How to classify underground energy storage capacities

European Workshop on Underground Energy Storage

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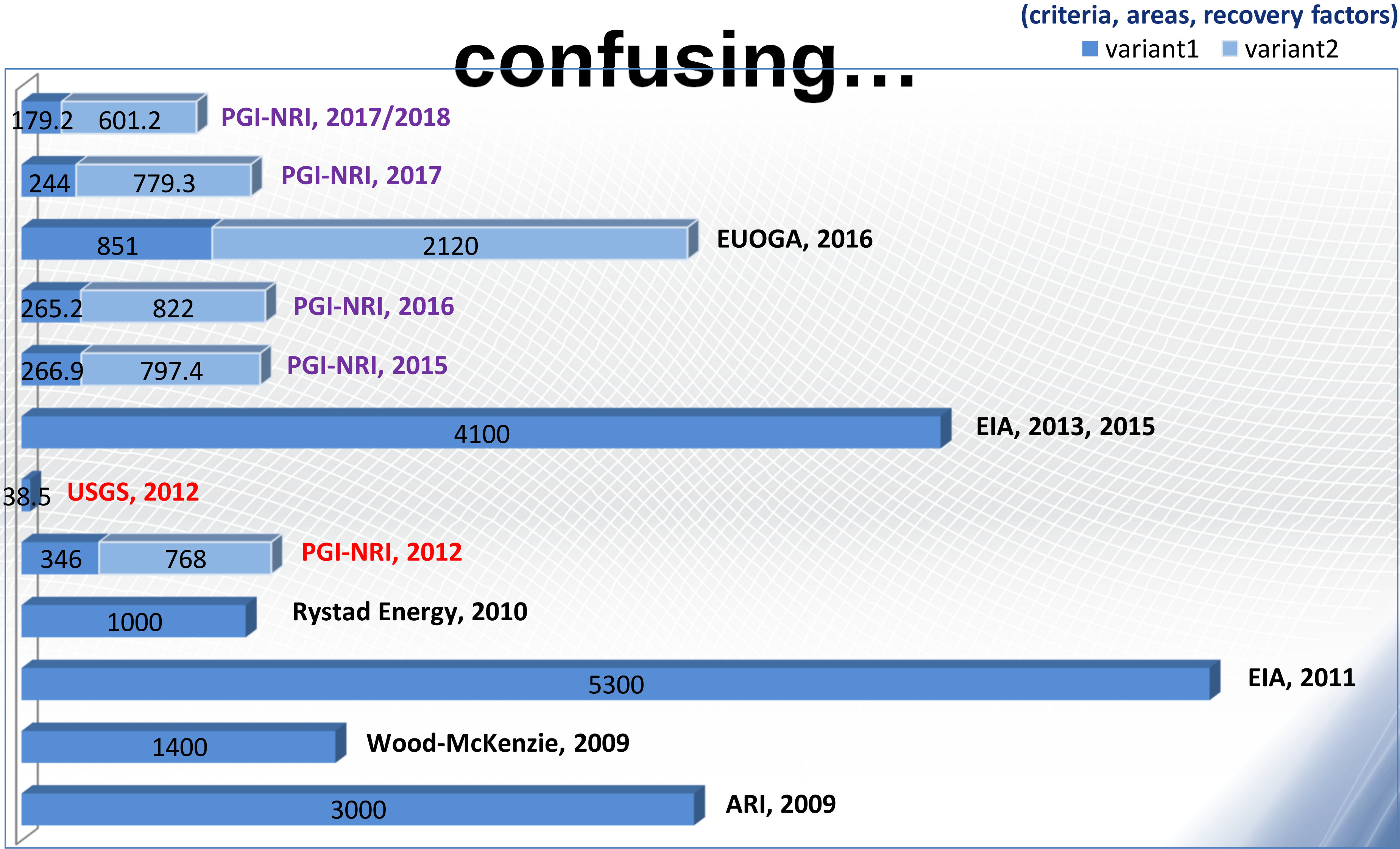
Pro’s and Con’s of resource estimates

- Good
  - Based only on technical factors
    - Storage volume distribution and properties
    - Cap rock distribution
    - Pore volumes where fluids can be retained
    - Storage efficiency factors
    - Good first pass to see where capacity lies

- Bad
  - Does not take geological risk into account
  - Does not take economics into account
  - Produces some large and misleading numbers
  - Need to make the limitations of the estimate clear

