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# Fast Cycle Gas Storage

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Sustainable Exploitation of the Subsurface

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Geological Society, Burlington House



# Outline

- Sub-surface gas storage – what is it?
  - The current UK gas market – “as is”
  - The future UK gas market – “to be”
  - Salt cavern fast cycle gas storage
  - Geology & engineering
- } Setting scene for fast cycle facilities as best use of subsurface space and mineral resource

# Subsurface gas storage – what is it?

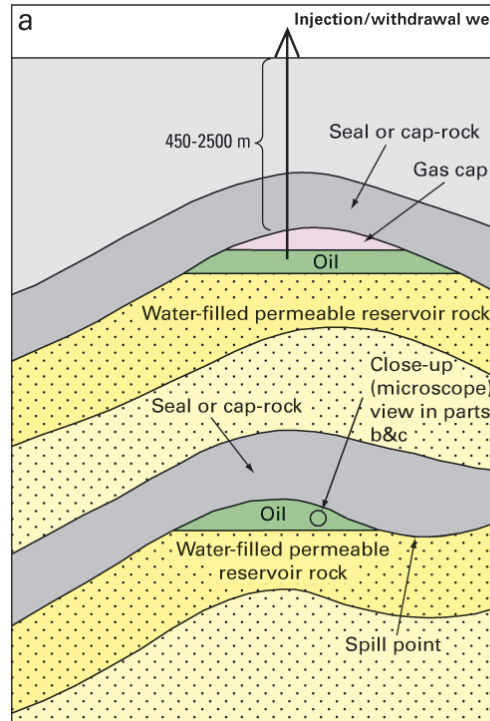
- Complex use of minerals and the subsurface
- Sustainable use of resource
  - Need to use in best way possible
  - Meet current societal needs
  - But not leaving legacy for future generations
    - *Mineral Planning*

# Subsurface gas storage – what is it?

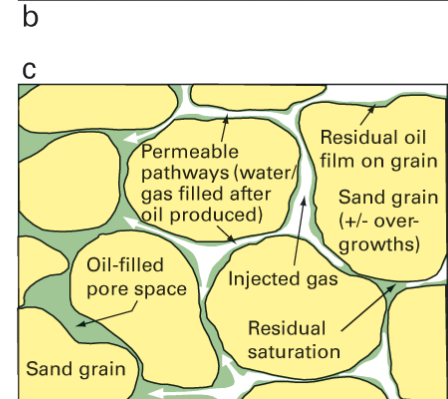
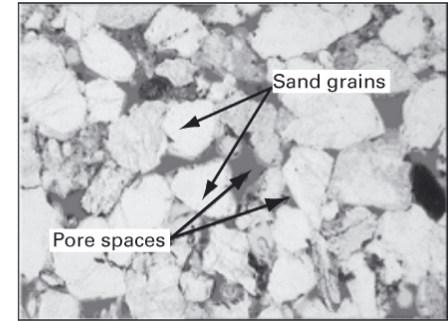
- Gas storage has key characteristics

- Main UK types

- Pore space storage
  - Depleted hydrocarbon fields
  - Aquifers
- Salt cavern storage



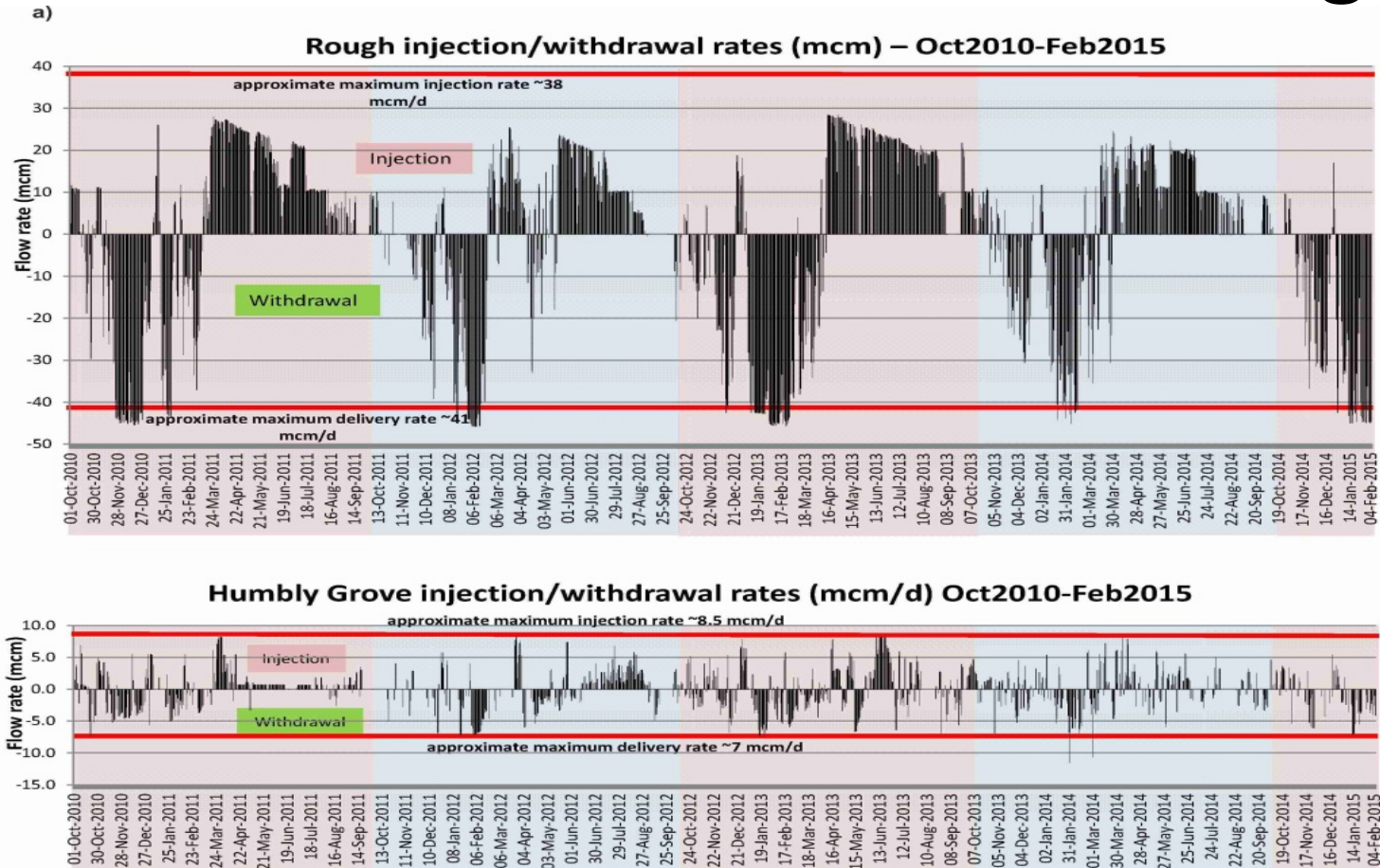
Porous media – depleted fields  
or aquifers



- Porous media – determined by

- Porosity
- Permeability
- Generally longer cycle storage –
  - Seasonal
  - Less responsive

