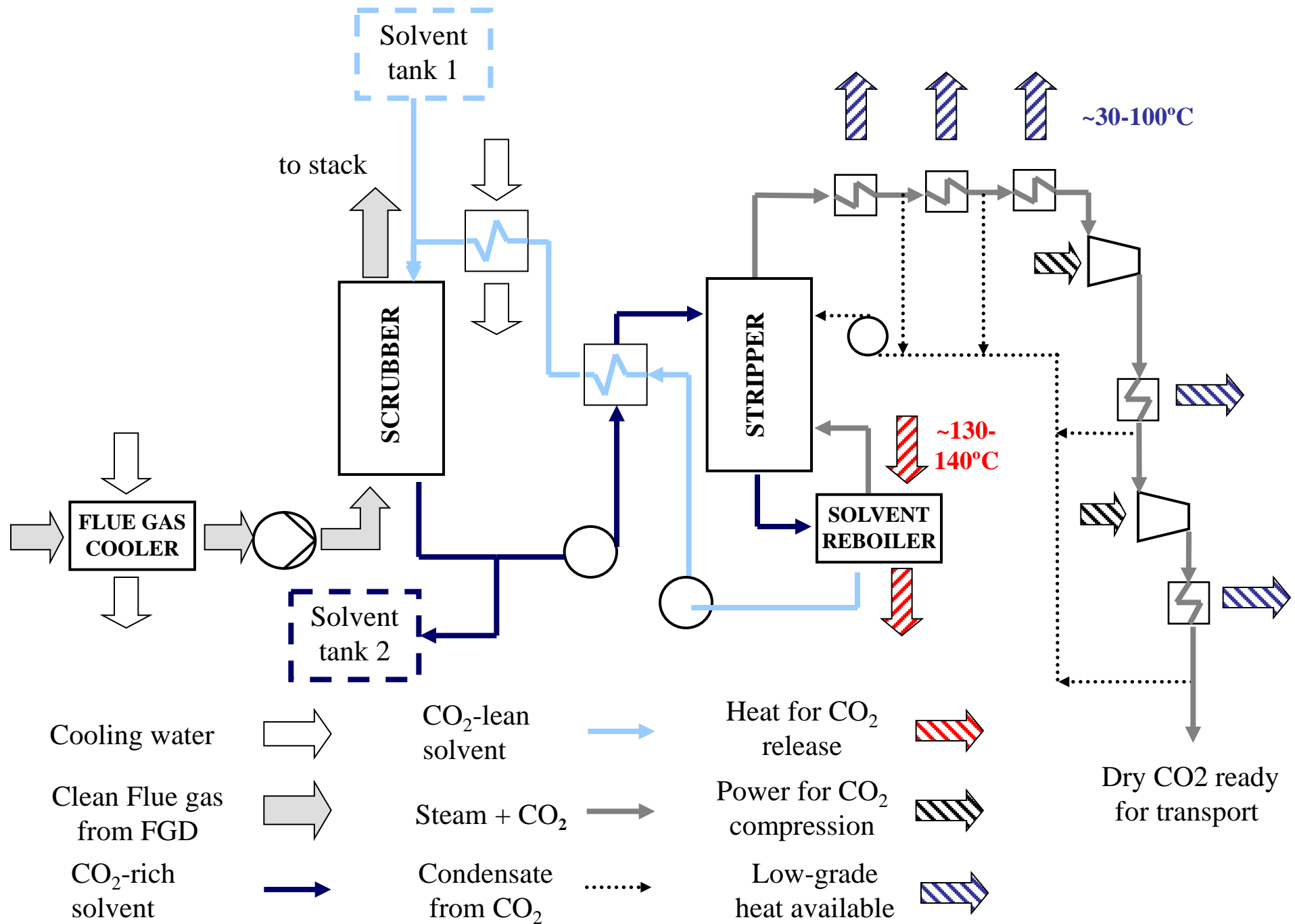
Temporary additional plant output

– CO₂ venting in flue gas

- Alter the penalty efficiency to generate more power at times when electricity value is high.
- How to proceed?
 - By-pass the solvent reboiler
 - Extra steam flow to the LP turbine
 - Shut down the compression train
- Absorber bypass valve to stack opened for extended venting and complete venting => **Sustain load**
- Warm standby without bypass (with blower & pump power required) for shorter periods or partial venting => **Keep the ability to re-capture CO₂ quickly**

