Storage alternatives – aquifers or depleted gas fields

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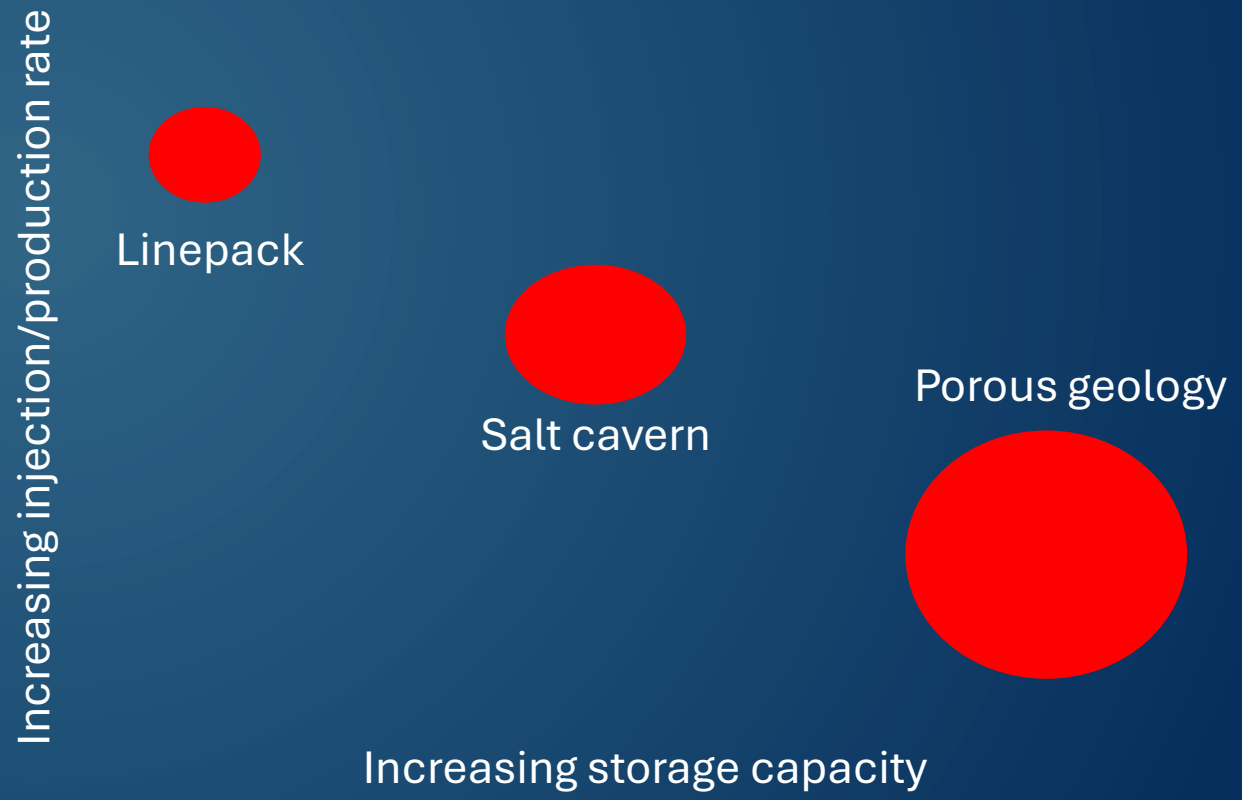
Agenda

- The storage hierarchy
- Integrity
- Pressure management
  - Cushion gas vs barrier gas
- Aquifer performance
- “Lost gas”
- Comparative economics