Resource assessments can be confusing…



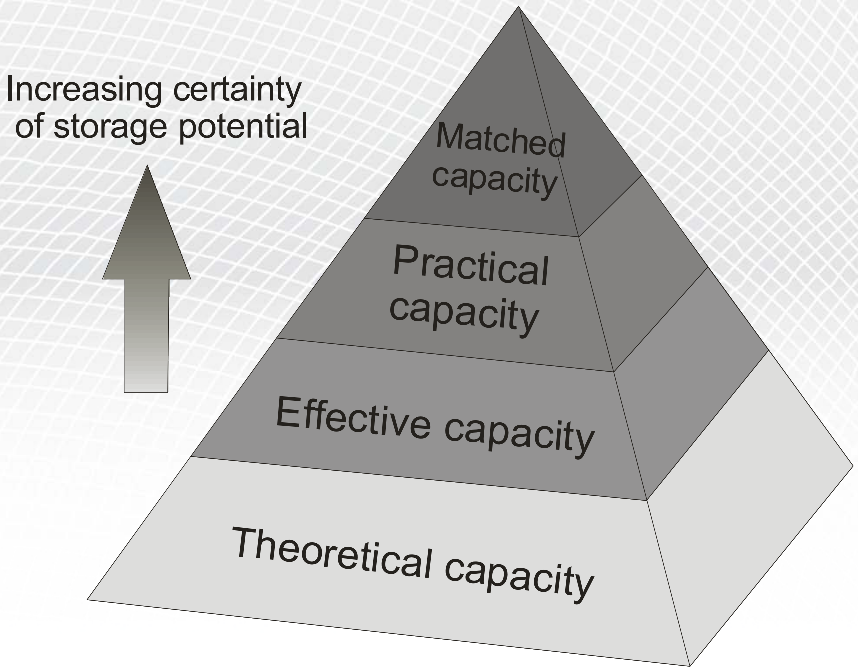
Acknowledgement: Adam Wojcicki, PGI

Aquifer (pore) storage

- Learn from CCS
- Simple calculations using basic volumes and geological parameters
- Static models:
  - Static capacity **estimates** need to be followed up by detailed assessments
  - The estimate does not take into account other factors such as pressure increases, time factors, injectivity, multiple injections into one storage unit, displacement of pore fluid etc……..
- Dynamic models…
  - Can potentially provide a **better estimate** of capacity. However more data is required, too time consuming and costly to do for a whole country, so can only be carried out on a site by site basis…….

Classification of storage capacity

CSLF (Carbon Sequestration Leadership Forum)



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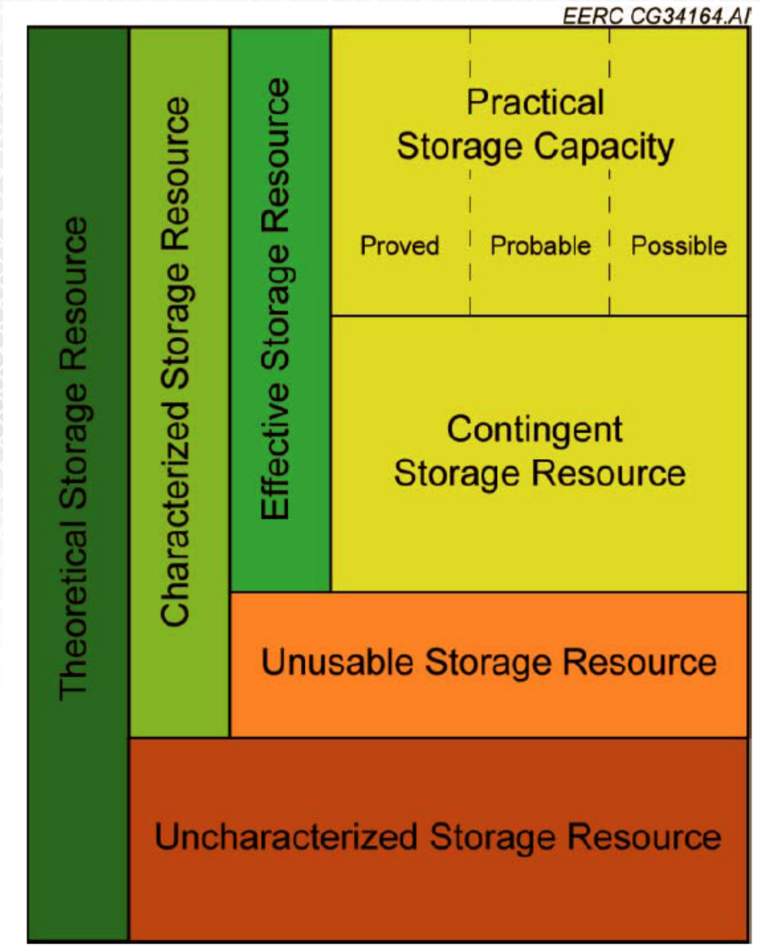


CSLF storage capacity estimations

The general idea (pore volume storage)

Consideration of physical/volumetric trapping mechanisms for CO_2 storage capacity estimations

Why? Because they are the dominant trapping mechanism during the period of injection !

