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## Hydrogen Storage and Flexible Carbon Capture and Storage

Den Gammer for UKCCSRC

8<sup>th</sup> September 2015

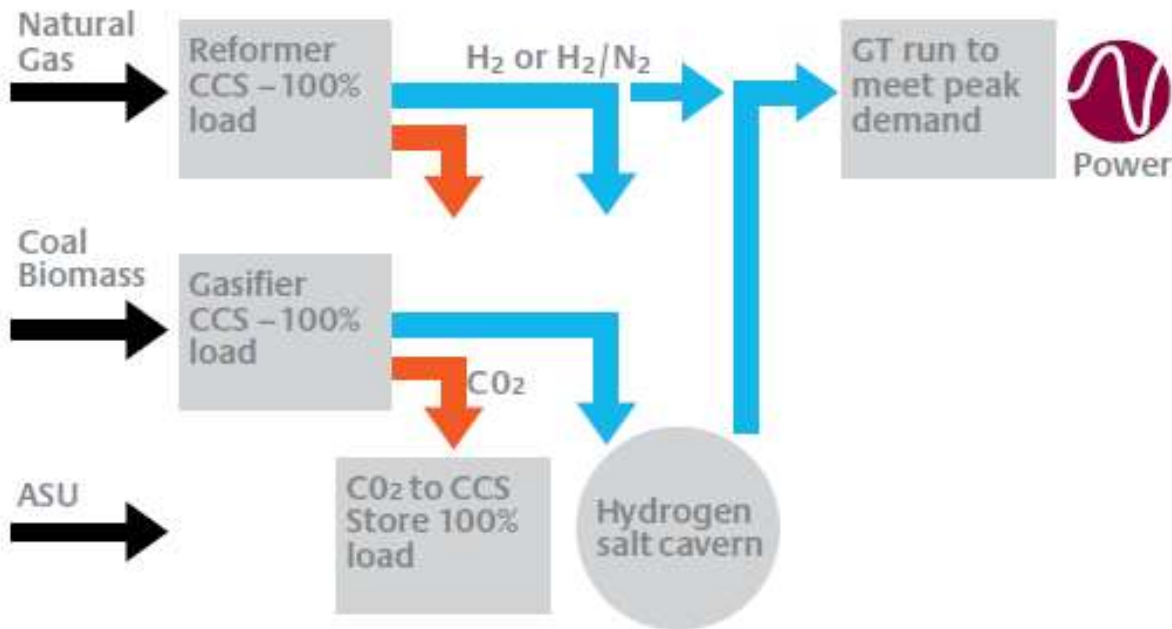
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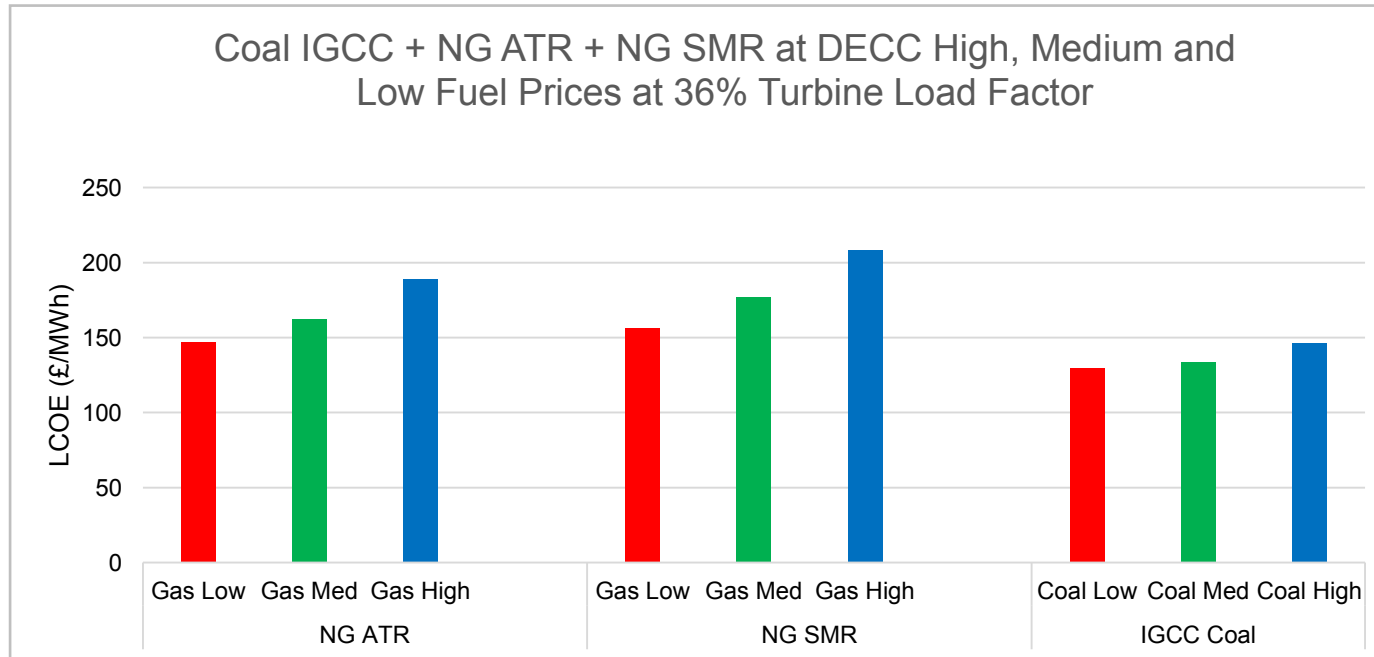
# Using H<sub>2</sub> storage to maximise use of CCS investment