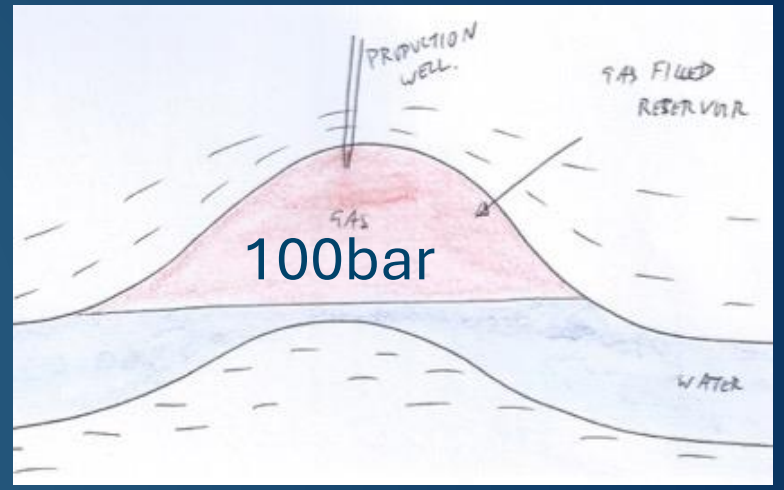


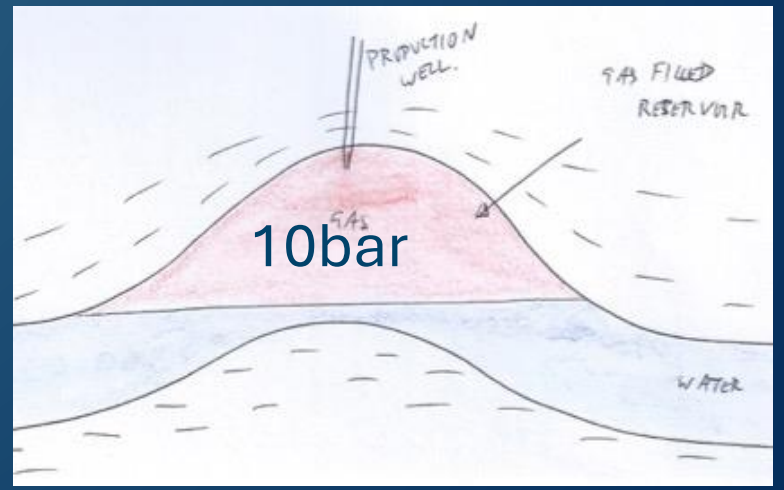
Integrity

Storage type	Depleted gas field	Aquifer
Storage integrity (structure)	Demonstrated by long history of hydrocarbon retention	Not demonstrated. Need to show why not hydrocarbon-bearing if a viable structure (ie not on migration route)
Storage integrity (wells)	Uncertain, especially if wells old or poorly documented	Unlikely to be an issue other than for the (likely few) wells on the structure
Characterisation	Excellent, multiple well penetrations, seismic surveys	Moderate, defined on seismic, potentially few well penetrations
Knowledge of reservoir	Excellent, based on well performance and reservoir modelling	Poor, based on analogy and limited well data

Let's talk about pressure – tanks and pistons

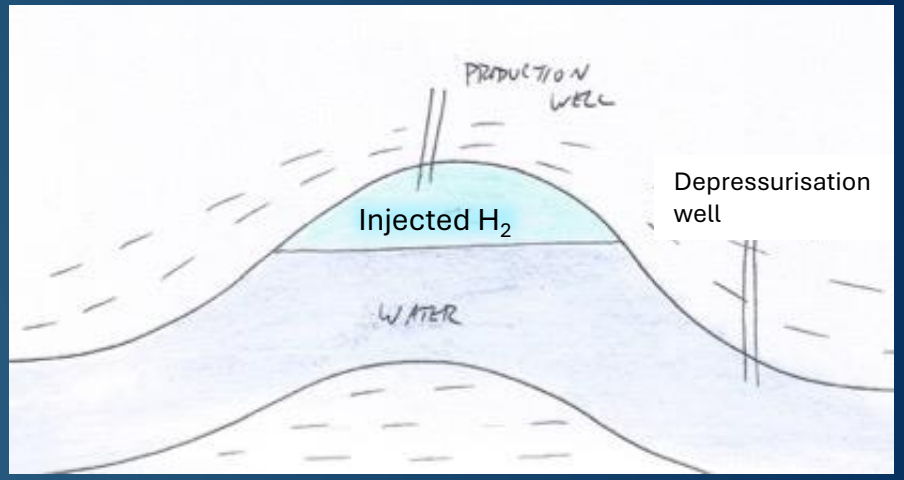
- Most of the subsurface is at hydrostatic pressure
  - The water column is connected all the way down
  - The pressure gradient is c. 0.45 psi/ft (or c. 0.1bar/m)
- Field depletion
  - As a first order approximation, gas fields are "tanks", aquifers are "pistons"
- Tanks
  - In a tank, as gas is produced, the water leg only very slowly encroaches into the gas zone
  - Pressure in the gas leg falls from the original hydrostatic pressure to a few bar
    - Ultimately determined by the depth of the field and the density of the produced gas
  - Over very long periods, water encroachment into the gas leg may repressurise the reservoir