⇨ Estimation of the mass of CO_2, that could be physically stored in the pore volume (voids) of the reservoir rock (pore volume calculation)

So for estimations we essentially use formulas of the form:

Mass of CO_2 = Pore volume of reservoir rock • CO_2 density

[kg] = [m^3] • [kg/m^3]

Hydrocarbon fields

- **Assumes:**
  - **most of the volume previously occupied by the produced hydrocarbons becomes available for storage**
  - **Gas/fluid will be injected into depleted oil and gas reservoirs until the reservoir pressure is brought back to the original reservoir pressure**

Gas and oil field storage capacities

Gas Reservoirs

$M_{CO2t} = \rho_{CO2r} \times R_f \times (1-F_{IG}) \times OGIP \times [(P_s \times Z_r \times T_r) / (P_r \times Z_s \times T_s)]$

This can be simplified to:

$M_{CO2t} = \rho_{CO2r} \times [V_{GAS}\ (stp) / Bg]$

Oil reservoirs

$M_{CO2t} = \rho_{CO2r} \times [R_f \times OOIP / B_f - V_{iw} + V_{pw}]$

This can be simplified to:

$M_{CO2} = (V_{OIL}\ (stp).B_o)\ .\ \rho CO_2$

M_{CO2t}	Theoretical storage capacity (10^6 tonnes)
ρ_{CO2r}	CO_2 density at reservoir conditions (kg m^{-3})
stp	Standard temperature and pressure
V_{GAS} *(stp)*	Volume of ultimately recoverable gas at stp (10^9 m^3)
Bg	Gas expansion factor (from reservoir conditions to stp)

V_{OIL} (stp) Volume of ultimately recoverable oil at stp (109 m3)

Bo Oil formation volume factor

Aquifer storage

Regional aquifer storage estimation:

$$M_{CO2} = A \cdot h \cdot \Phi_{rock} \cdot \rho_{CO2} \cdot E_r$$

M_{CO2}: Mass of stored CO_2

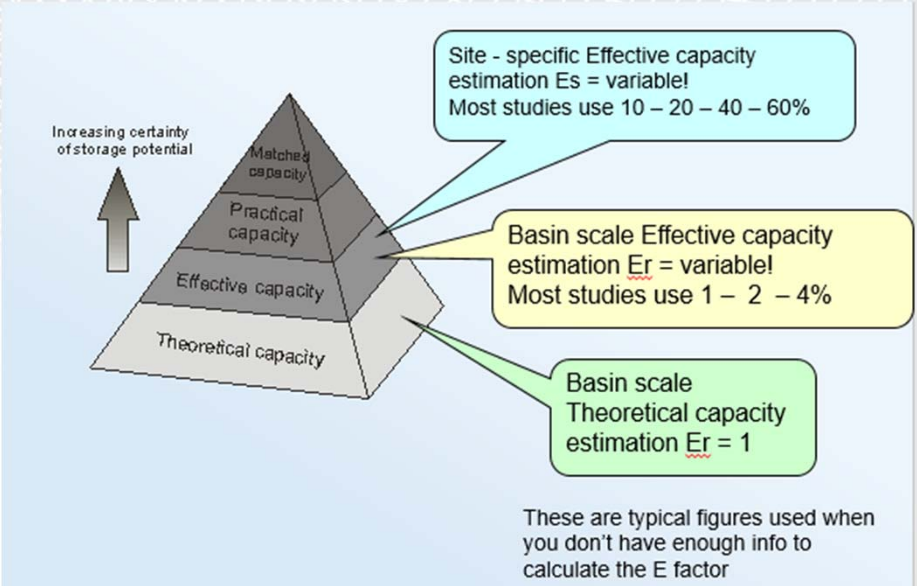
A: Areal extent of aquifer (or area being assessed)

