

Hydrogen Storage and a Clean, Responsive Power System

Fuel Cell and Hydrogen Conference, Birmingham, 20th May 2015 Den Gammer

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ETI technology programme areas



ETI members bp **CATERPILLAR® edf** ENERGY **EPSRC** Rolls-Royce Pioneering research and skills 懋 榆 Department of Energy & Climate Change **Innovate UK** Department for Business Technology Strategy Board Innovation & Skills ETI programme associate

HITACHI Inspire the Next



Total System Cost

ESME – ETI's system design tool

100

90

80

70

60

40

30

20

10

2010

٩Š 50

integrating power, heat, transport and infrastructure providing national / regional system designs

Wave Power

Tidal Stream

Hydro Power

Onshore Wind

Offshore Wind

Anaerobic Digestion CHP Plant

Biogas Production with CCS

Biomass Fired Generation

Incineration of Waste

H2 Turbine

Nuclear

CCGT

PC Coal

OCGT

Power Capacity (GW)

CCGT w CCS H2 Turbine

IGCC Coal w CCS

Offshore Wind

Onshore Wind PC Coal w CCS

Nuclear OCGT

-5.4

Hydro Power

2050

Macro CHP

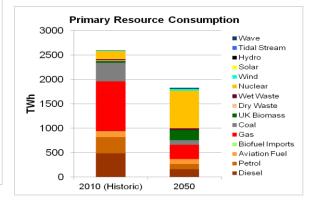
Biogas Production w CCS

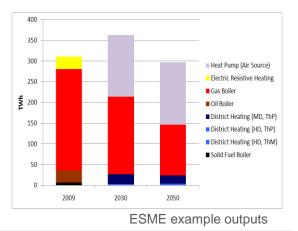
CCGT with CCS

■ IGCC Coal with CCS

Oil Fired Generation

■ PC Coal with CCS





SMF **Energy System** Modelling Environment





260

270

600

500

280

290

£bn/year

Net CO2 Emissions

300

310

320

International A&S

Transport Sector

Buildings Sector

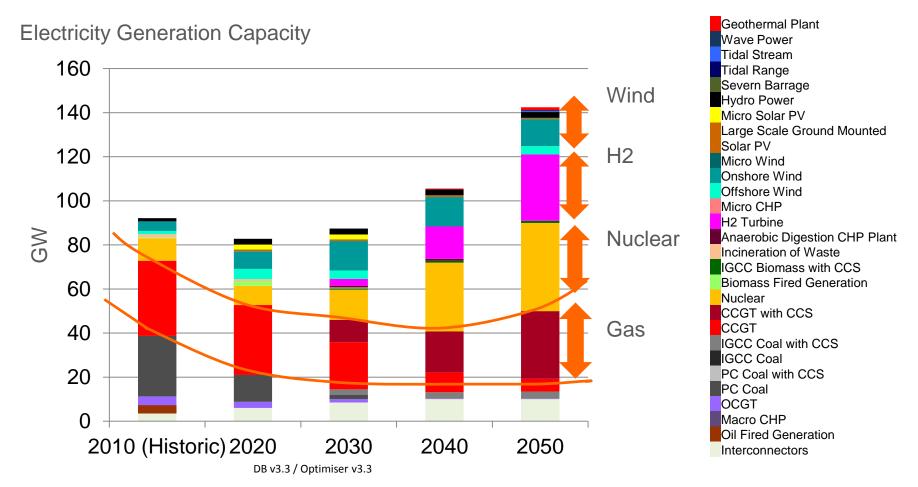
Power Sector

330





ESME – a place for H2 in power capacity post 2030

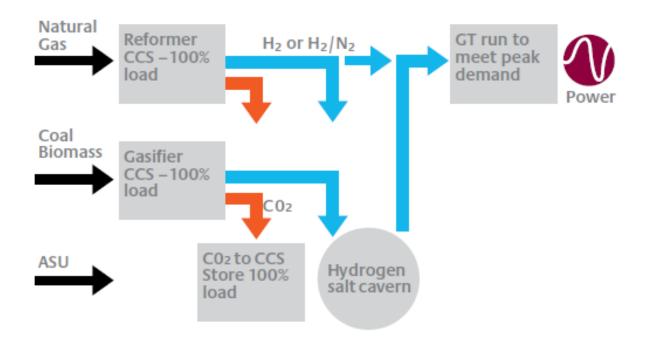






Using H2 storage to maximise use of CCS investment

Power station configurations using H₂ storage



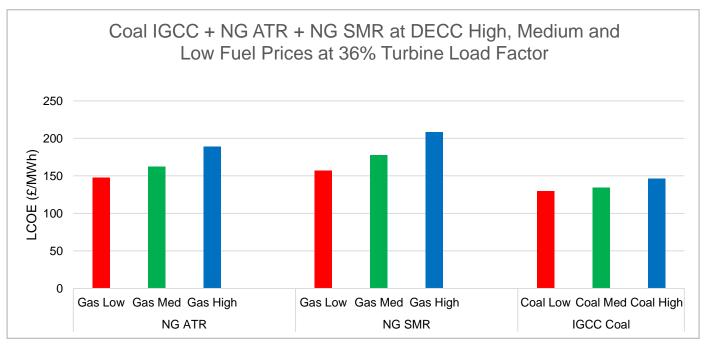








Power complex cost structure via H2



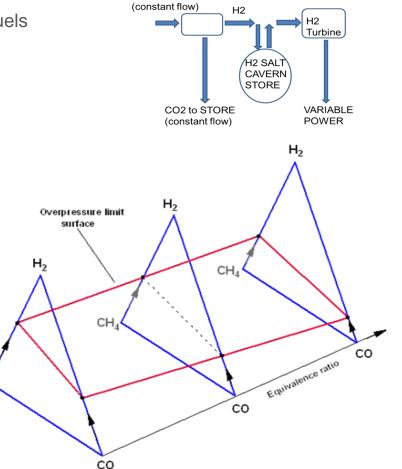
- Technology selection for H2 production was not as important as primary fuel choice or price.
- Coal price less volatile, less impactful.
- Biomass is most valued feedstock at system level (ESME) for emission reduction
- At 36% Turbine load factor, there is a marked reduction in relative size of H2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