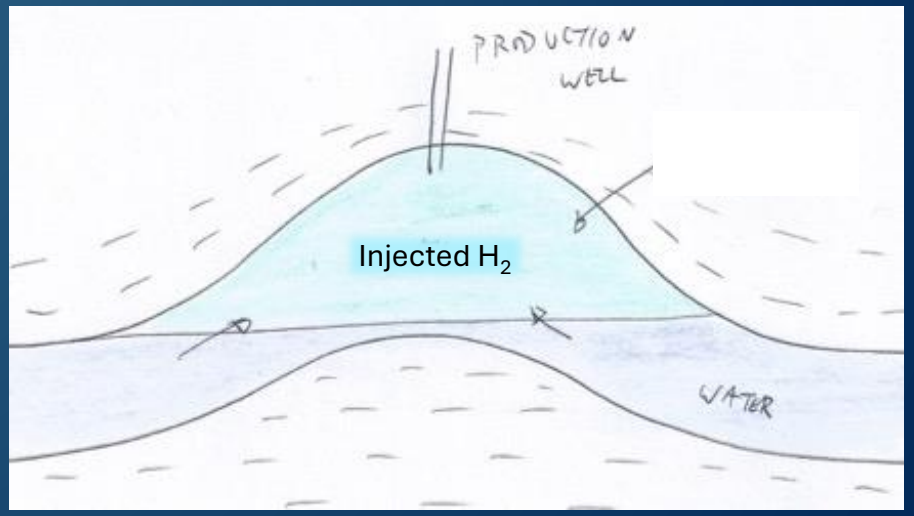




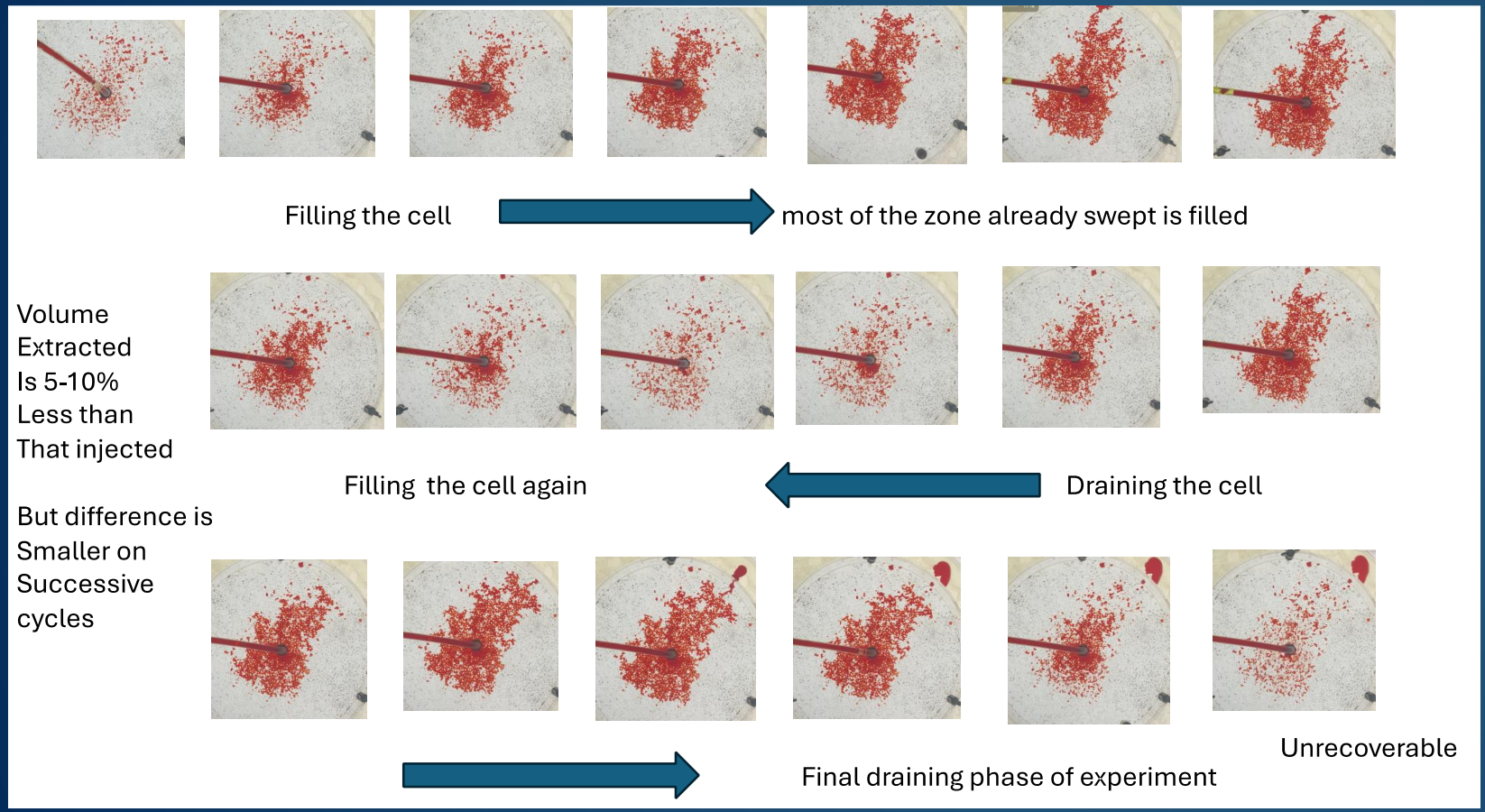
Tanks and pistons (cont'd)

- In an aquifer, modelling suggests that the water surface moves grossly like a piston
  - There is mixing and interfingering
  - Some injected hydrogen is permanently trapped
  - Reservoir quality and injection rates are important
  - Quasi-isobaric operation
    - Water removal may be required to create space and manage pressure