h: Average thickness of aquifer

Φ_{rock}: Average porosity of reservoir rock over thickness h

ρ_{CO2}: Average density of CO_2 under reservoir conditions

E_r: Regional storage efficiency factor

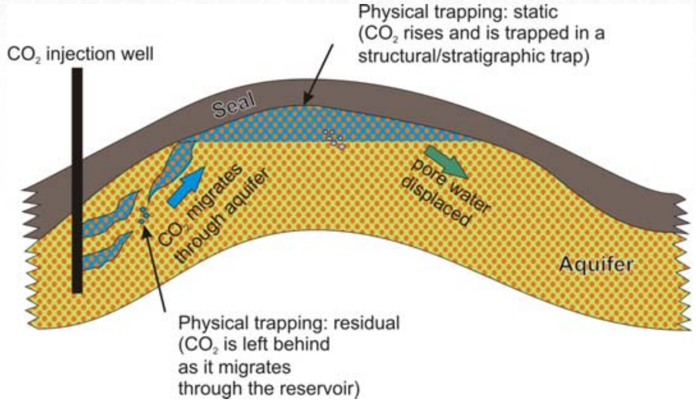


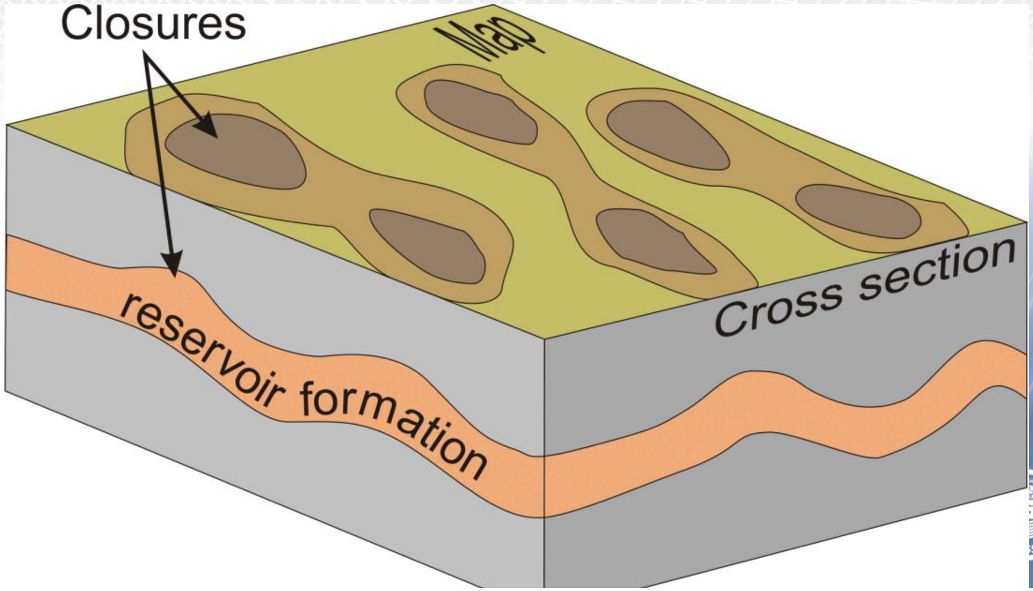
⇨ Effective Capacity

Aquifer storage- considerations

Storage capacity:

- In structural and stratigraphic traps
- Processes between gas injection site and trapping points
  - Dissolved in formation waters?
  - Mineral precipitation
  - Other processes (e.g., H2 and microbial action)





Practical and matched capacity

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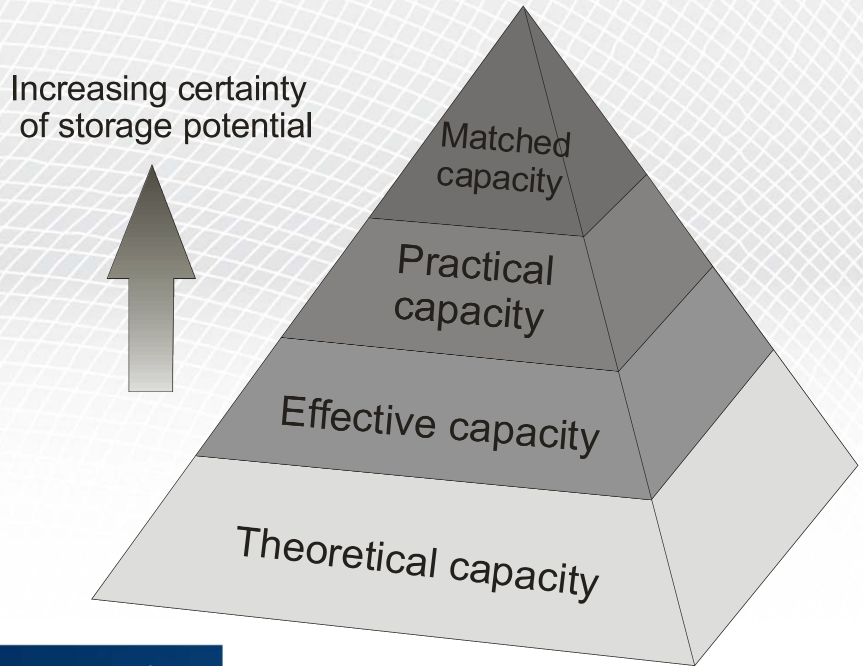