# Current 'traditional seasonal storage'



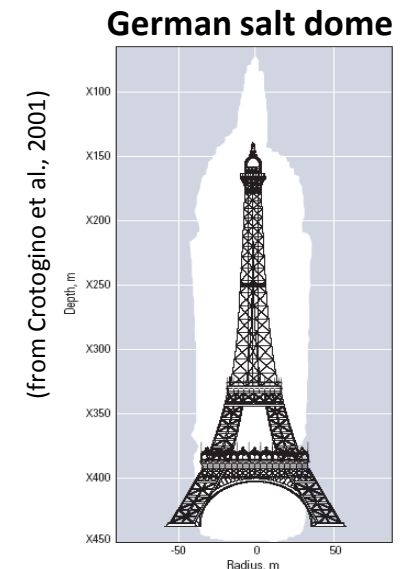
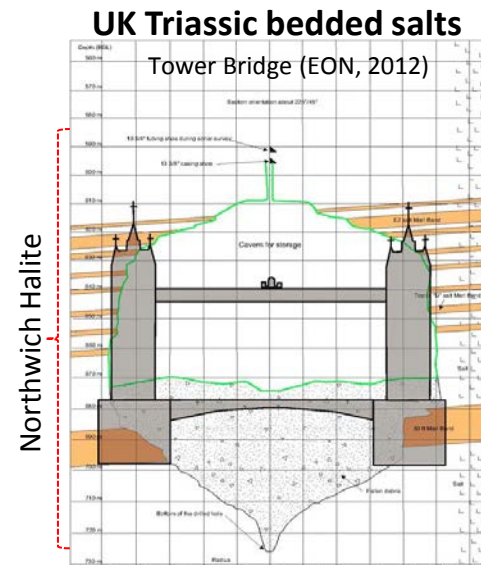
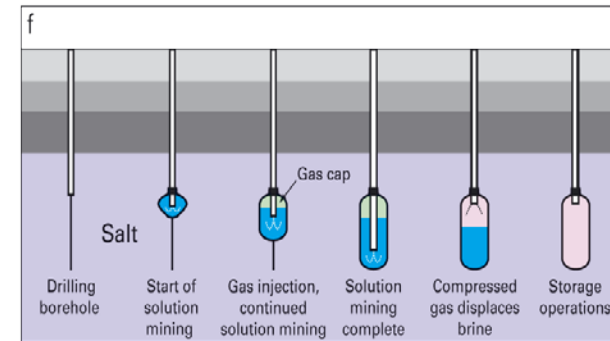
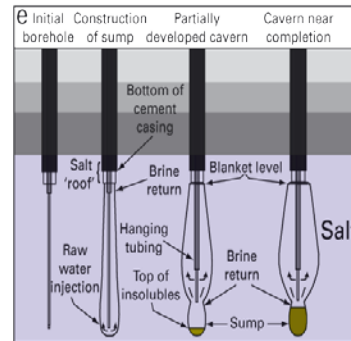
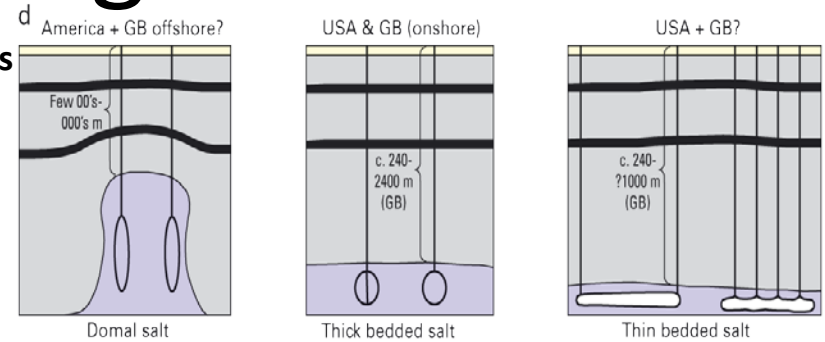
- Long wavelength injection/withdrawal 'periodicity' - seasonal
- Typically seen in depleted hydrocarbon fields
  - Rough
  - Humbly Grove

# Subsurface gas storage – what is it?

## Solution-mined salt caverns

Salt caverns - essentially

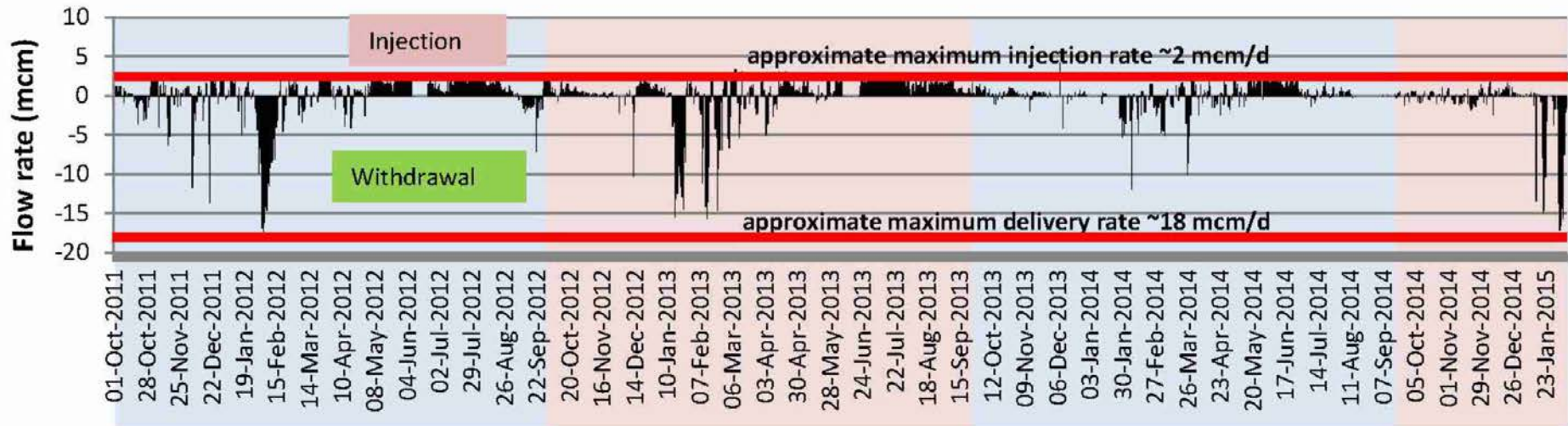
- Large pressure vessel with well to surface
- More responsive
- Range of operational modes
  - Seasonal
  - Increasingly fast cycle – weekly, daily & even hourly
- But requires planning ahead of construction
  - Differing operational pressure ranges lead to different temperatures and stresses on cavern walls – potential stability issues if not specifically designed/constructed
  - Differing cavern spacings etc.



