Hydrogen Storage and Flexible Carbon Capture and Storage

Den Gammer for ERP

14th October 2015
Energy Systems Modelling Environment

- Least cost optimisation, policy neutral
- Deployment & utilisation of >250 technologies
- Pathway and supply chain constraints to 2050
- Spatial and temporal resolution sufficient for system engineering
- Probabilistic treatment of key uncertainties
ESME – a place for H2 in power capacity post 2030

Electricity Generation Capacity

- Wind (greens)
- H2 (purple)
- Nuclear (orange & yellows)
- Gas (reds & browns)

©2015 Energy Technologies Institute LLP - Subject to notes on page 1
Using H2 storage to maximise use of CCS investment

Power station configurations using H2 storage

1. Natural Gas
   - Reformer CCS – 100% load
     - H2 or H2/N2
     - GT run to meet peak demand

2. Coal Biomass
   - Gasifier CCS – 100% load
     - C02
     - C02 to CCS Store 100% load

- ASU
- Hydrogen salt cavern

UK salt beds are not widespread but are situated in good locations.
Configuration Benefit

- **NO H₂ STORE**: Gas is reformed and CO₂ captured sized to meet peak GT load. H₂ or H₂/N₂ is then used to meet peak demand. CO₂ pipelines & wells are sized for peak flow.

- **LARGE H₂ STORE**: Gas is reformed and CO₂ captured sized for average GT load. It runs 100% of the time. CO₂ pipe and wells are sized for average GT load. Hydrogen salt cavern fills "daily". GT is sized to meet peak demand.

The average load could be a small fraction of the peak load. GT capex << rest of plant.
UK Salt fields

- Used for natural gas and hydrocarbons
- Over 30 large caverns in use
- Offshore operation is twice the cost of onshore
- Screening led us to focus in 3 areas

<table>
<thead>
<tr>
<th>Region</th>
<th>Typical Depth, m</th>
<th>Bed Thickness, m</th>
<th>Cavern size, 000m3</th>
<th>Pressure bara</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teesside</td>
<td>300</td>
<td>35</td>
<td>70</td>
<td>45</td>
</tr>
<tr>
<td>Cheshire</td>
<td>800</td>
<td>200</td>
<td>300</td>
<td>105</td>
</tr>
<tr>
<td>E Yorkshire</td>
<td>1800</td>
<td>175</td>
<td>300</td>
<td>270</td>
</tr>
</tbody>
</table>
H2 Storage - Metrics

- Salt caverns are already used for H2 in UK and US
- One cavern family - 30GWhe daily
  (c.f. Pumped hydro at Dinorwig 10GWhe, 75% efficient)
- Coal/bio to power – no penalty for going via H2
- Gas to power – penalty for going via H2

- Geographical limitation of stores
- “Fast churn” stores in operation on natural gas duty
- Rapid empty modes used for CAES
  (compressed air energy storage – Germany)
- Stores can be run on a “constant pressure” basis by flooding with brine – not covered in the ETI analysis
Cost structure varies with store depth

- Although the component costs change with depth, overall costs are similar.
- Deep stores have a round trip energy hit (takes 2% points off LHV efficiency of 34% for Yorkshire).
- Shallow stores are unlikely to provide strategic quantities of storage, although constant pressure operation may improve the case.

Distribution of costs for stores of different depth, all stores designed in a constant volume - variable pressure mode.
H2 store is cost effective at low load factors

- CCGT with CCS is compared to an IGCC with a H2 Store
- “Oxymembrane” means H2 derived from methane by technology in development (separation assisted by membrane per the “Cachet” project)
- Fuel Price assumptions shown in brackets
Summary

• H₂ storage in caverns could supply grid level quantities of load following and peaking power
• For schemes operating below 40% load factor (turbine) the store adds value by reducing overall system investment. ETI modelling suggests this could happen after 2030
• For schemes above 50% load factor conventional CCS (CCGT plus post combustion capture) are better
• Storage configurations are extendable for both H₂ supply and demand options

Thank you for listening
For more information please visit - www.eti.co.uk
Safe combustion of Hydrogen rich mixtures

ETI High Hydrogen Project

- Understanding limits on safe use of hydrogen-rich fuels in power production by GTs and engines
- Laboratory test work completed
- Large scale testing in HSL Buxton underway
Next Step 1/6th scale 350Mwe Heat Recovery Steam Generator (HRSG)

- Effects of steam tubes on overpressure
- Final test of scalability of results
Pre–Combustion Power complex cost structures

Coal IGCC + NG ATR + NG SMR at DECC High, Medium and Low Fuel Prices at 36% Turbine Load Factor

- Technology selection for H2 production was not as important as primary fuel choice or price
- Coal price less volatile, less impactful. Opens door to co-firing waste and biomass
- Biomass is most valued feedstock at system level (ESME) for emission reduction
- At 36% Turbine load factor, there is a marked reduction in relative size of H2 plant costs
- CCS pipeline and storage costs are not included above
- Often need to store N2 for large H2 Turbines