Practical Capacity-

Economical , regulatory, legal constraints will reduce capacity

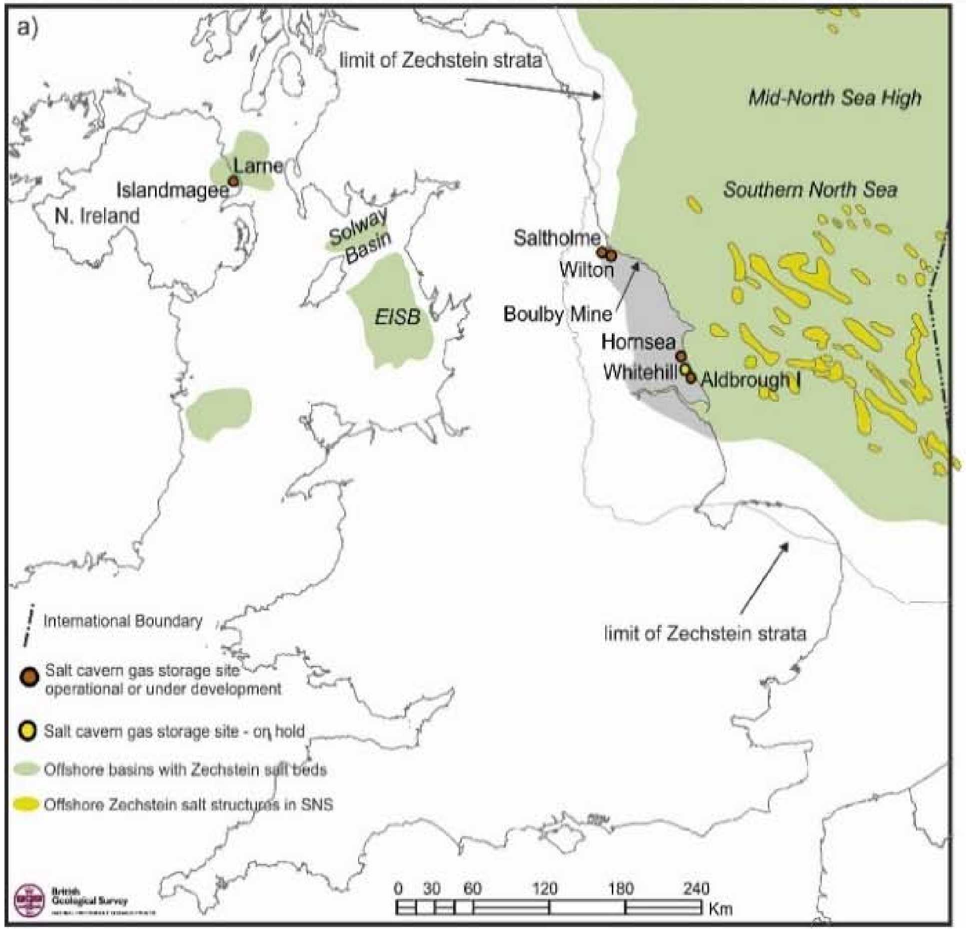
Matched Capacity

Is the site connected to a source?