## Power station configurations using H<sub>2</sub> storage





## Pre-Combustion Power complex cost structures



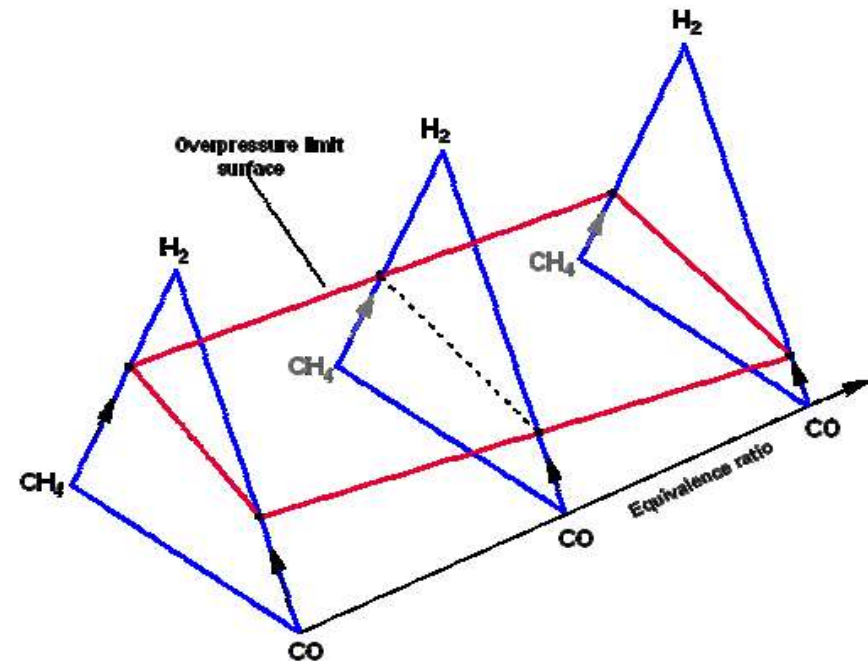
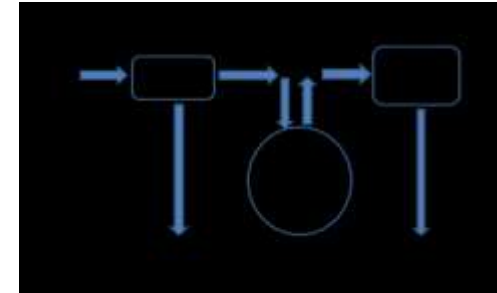
- Technology selection for H<sub>2</sub> production was not as important as primary fuel choice or price.
- Coal price less volatile, less impactful. Opens door to co-firing waste and biomass.
- Biomass is most valued feedstock at system level (ESME) for emission reduction
- At 36% Turbine load factor, there is a marked reduction in relative size of H<sub>2</sub> plant costs
- CCS pipeline and storage costs are not included above
- Often need to store N<sub>2</sub> for large H<sub>2</sub> Turbines



