
Northern
Endurance
Partnership
CCS Networks Industry
Best Practice Forum 2025

Disclaimer

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- By participating, each attendee agrees that they will not disclose to, request from, or discuss with any competitor any competitively sensitive information relating to their specific activities.
- Competitively sensitive information includes, without limitation, current or future prices or price elements, pricing strategies, discounts, bids or intentions to bid, margins, costs, capacity, output, production plans, procurement terms, suppliers on preferential terms, allocations of customers or territories, market entry or exit plans, commercial strategies, or any information that could reduce strategic uncertainty between competitors. No discussion, agreement, understanding, or signalling (either formal or informal) about coordinating conduct in the marketplace is permitted.
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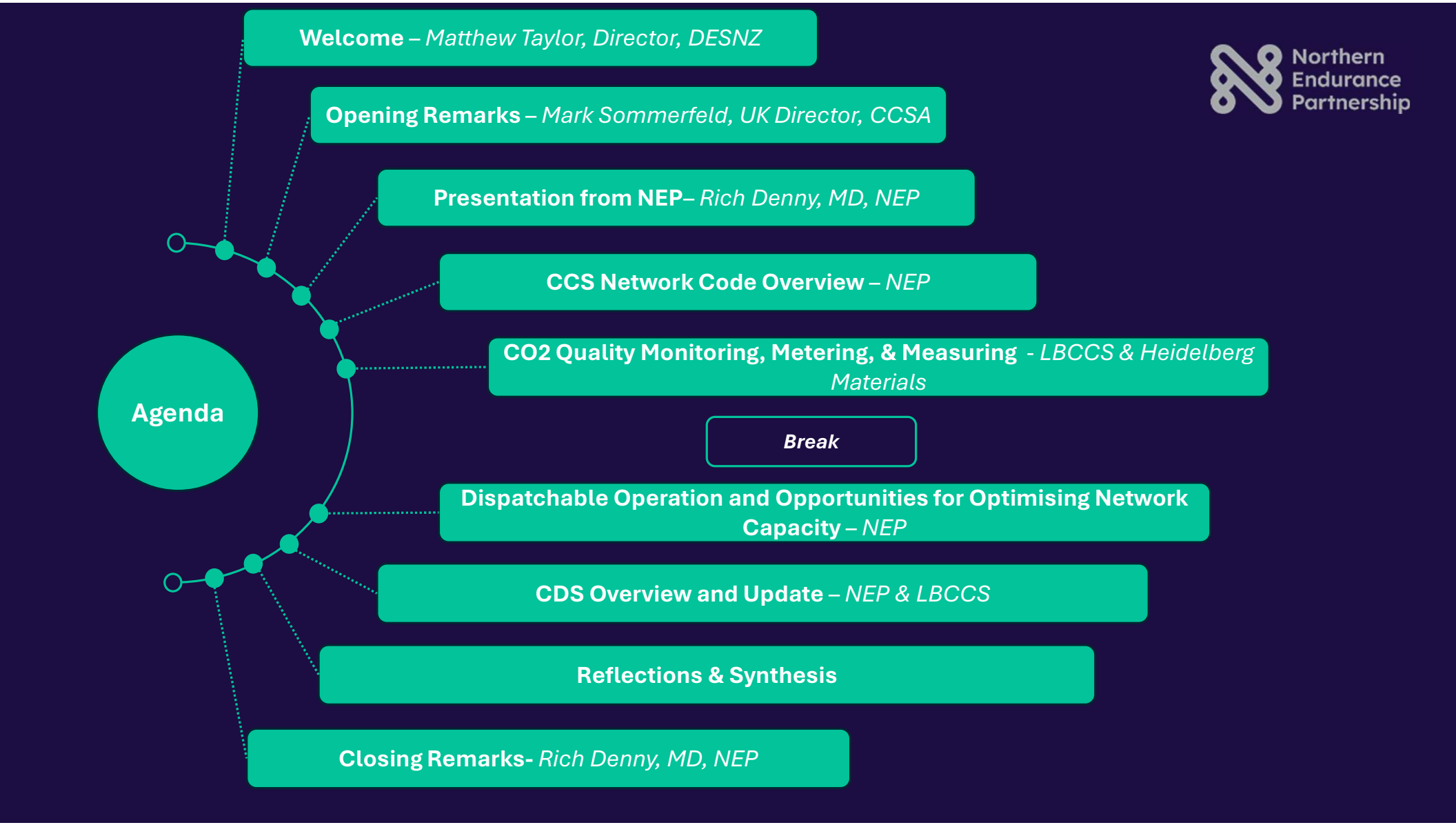