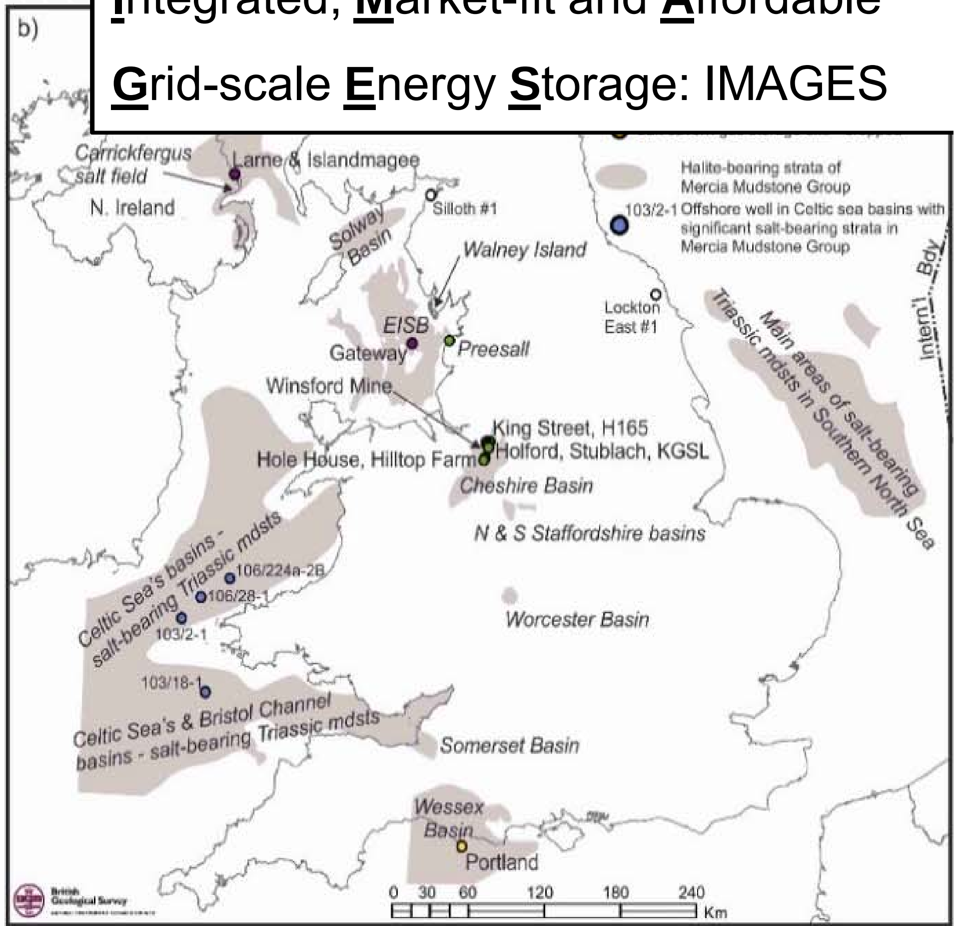
Cavern storage

Integrated, Market-fit and Affordable

Grid-scale Energy Storage: IMAGES



Permian



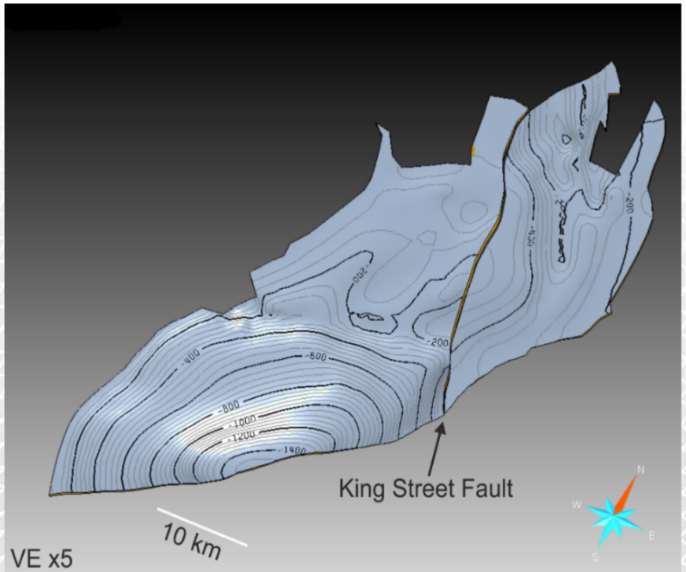
Triassic

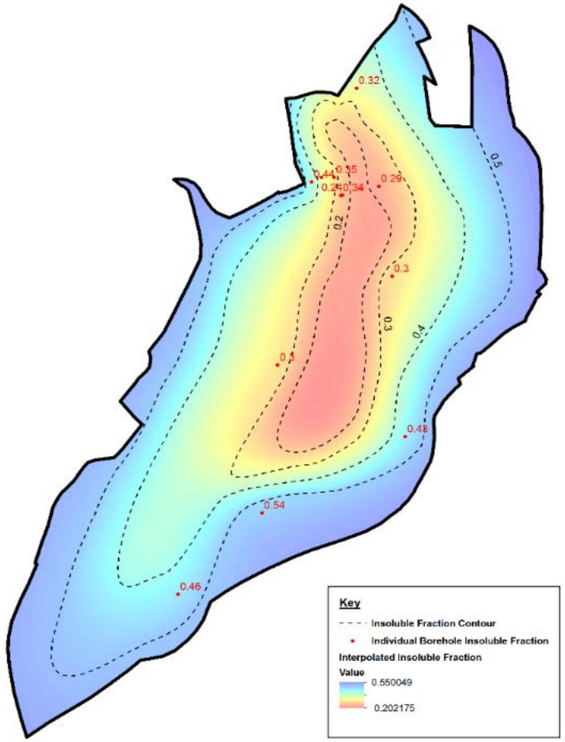
Parameters

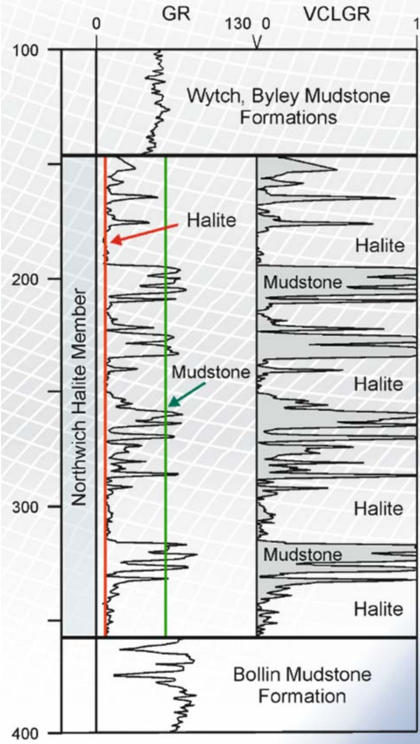
- Holford #165-
  - Operational
  - Triassic, bedded halite
  - 1 cavern, 70 m x 70 m x 70 m