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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



Fossil Fuel

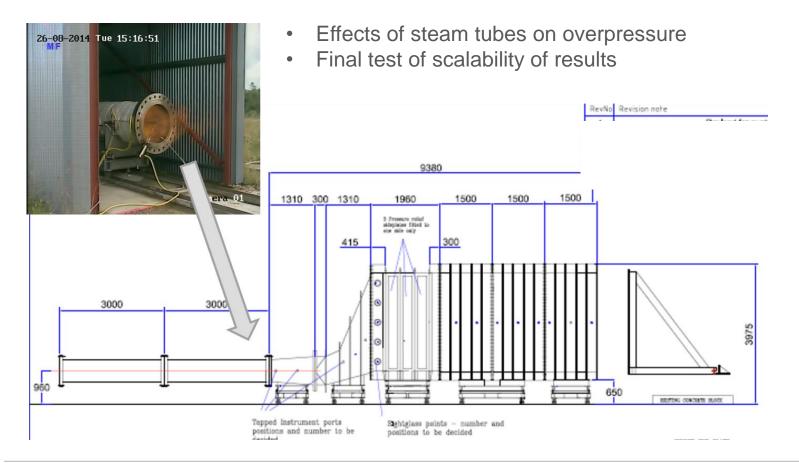








Next Step 1/6th scale 350Mwe Heat Recovery Steam Generator (HRSG)

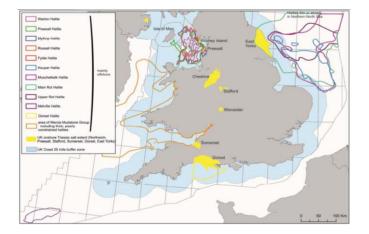






UK Salt fields

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



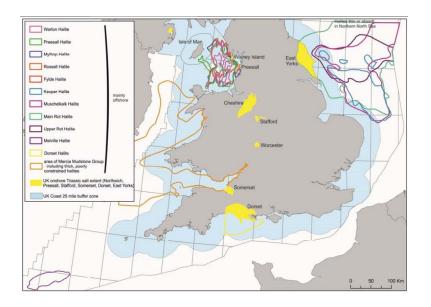
Region	Typical Depth, m	Bed Thickness, m	Cavern size, 000m3	Pressure bara
Teesside	300	35	70	45
Cheshire	800	200	300	105
E Yorkshire	1800	175	300	270

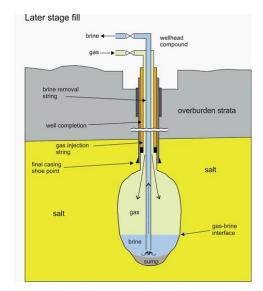




H2 Storage - Metrics

- 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





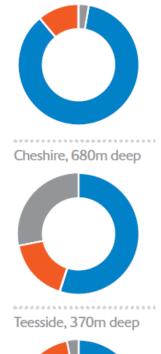
- Geographical limitation of stores
- "Fast churn" stores in operation on natural gas
 duty
- Rapid empty modes used for CAES (compressed air energy storage – Germany)
- Stores can be run on a "constant pressure basis" by flooding with brine – not covered in the ETI analysis.





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.



Yorkshire, 1800m deep



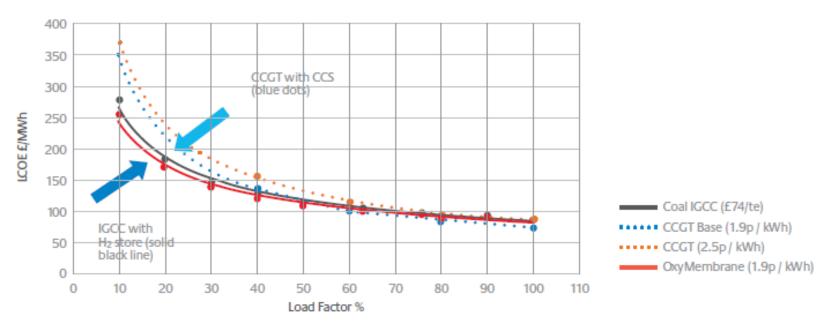
Distribution of costs for stores of different depth, all stores designed in a constant volume - variable pressure mode.





H2 store is cost effective at low load factors

Levelised cost changes with load factor



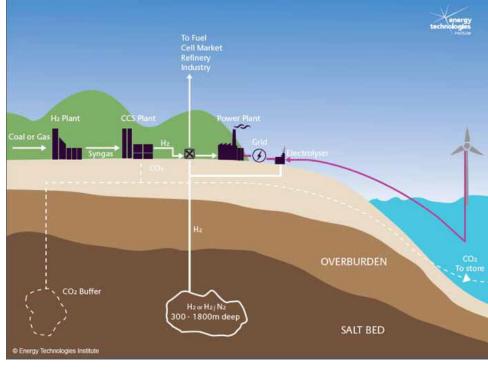
- CCGT with CCS is compared to an IGCC with a H2 Store
- "Oxymembrane" means H2 derived from methane by technology in development (separation assisted by membrane per the "Cachet" project)
- Fuel Price assumptions shown in brackets.





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.



Thank you for listening For more information please visit - www.eti.co.uk





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