# Safe combustion of Hydrogen rich mixtures

## ETI High Hydrogen Project

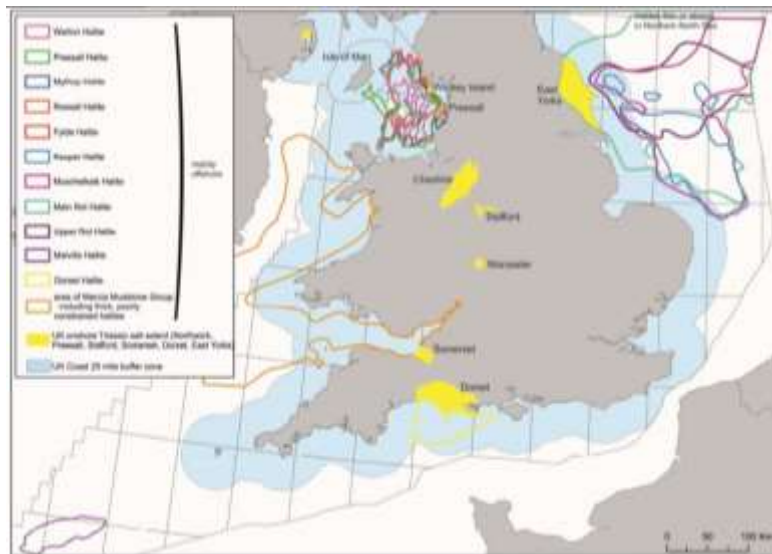
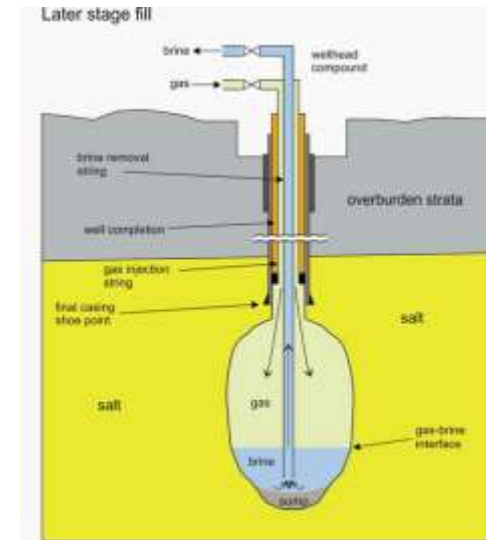
- Understanding limits on safe use of hydrogen-rich fuels in power production by GTs and engines.
- Laboratory test work completed
- Large scale testing in HSL Buxton underway