  - Cavern depth (top, base): 350, 420 m bgl
  - Cavern volume 175,000 m^3
  - Pressure range: Max = ~8.5MPa/1233psi/85bar; Min = ~7MPa/1015psi/70bar

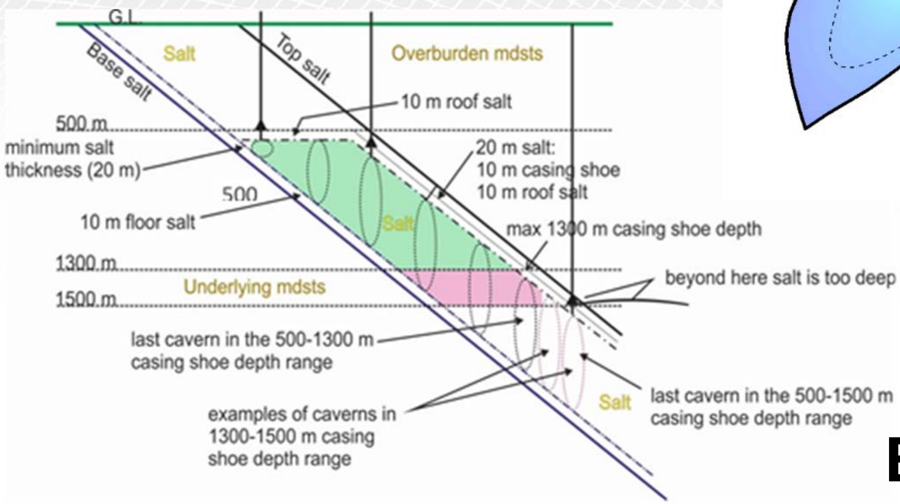
Status	Age, sites	Volume (mcm)
Operational	**Triassic: 5 sites**	**16+**
	Permian: 2 sites	**4.41**
Sum	**7 sites**	**20.41+**
Planned	**Triassic: 5 sites,**	**40.27**
	Permian: 2 sites	**5.86**
Sum		**46.13**
Total		**66.54**