Experimental results – simple reservoir



Initial experiments involve flowing coloured water into oil saturated bead pack

Injection of gas into aquifer develops “fingers” and “islands”

Gas production leaves some stranded gas

Sequential cycles see lower losses

These early experiments ignore gravitational effects and reservoir heterogeneity, and use water/oil

Experimental results – layered reservoir

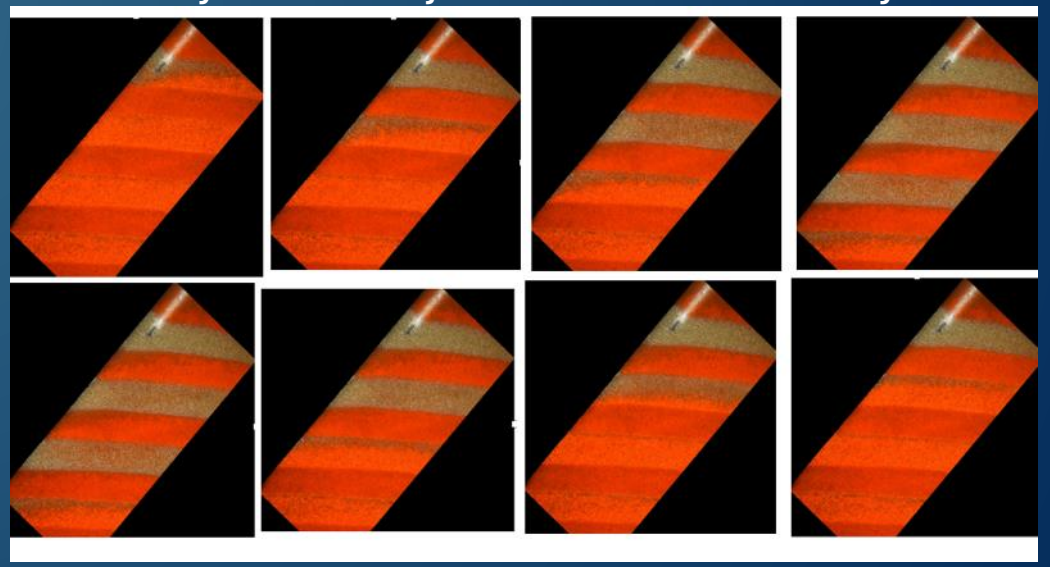
Injected gas flows into high perm layers