Agenda
Welcome – Matthew Taylor, Director, DESNZ
Opening Remarks – Mark Sommerfeld, UK Director, CCSA
Presentation from NEP– Rich Denny, MD, NEP
CCS Network Code Overview – NEP
CO2 Quality Monitoring, Metering, & Measuring - LBCCS & Heidelberg Materials
Break
Dispatchable Operation and Opportunities for Optimising Network Capacity – NEP
CDS Overview and Update – NEP & LBCCS
Reflections & Synthesis
Closing Remarks- Rich Denny, MD, NEP
Northern Endurance Partnership

Welcome

Northern Endurance Partnership

Matthew Taylor, Director, DESNZ

Opening remarks

Northern Endurance Partnership

Mark Sommerfield, UK
Director, CCSA

The Northern Endurance Partnership

EAST CO_2AST CLUSTER

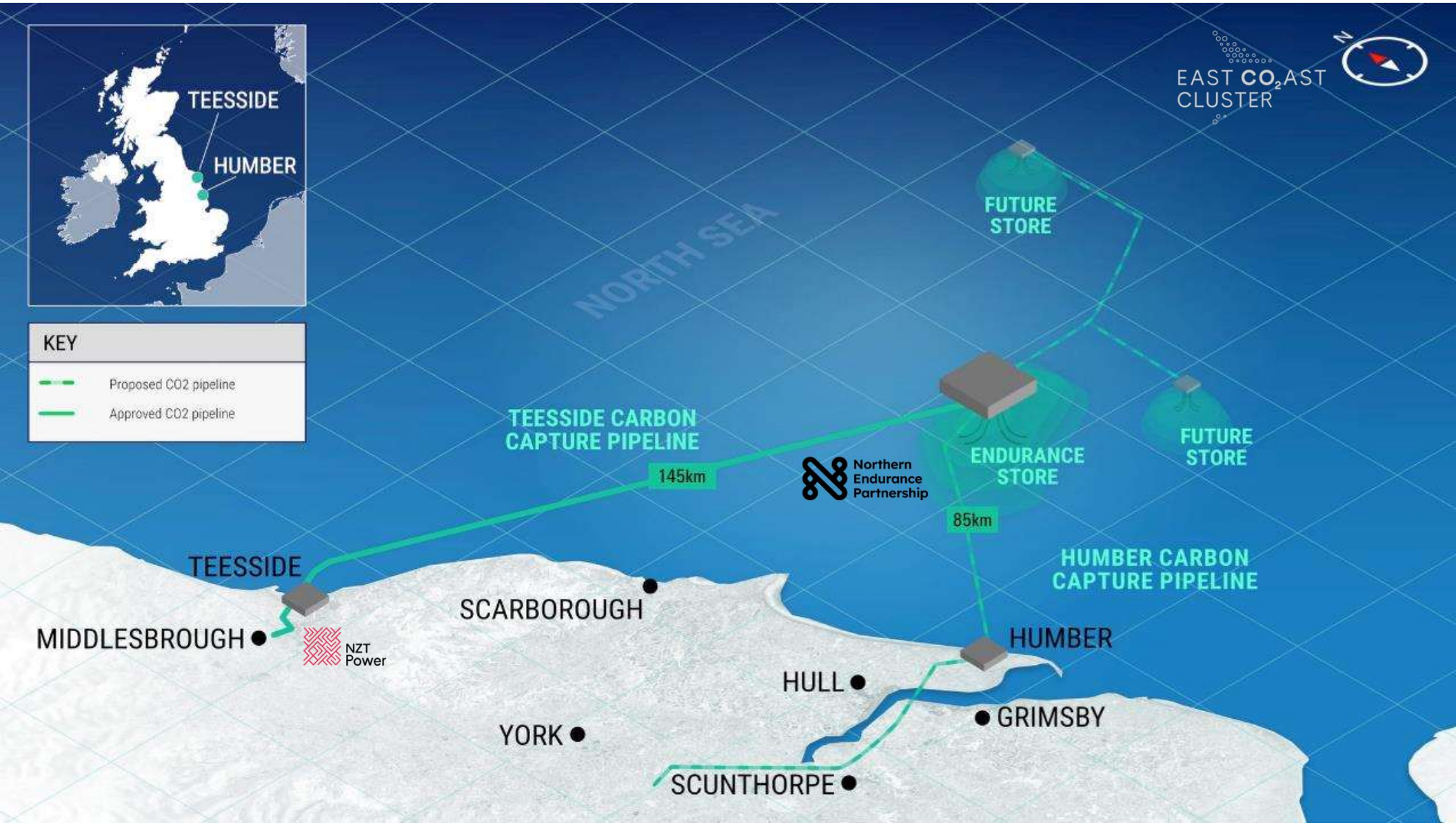
Track-1 CCUS Cluster covering almost 50% of the UK's total industrial cluster emissions (Teesside & Humber)