# 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

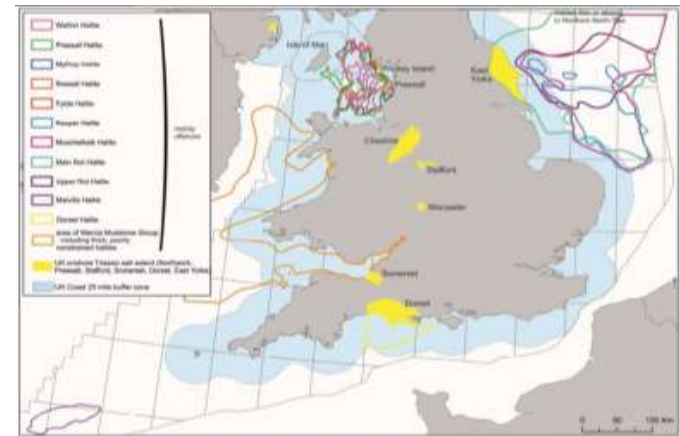


- Geographical limitation of stores
- “Fast churn” stores in operation on natural gas duty
- Rapid empty modes used for CAES  
(compressed air energy storage – Germany )
- Stores can be run on a “constant pressure basis” by flooding with brine – not covered in the ETI analysis.



# 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, 000m <sup>3</sup>	Pressure bara
Teesside	300	35	70	45
Cheshire	800	200	300	105
E Yorkshire	1800	175	300	270



## 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.

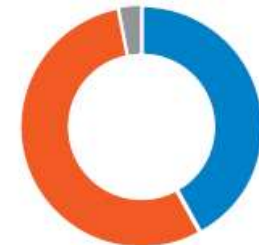
Yorkshire, 1800m deep



Cheshire, 680m deep



Teesside, 370m deep

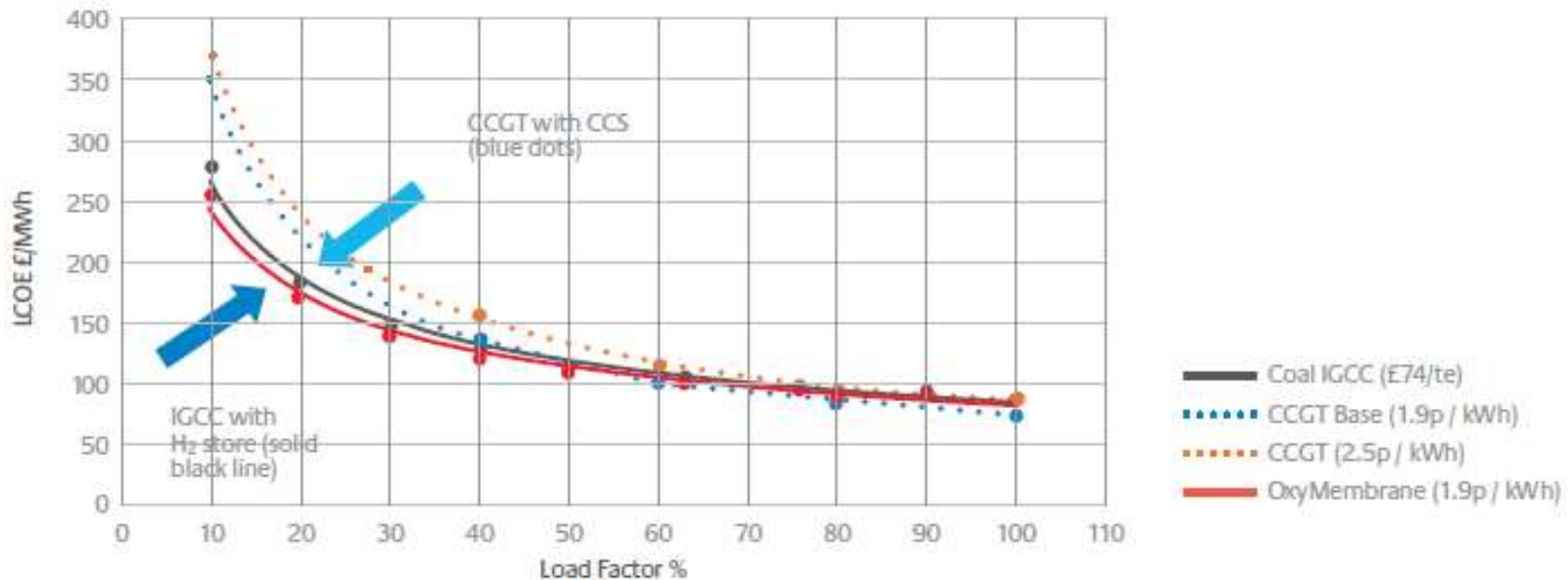


Distribution of costs for stores of different depth, all stores designed in a constant volume - variable pressure mode.