Some gas trapped by low perm layers

In real life, reservoirs are heterogenous, tilted, faulted…

Experiments find that reservoir layering show that this isn't a killer

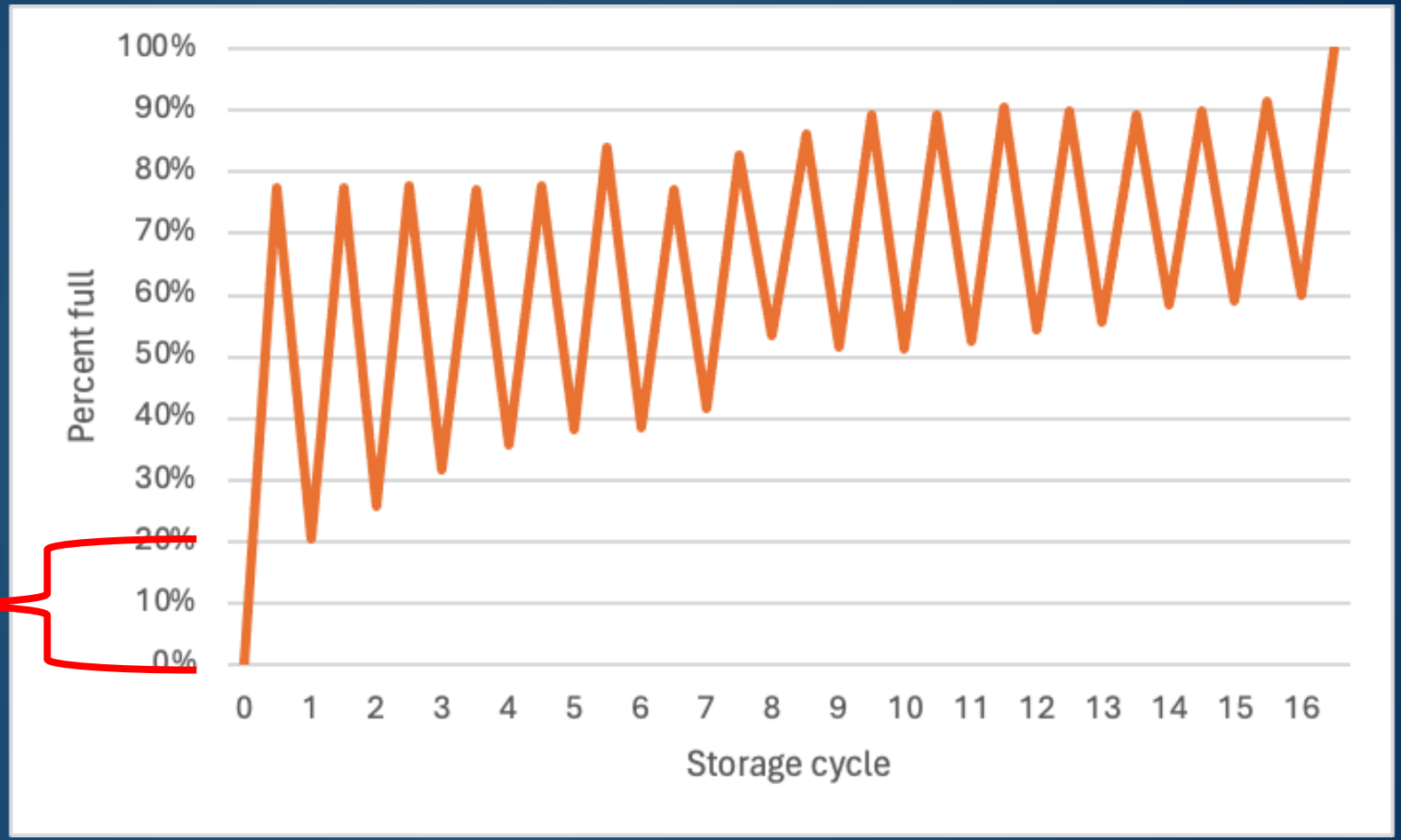
Start of cycle Injection End of cycle



Start of cycle Recovery End of cycle