# Salt caverns – fulfill ‘traditional seasonal storage’ role

- Hornsea
  - Designed & constructed in late 1970s
  - Deep - ~1500 m
- Gas market much different then – North Sea starting up

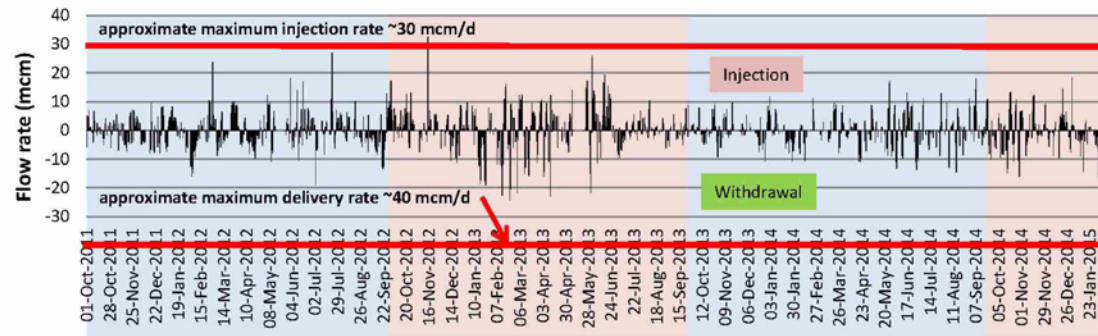
Hornsea injection/withdrawal rates (mcm) Oct2011-Feb2015



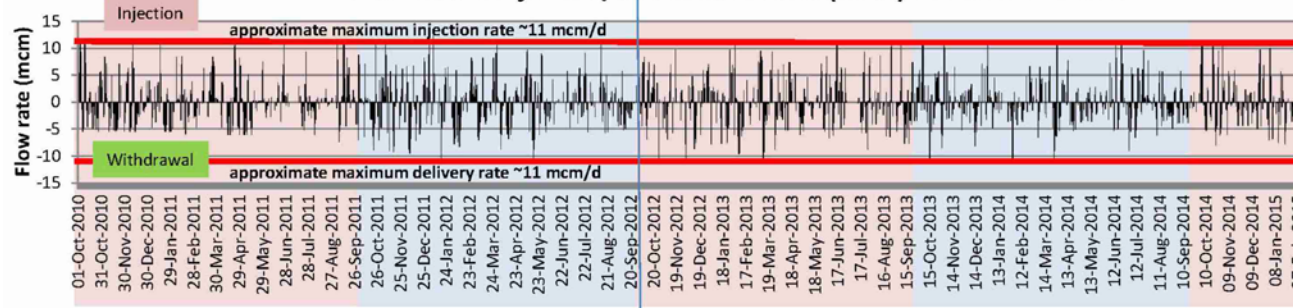
# Salt caverns – Faster cycle operations

- Shorter cycles – more reactive
- Increasingly a move to rapid-cycle operational mode
- Can cycle gas **multiple times** each year, providing much more flexibility per unit of working capacity
- Shallower salt deposits – lower maximum pressures

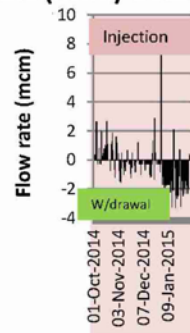
Aldbrough injection/withdrawal rates (mcm) Oct2011-Feb2015



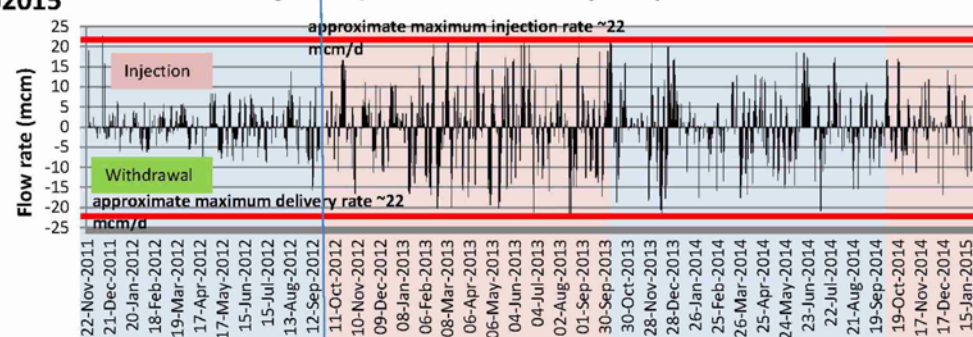
Hole House injection/withdrawal rates (mcm) Oct2010-Feb2015



Stublach injection/withdrawal rate (mcm) Oct2014-Feb2015



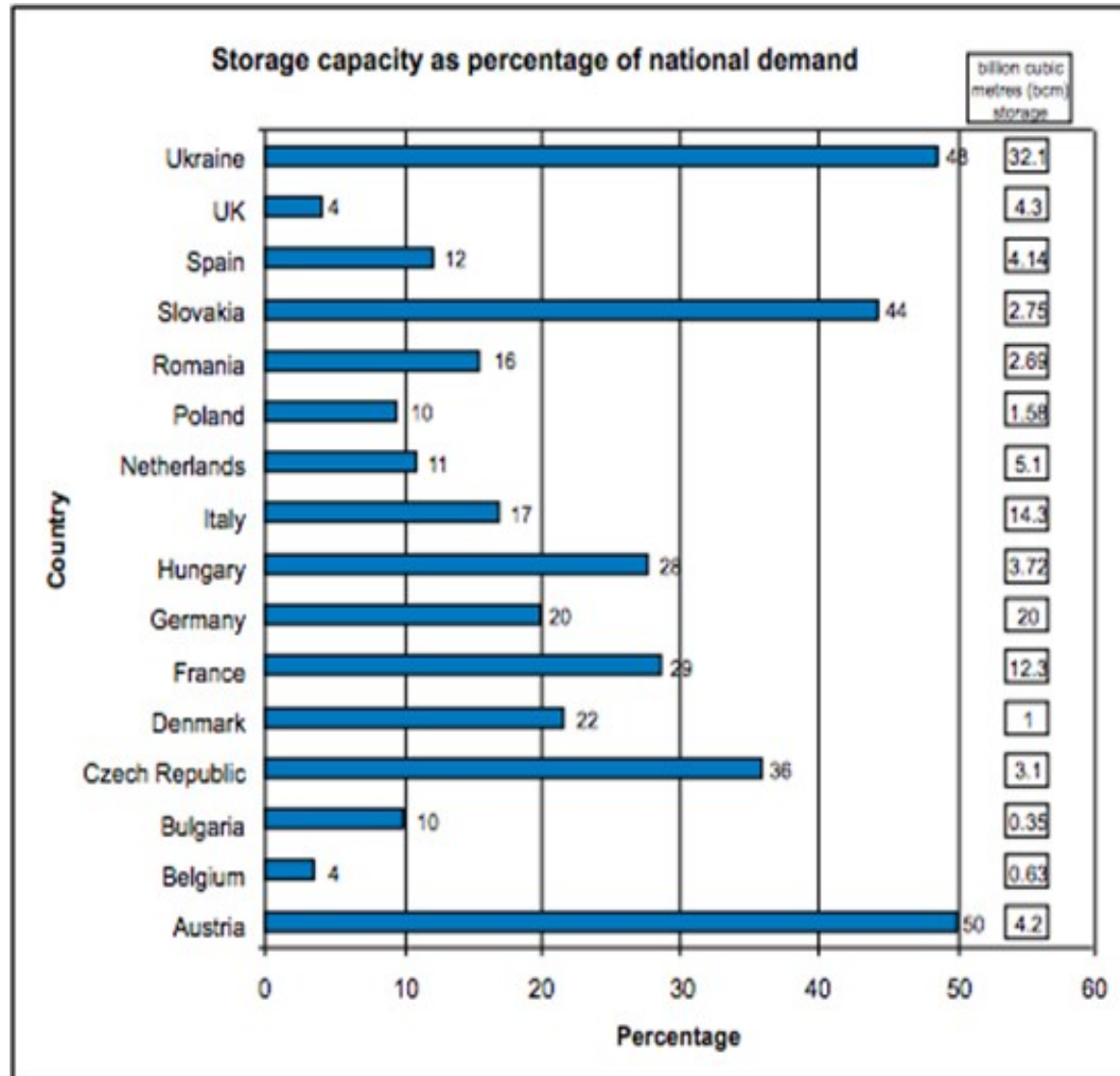
Holford injection/withdrawal rates (mcm) Oct2011-Feb2015