## H2 store is cost effective at low load factors

### Levelised cost changes with load factor



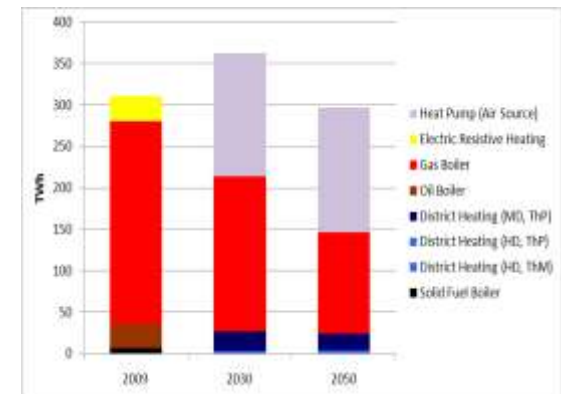
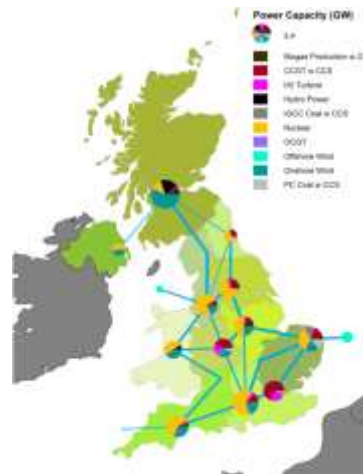
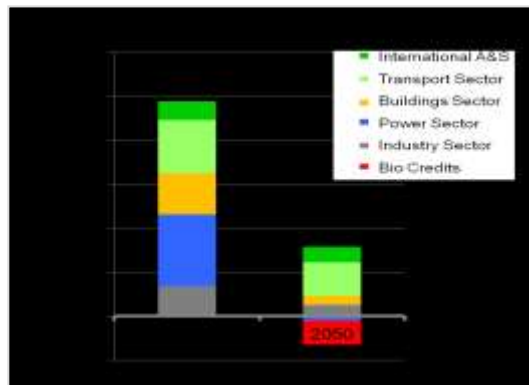
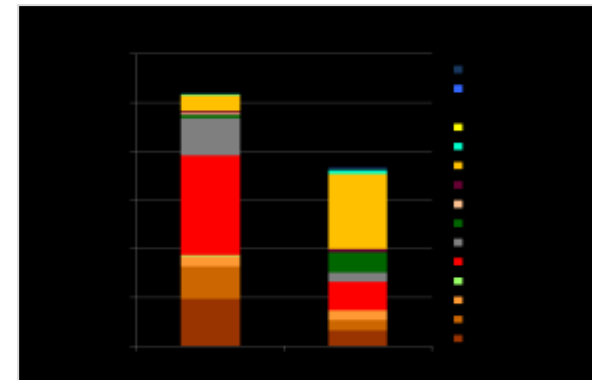
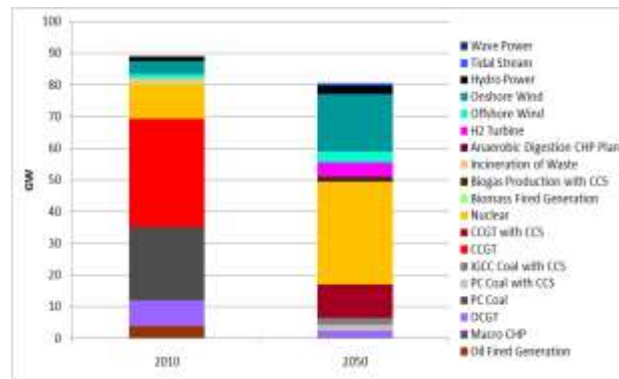
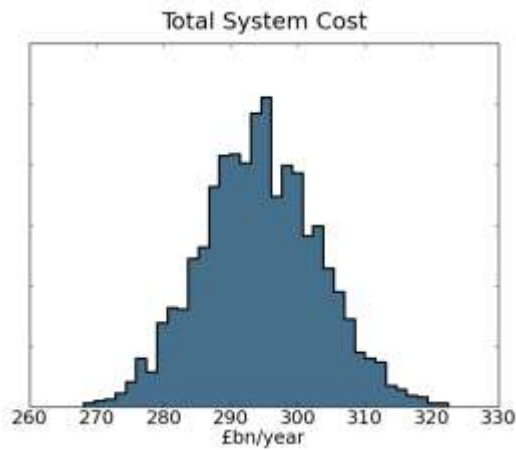
- CCGT with CCS is compared to an IGCC with a H2 Store
- “Oxymembrane” means H2 derived from methane by technology in development (separation assisted by membrane per the “Cachet” project)
- Fuel Price assumptions shown in brackets.