Northern Endurance Partnership

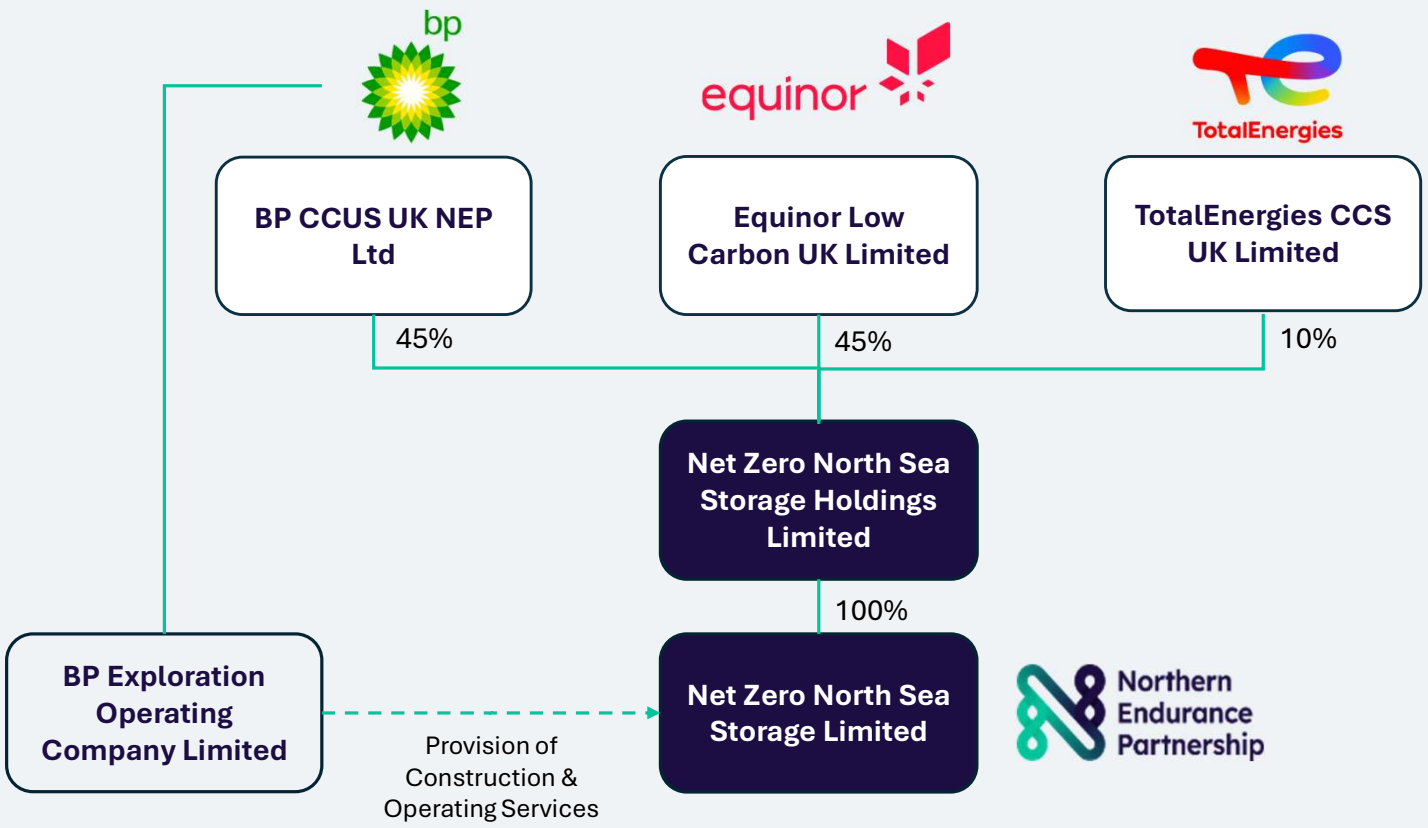
Developer of onshore and offshore infrastructure needed to transport CO2 from carbon capture projects across Teesside and the Humber – collectively known as the East Coast Cluster - to secure storage under the North Sea.

Power Industrial Hydrogen BECCs

A diverse mix of carbon capture projects essential to the UK meeting net zero targets while protecting and creating tens of thousands of jobs.