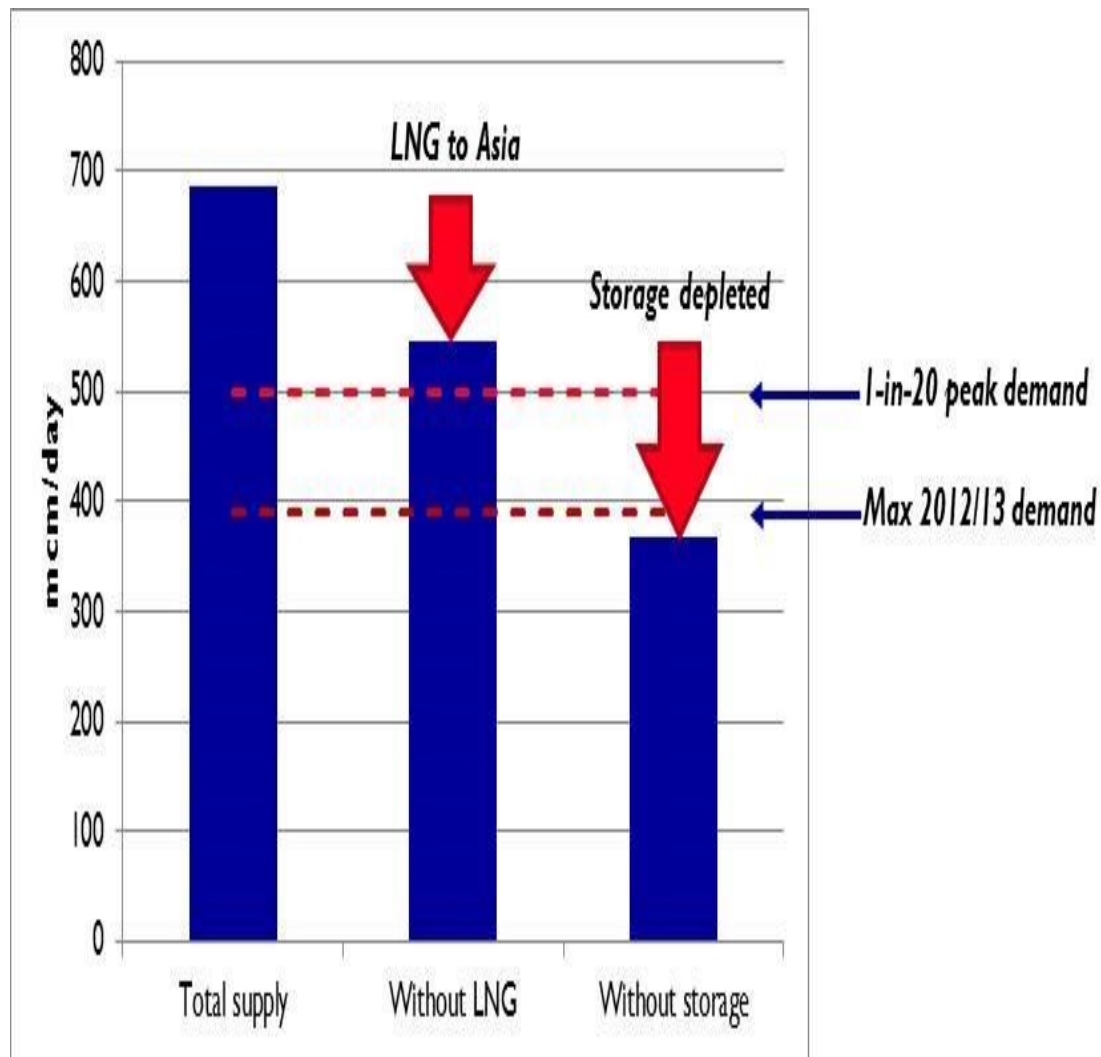
# The current UK gas market – “as is”

- The key points:
  - UK became a net importer of gas in 2004 with around 60 percent imported in 2013/14
  - UK - very little gas storage capacity compared to the rest of Europe



# The current UK gas market – “as is”

- The key points:
  - If gas markets **do not work** efficiently, **nor** respond quickly and our infrastructure **does not** operate as planned the UK has a problem.
  - The new role of gas in the UK energy mix is one of providing flexibility, in both demand and supply



# The current UK gas market – “as is”

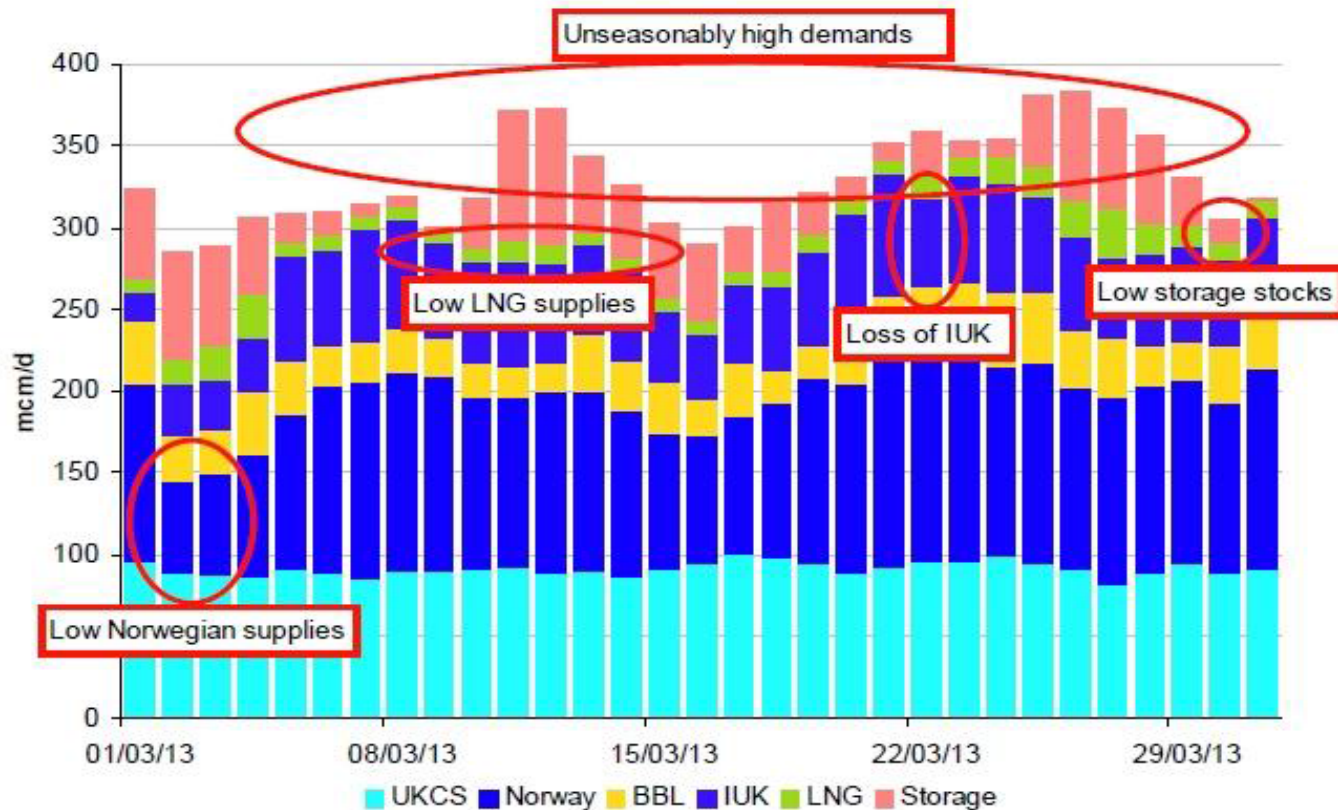


- The key points:
  - Events will continue to happen as we become more dependent on imports.