# ESME – ETI’s system design tool

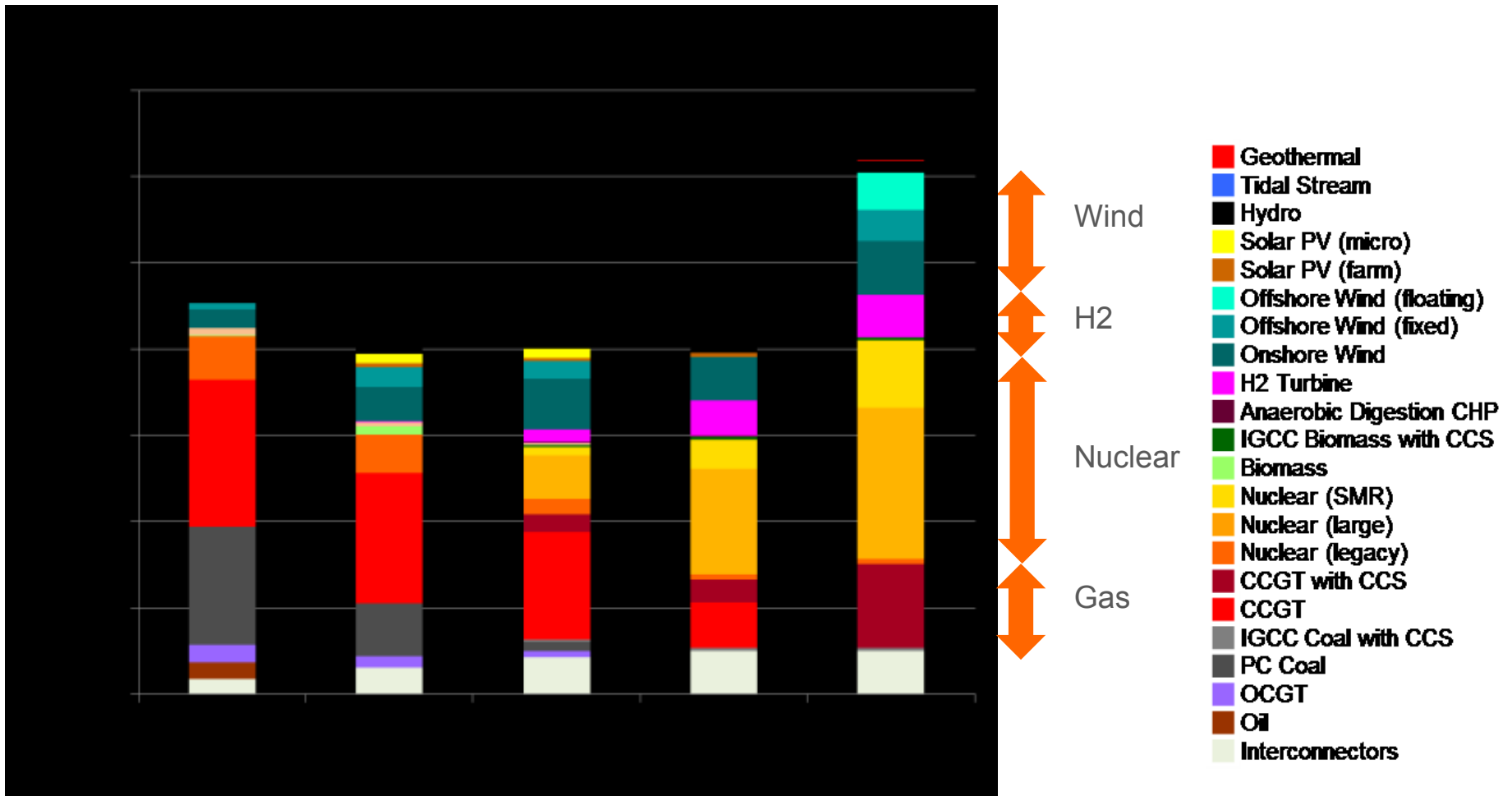
integrating power, heat, transport and infrastructure  
providing national / regional system designs