Gas storage efficiency

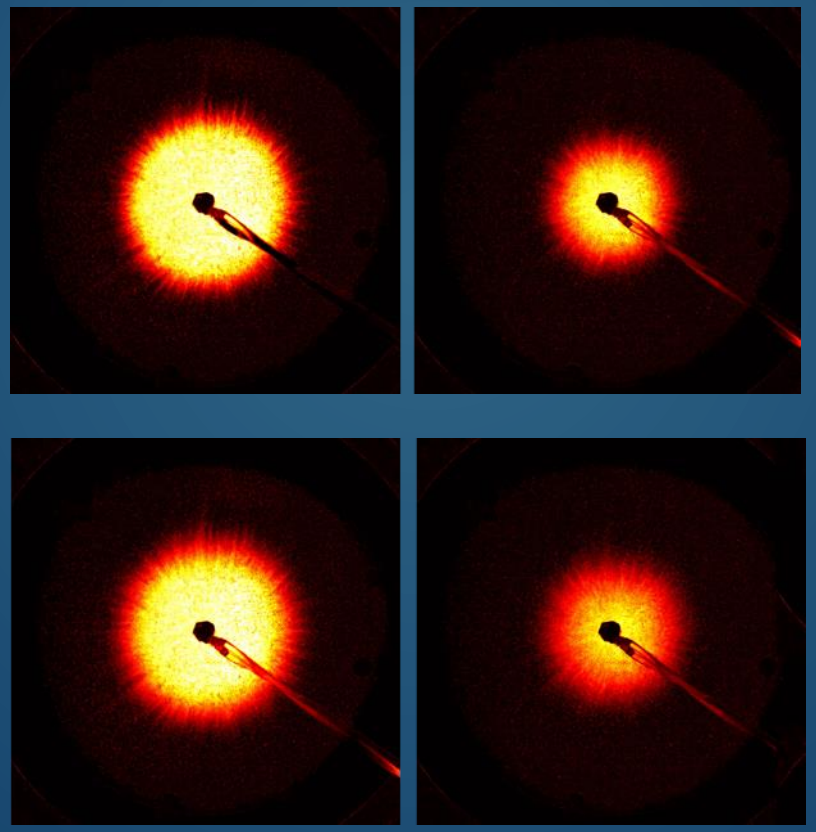
Lost gas - can we do something clever here?



A role for barrier gas

- The first gas injected sustains the highest losses
- Could we use an inert and cheap gas as this sacrificial component?
  - Nitrogen?
  - CO2?