# The current UK gas market – “as is” - events affecting gas supply market

Date & brief description of event	Resulting consequence (s) of event	Source of reported event
February 2006 – explosion and fire on Rough gas storage platform.	Platform and production shut down caused major disruption between February and June. Wholesale gas prices rose by 40 percent, peaking at 70p/therm.	HSE (2006) Centrica (2006) Guilietti et al (2012).
March 2006 – cold spell overlapping with ongoing Rough incident.	Gas prices rose to 259p/therm and a Gas Balancing Alert issued, resulting in significant demand side response.	OFGEM (2006).
July 2007 – disruption to major Central Area Transmission System (CATS) North Sea gas pipeline damaged by ship’s anchor.	CATS Pipeline shut down for 64 days which led to abrupt increases as prices were low at the time.	National Grid (2008) Watson (2010).
February 2008 – fire at Shell’s Bacton sub-terminal.	Immediate loss of 30 mcm/d resulting in gas price increases of 25 percent within day and 10 percent after. Supplies affected for four days.	National Grid (2008).
January 2009 – Russia cut gas exports to Europe by 60 percent, plunging the continent into an energy supply crisis within hours as a dispute with Ukraine escalated.	Sparked fears of gas supply shortages in Europe and rising energy prices in the UK at a time when the UK suffered its coldest nights this century with temperatures plunging to -10 degrees centigrade.	Lea (2009) DECC (2009) Pirani et al (2009).
January 2010 – sustained snow and freezing conditions led to a 30 percent increase over normal seasonal demand. Norwegian supply interruptions during period of high demand.	Natural gas prices jumped to their highest level in 10 months peaking at 64p/therm within day and end day of 50p/therm (compared to average price for winter of 31p/therm). Reports of less than 8 days gas supply and series of Gas Balancing Alerts issued. 100 factories customer had their gas cut.	Wardrup (2010) Evans & Wardrup (2010) National Grid (2010).
February 2012 – Russian supply restrictions during cold weather in both UK and continental Europe.	No supply problems but gas prices rose sharply from 55-60p/therm to £1/therm	Henderson & Heather (2012).
March 2013 – ‘perfect storm’ of events: 1. Temperatures across Western Continental Europe significantly lower than the seasonal norm, resulting in high demand. 2. Over the winter period relatively low levels of LNG supply due to supplies being sold into higher priced markets in Asia and Latin America. 3. 22 <sup>nd</sup> March IUK interconnector experienced an unplanned shutdown due to a steam release from a heater pump, which triggered an automatic cessation of flows from Belgium	Gas prices rose dramatically hitting a peak of 95p/therm on 12 <sup>th</sup> March and rising again to 105p/therm on 22 <sup>nd</sup> and 25 <sup>th</sup> March, with prices traded during the day significantly higher. To meet demand over and above gas from the UK and Norwegian continental shelf led to increased dependence on interconnectors and gas from storage, which had already reached very low levels by late March. On 22 <sup>nd</sup> March ‘within’ day wholesale prices increased to 150p/therm in response to the market sourcing alternative gas supplies to make up the shortfall	Timera Energy 2013 DECC 2014
March 2014 – escalation of conflict between Russia & Ukraine	Oil & gas prices rose amid security of supply concerns, as UK day ahead gas prices rose more than 8 percent.	Gosden (2014)
June 2014 – Russia cuts Ukraine supply after talks fail	Europe faced gas supply disruptions after Ukraine failed to broker an 11 <sup>th</sup> hour deal with Russia. Gas prices volatile into August 2014.	AFP (2014)

# The current UK gas market – “as is”

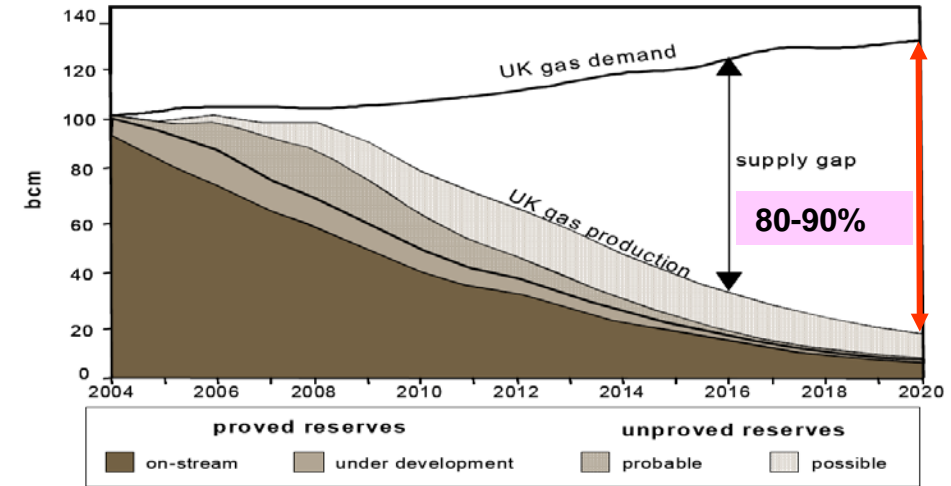


- Since 2006 there have been 11 events that have caused problems in UK gas market, the biggest being the Rough outage and cold spell in 2006 which caused gas prices to rise to 259p per therm.
- March 2013 was the last “stress” test.

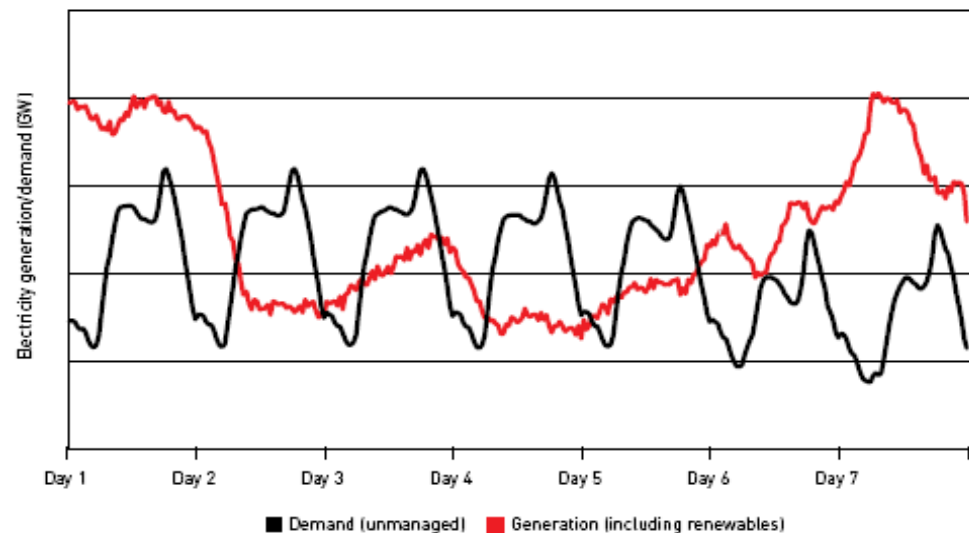
# The future UK gas market – “to be”