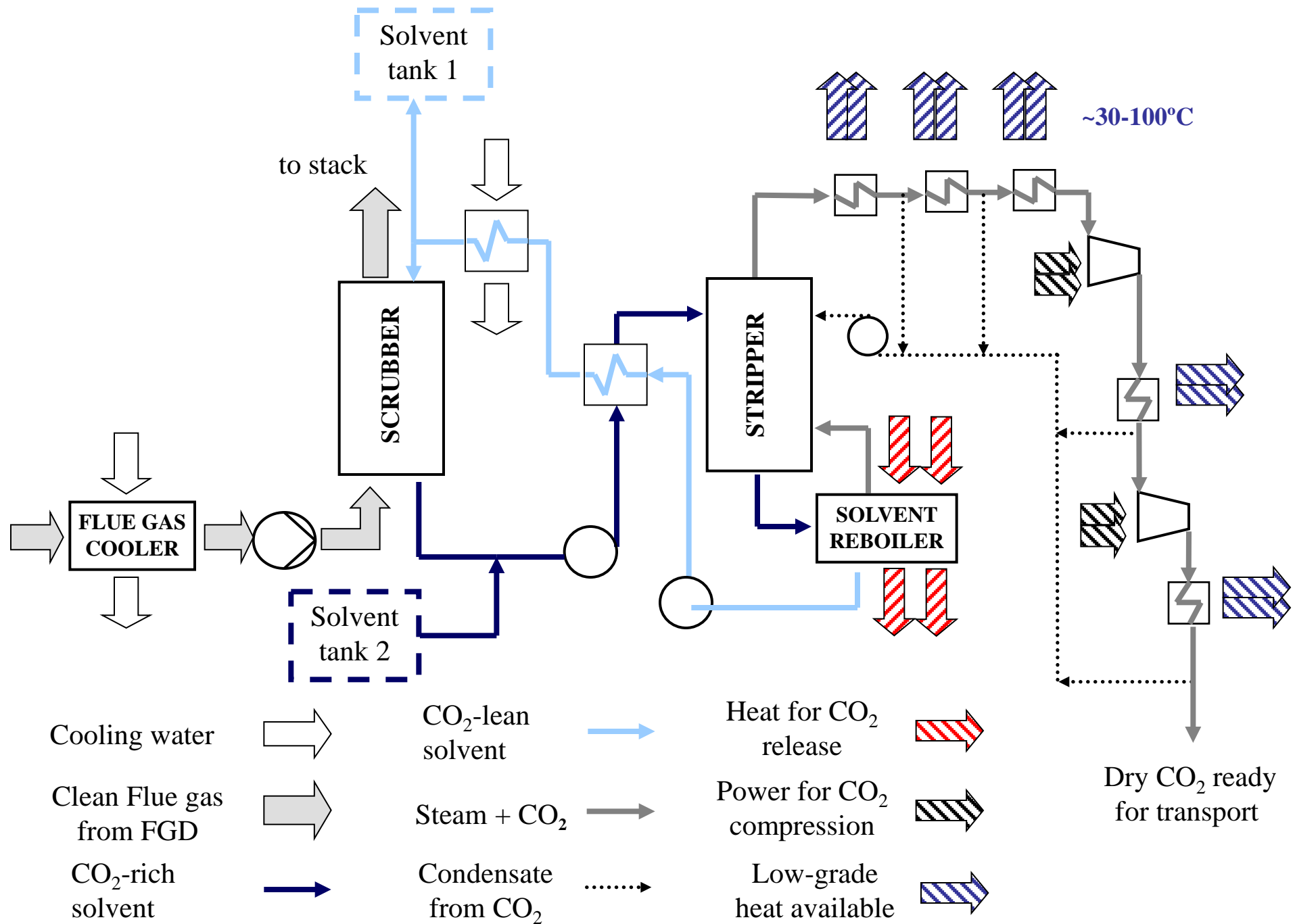
Solvent storage

- CO₂ venting generates additional CO₂ emissions
- Depending on legislation or CO₂ prices this may not be worth doing.
- => Solvent storage and delayed regeneration



Additional solvent regeneration

- After storage solvent would be regenerated when electricity prices are low (at nights) when plant efficiency matters less



Technical issues

- The extra flow to the LP turbine increases the pressure at the IP/LP crossover up to 7.1 bar
- Throttling the reboiler line is required
- Increase of numbers of shutdown/start-up procedures of the compression train => fatigue of equipment
- The turbine blades/bearings have to be reinforced

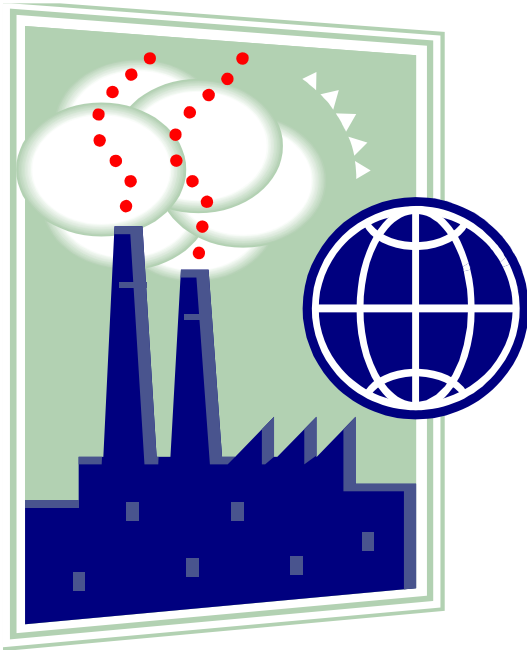
Technical issues

- Extra cooling capacity is required in the condenser
- Extra generator capacity required
- The LP turbine has to be oversized

- => Need extra investment
- => But required extra capacities may already exist in a plant retrofitted with capture

Conclusions

- The capture plant can provide additional flexibility to a PC plant with post-combustion CO₂ capture.
- Indefinite extra capacity with CO₂ venting
- ‘Pumped-storage’ capability with solvent storage and no CO₂ venting
- Increase the load factor of the plant
- Generate additional sources of revenue
- **Mitigate costs of capture**



ANY QUESTIONS?

Acknowledgements: DTI 407 project participants, BCURA,
UK Carbon Capture and Storage Consortium

Martin Lord, Alstom Power UK

Technical issues

- At part-load need to maintain LP inlet minimum mass flow to protect turbine
- Equipment (stripper, reboiler and compressors) has to be oversized
- Size: 2 tanks of 40m (or 4 at 10m) x 33m diameter for 8h storage capacity.
- Transport issues related to a non-constant flow of CO₂ => Buffer capacity required.