Geological model: halite









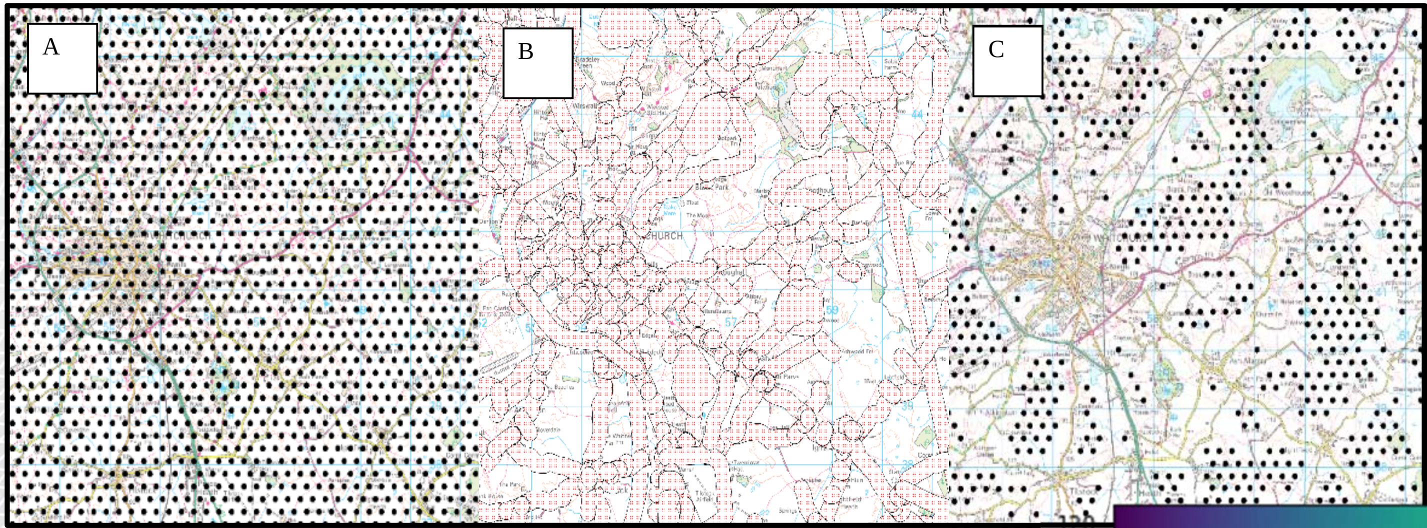
Insolubles

Estimate maximum cavern volume

Constraints

- **Halite**
  - Thickness of halite >20 m
  - Casing shoe 250 m – 1500 m (deeper- ref. Gaelectric)
  - 10 m roof salt, plus casing shoe 10 m below roof
  - Floor salt >10 m
- **Cavern**
  - Radius 50 m
  - Pillars 3R = 150 m
  - Regular hexagonal close packed grid
- **Sources of error**
  - Maximum volumes rarely utilised
  - Raw caverns assumes cylindrical (shape factor 0.7 applied)
  - Insolubles modelled across basins (20% volume reduction)
  - Remove unfeasible caverns (existing infrastructure and facilities, geology- faults, wet rockhead) (74% volume reduction)

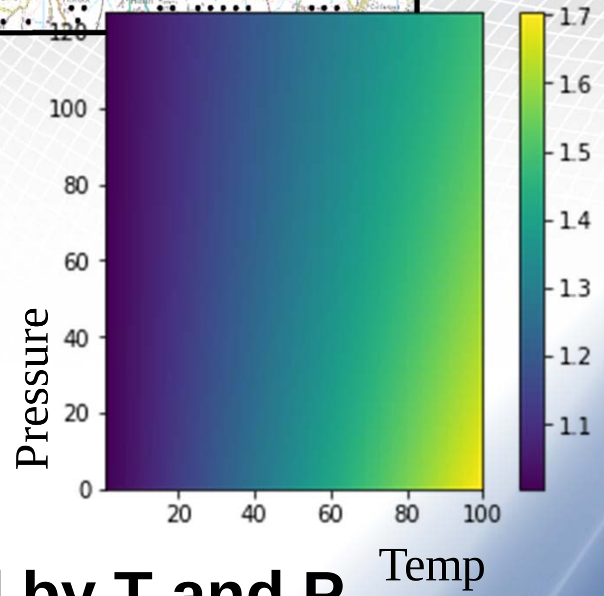
Buffering- potential caverns



$CavernCapacity = mworkingGas * LHV gas$

LHV used for Hydrogen is 119.96 MJ/Kg or 3.332 x 10-5 GWh/Kg

LHV: Lower Heating Value



Compressibility influenced by T and P

For H-storage, rank potential caverns by GWh based on capacitiy

Blue – 180 GWh
Orange – 16500 GWh

Confidence given by comparing to existing cavern volumes

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Thanks for listening!

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