- Two major shifts in UK gas market:
  - Import dependency is increasing as UK domestic gas production declines.
  - Demand fluctuations are increasing as more intermittent renewable generation capacity rises.
- Increasing UK gas system stress, demand and price volatility

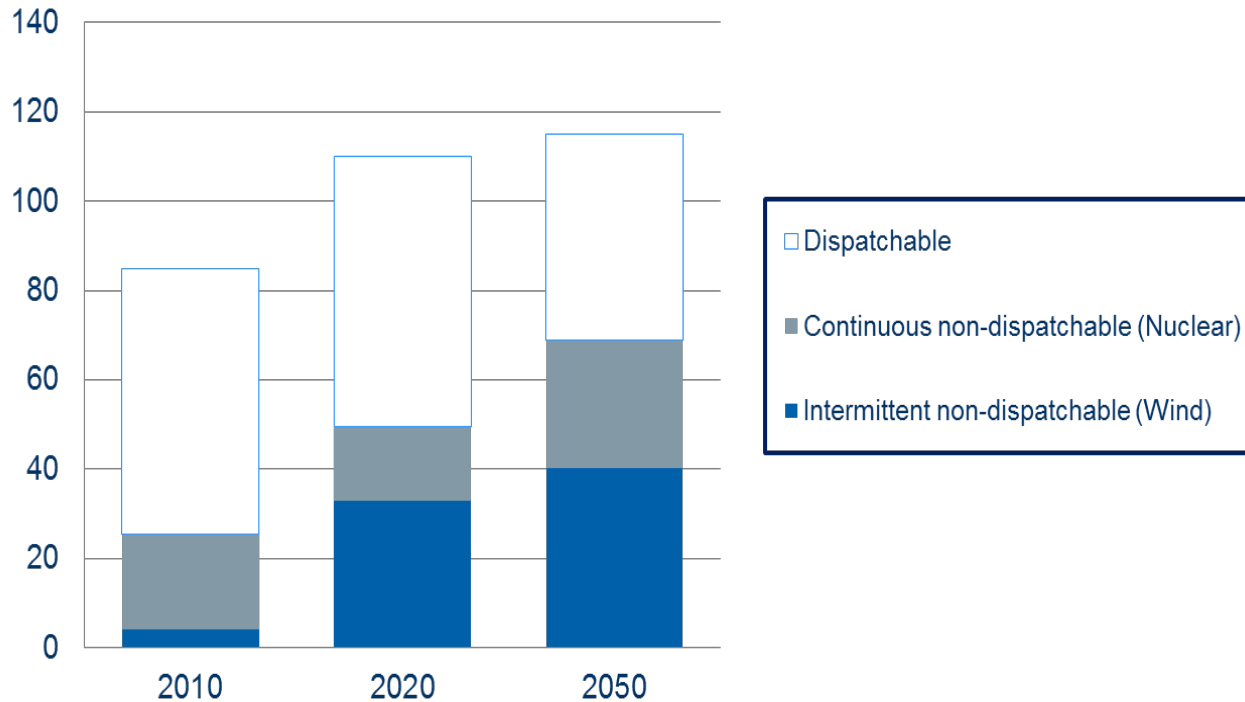
UK gas production and demand to 2020



Source: Modified from WoodMackenzie 2004, 'From surplus to shortage'

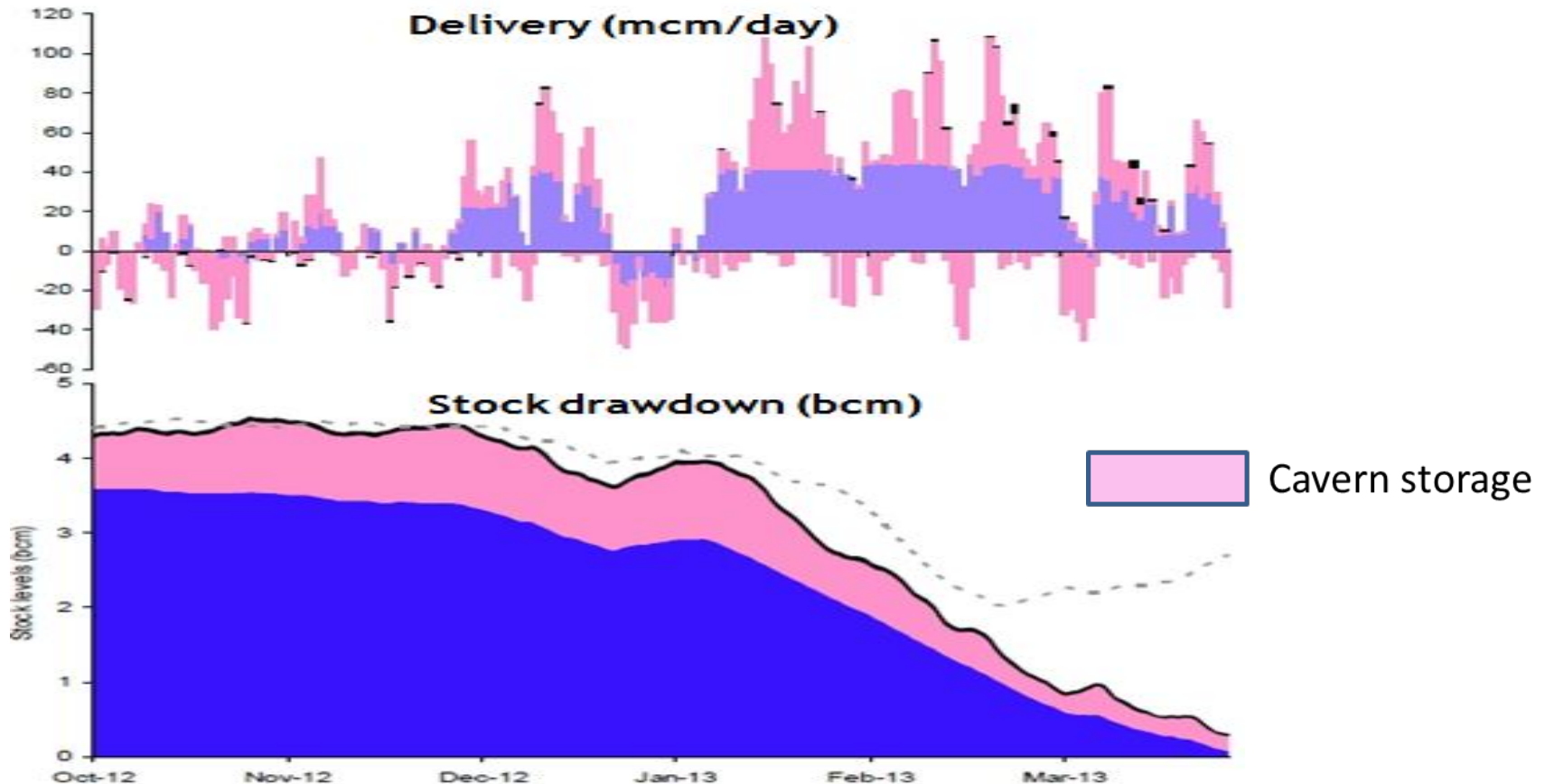


# The future UK gas market – “to be”



- The key points:
  - Risks to UK gas supply are likely to increase as the UKCS reduces, reliance on LNG increases, coal retires and a need for CCGT’s to back up wind.