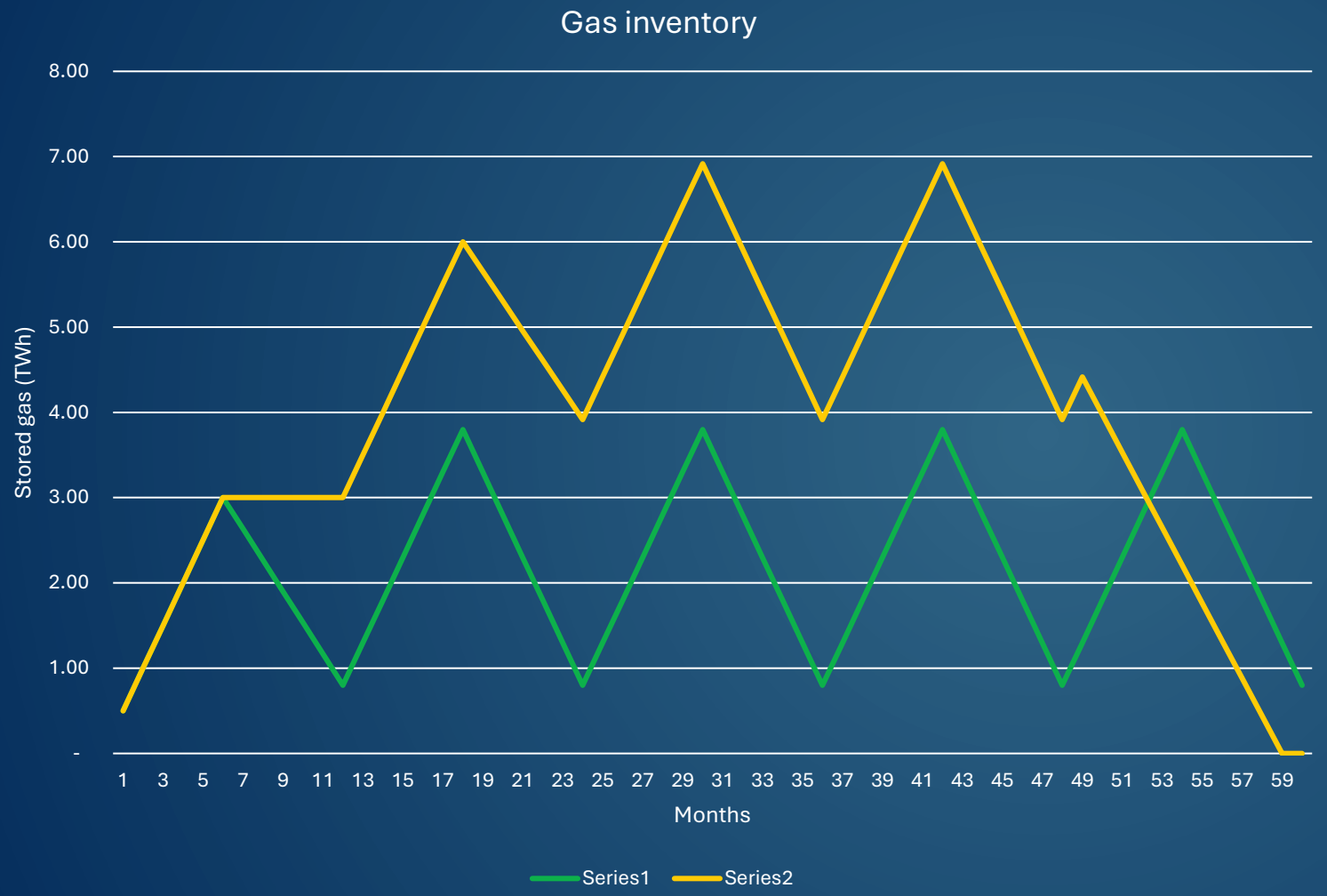
  Recognise requirement for deblending of barrier gas and water



Lab-based experiments

- Cycles 1 -4
- Orange area shows mixed zone

Relative economics



Key comparison: Net Present Cost

Cushion gas is recovered at end of life (slowly)

Barrier gas (or early injection gas) is permanently lost

Value difference is key

Low cost Barrier gas would improve aquifer economics

Aquifers vs depleted fields - summary

Storage type	Depleted gas field	Aquifer
Integrity	Structure – good Wells – need to confirm	Structure – need to confirm Wells - good
Pressure	Low – requires cushion gas	High – may require relief
Injection	Wide pressure range required	Narrow (but high) pressure range
Deblending	Stored hydrogen will mix with residual methane and water	Stored hydrogen will mix with barrier gas (if used) and water
Cost performance	Cushion gas impacts capex budget	Net present cost of lost gas less than NPC of cushion gas More opportunities from barrier gas
Permitting	“Conventional wisdom” although no sites currently licensed	In NSTA contemplation, but no licenses issued

Thank You

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