ESME example outputs



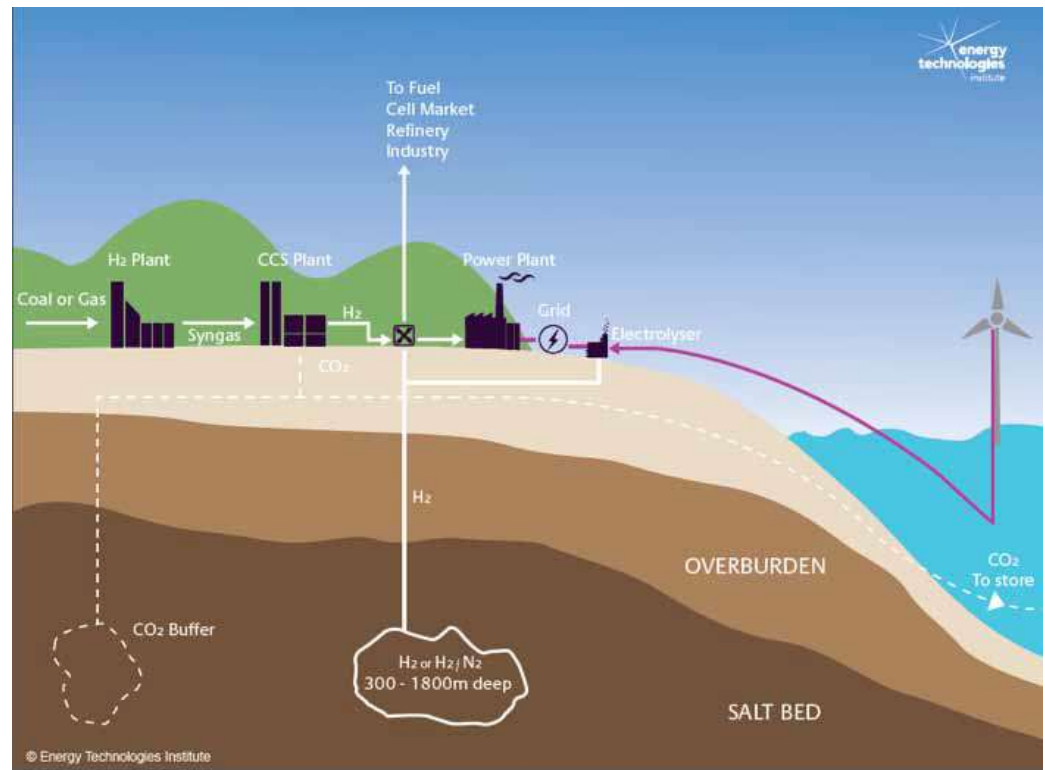
# ESME – a place for H2 in power capacity post 2030





## Summary

- H<sub>2</sub> 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.



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



- Effects of steam tubes on overpressure
- Final test of scalability of results