# The future UK gas market – “to be”



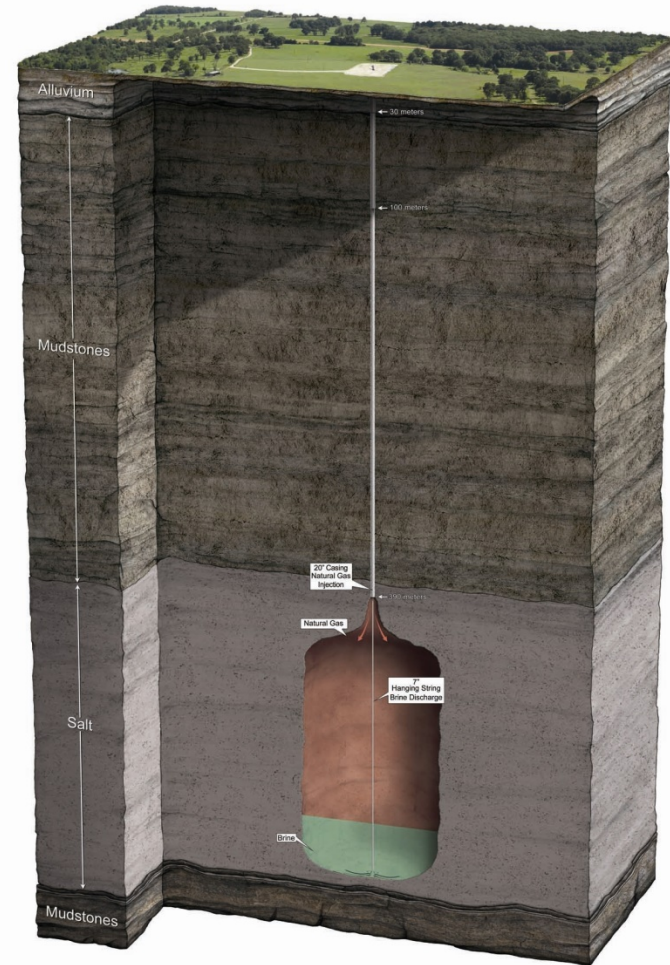
- The key points:

The UK government recognises storage facilities can add flexibility and increase deliverability (currently 154 mcm/day) to meet demand. (Source DECC/OFGEM Statutory Security of Supply report 2014)<sub>16</sub>



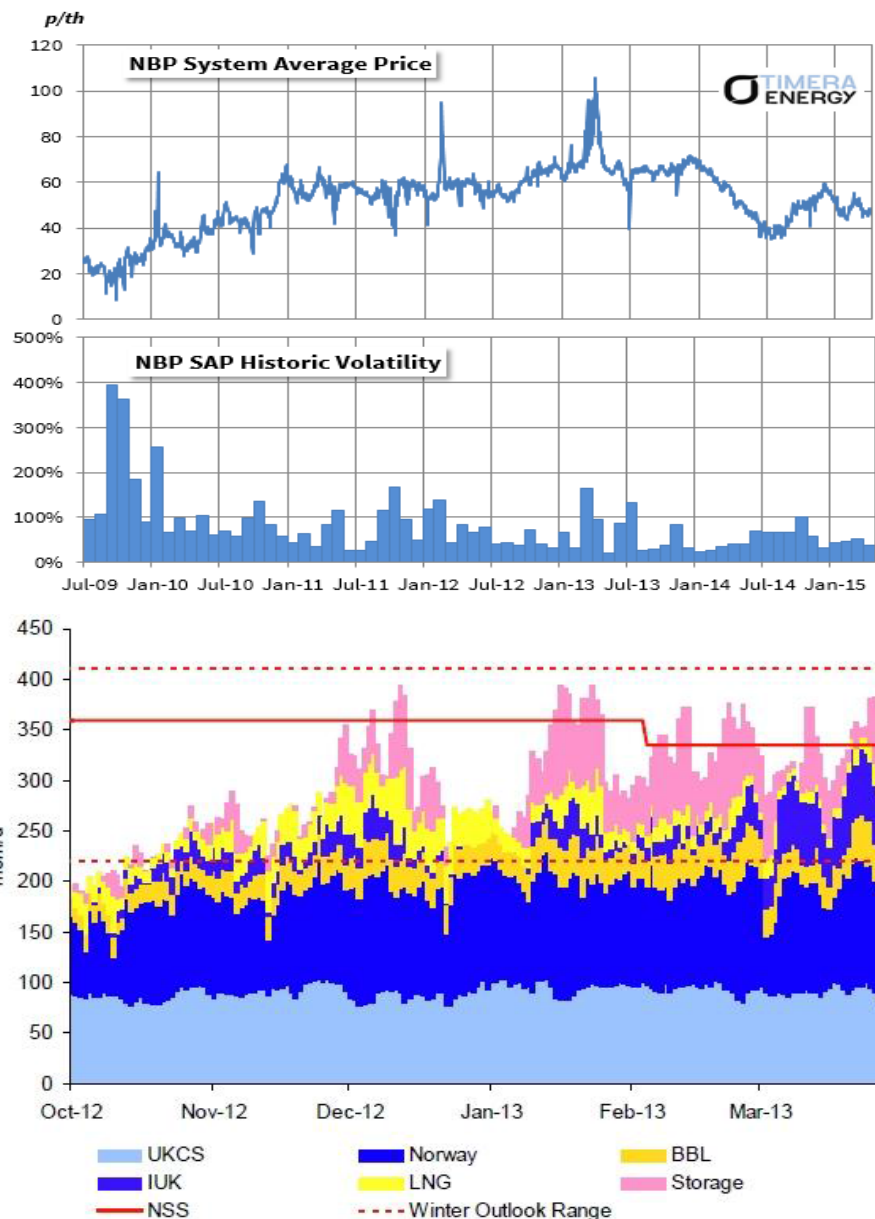
# Salt Cavern Fast Cycle Gas Storage

- ‘huff ‘n puff’
- Its most distinguishing characteristic is deliverability (mcm/d), **not** working gas volume or space
- Carbon – shallow salt strata, rapid volume in and out of storage means low energy costs and lower CO<sub>2</sub>



# Salt Cavern Fast Cycle Gas Storage

- Facilities - cycle quickly across the winter providing
  - dampening short term gas market price volatility and increasing short term market liquidity (**keeping gas prices down!**).
  - deliverability insurance capability in times of major system stress
- Currently much smaller volume of consented salt cavern fast cycle capacity in the UK with limited salt strata to do more
  - Depth – shallow enough to operate within pressure ranges and gradients of rapid cycle
  - Thickness & purity



# Geology & Engineering

- Exploitation of the subsurface for fast cycle gas storage is complex.
- It needs to be a justified use of resources.
- The ability of fast-cycle facilities to provide large volumes over shorter periods is critical to the UK.
- Can existing & new facilities deliver more, be better utilized?
- Can we use / reuse some of the halite within the Triassic rocks we currently know about?
  - Hole House extension converting 10 former brine caverns
  - Beyond life of storage facility, caverns could be worked for additional brine – pillars don't need to be as thick?



(from McCusker, 2012)

# Geology & Engineering

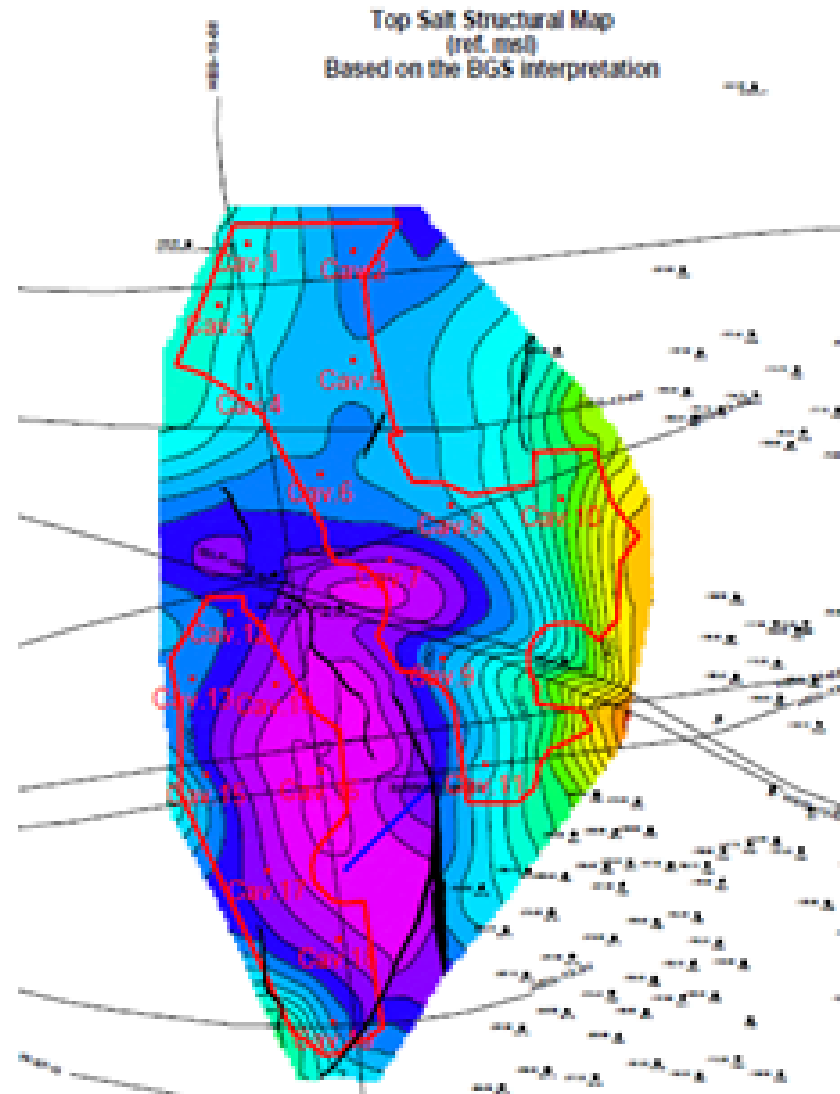
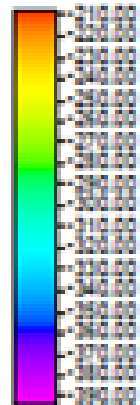
- The Industry challenge – can the geologists and engineers overcome these capacity and utilization shortfalls?
- Subsurface investigation – new technologies and techniques that support geological characterization.
- Subsurface construction – evolving technologies and techniques.

Location	Static Capacity mcm	% of max	No of permitted cycles/yr	Dynamic capacity Mcm/yr	Actual Volume delivered/yr	% of max
Aldbrough	330	45.3	18.2	6000	563.2	<b>13.6</b>
Hole house	55	45.9	20.6	1133	470	<b>41.0</b>
Holford	160	49.5	24.1	3850	899	<b>23.5</b>
Hornsea	325	69.3	1.9	630	215	<b>33.4</b>
Humbly Grove	254	51.3	5.4	1375	347	<b>25.4</b>
Rough	3650	54.4	1.3	4705	1713	<b>42.7</b>

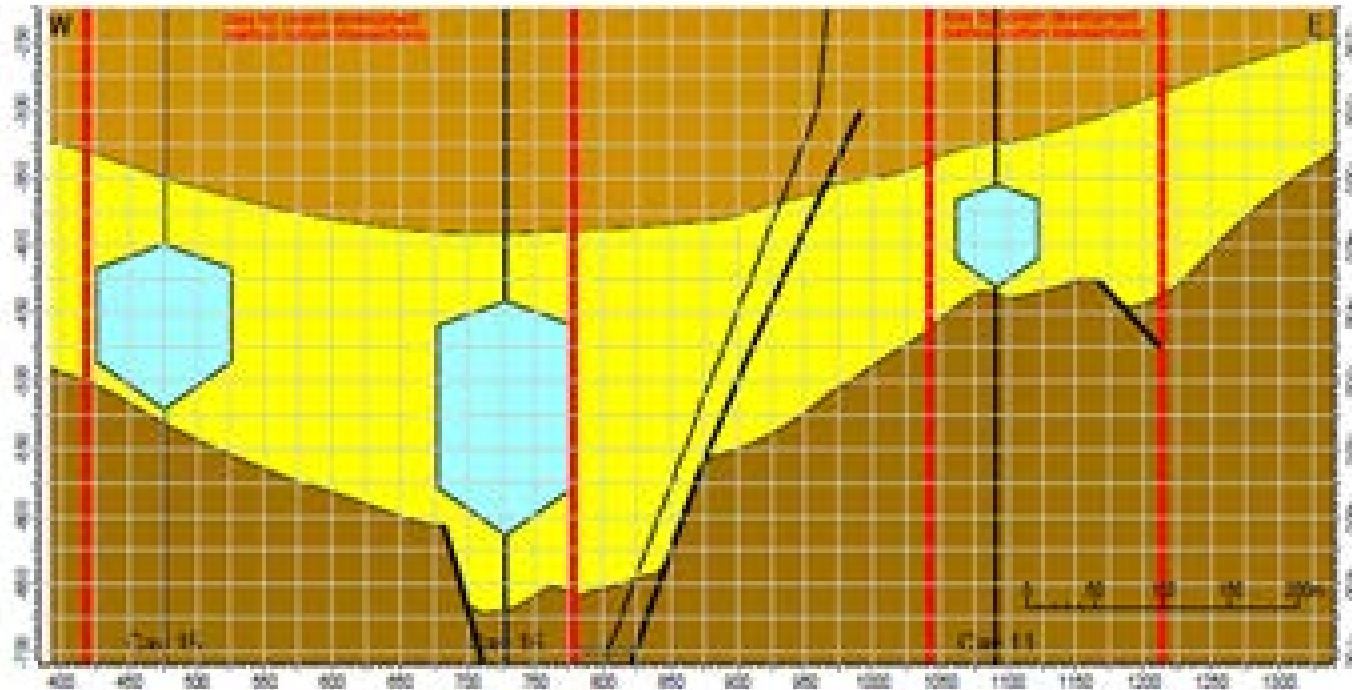
# Geology & Engineering

Faulted syncline

Elevation depth [m]



# Geology & Engineering





# Summary

Fast cycle gas storage is considered a sustainable use of the subsurface because:

- More efficient use of void space
- Gas underpins social and economic factors
  - Fast cycle supply offsets renewable intermittency
  - Increased storage adds to national strategic capacity