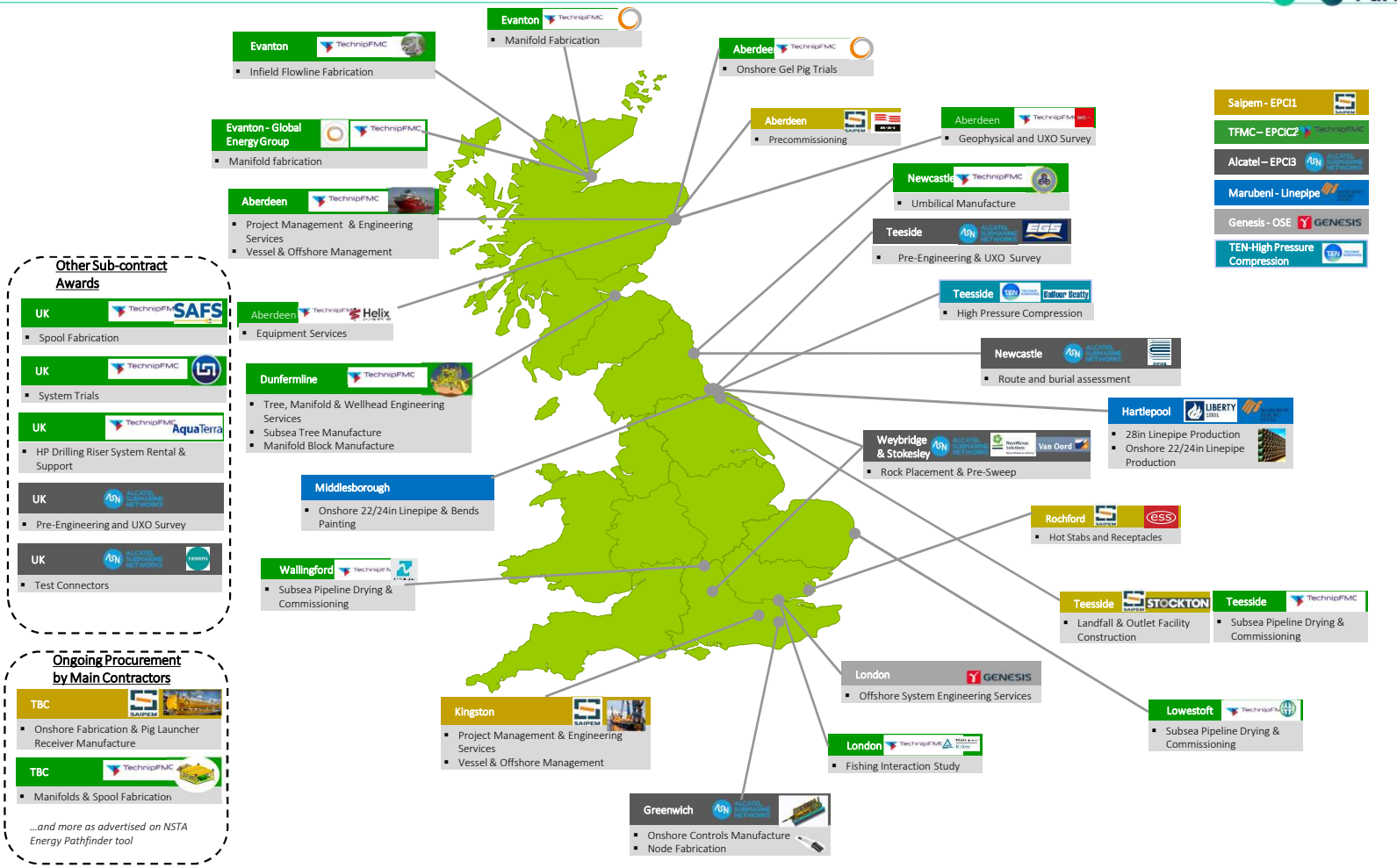

TEESSIDE
HUMBER
KEY
Proposed CO2 pipeline
Approved CO2 pipeline
EAST CO2AST CLUSTER
N
NORTH SEA
FUTURE STORE
TEESSIDE CARBON CAPTURE PIPELINE
145km
Northern Endurance Partnership
ENDURANCE STORE
FUTURE STORE
85km
HUMBER CARBON CAPTURE PIPELINE
TEESSIDE
SCARBOROUGH
MIDDLESBROUGH
NZT Power
HUMBER
HULL
GRIMSBY
YORK
SCUNTHORPE

NEP Structure



NEP is in an incorporated joint venture established solely to develop and operate CO_2 transportation and storage infrastructure on behalf of the NEP Shareholders – bp, Equinor and TotalEnergies.

NZT and NEP Supply Chain – UK Content



Investing in Teesside's Future by Backing Local Skills Training

- NZT Power and NEP Operational Scholarship Programme
- Balfour Beatty - NZT Power & NEP Power Project Apprentice Scheme
- The Tees Valley Net Zero Industry Scholarship

Humber Carbon Capture Pipeline

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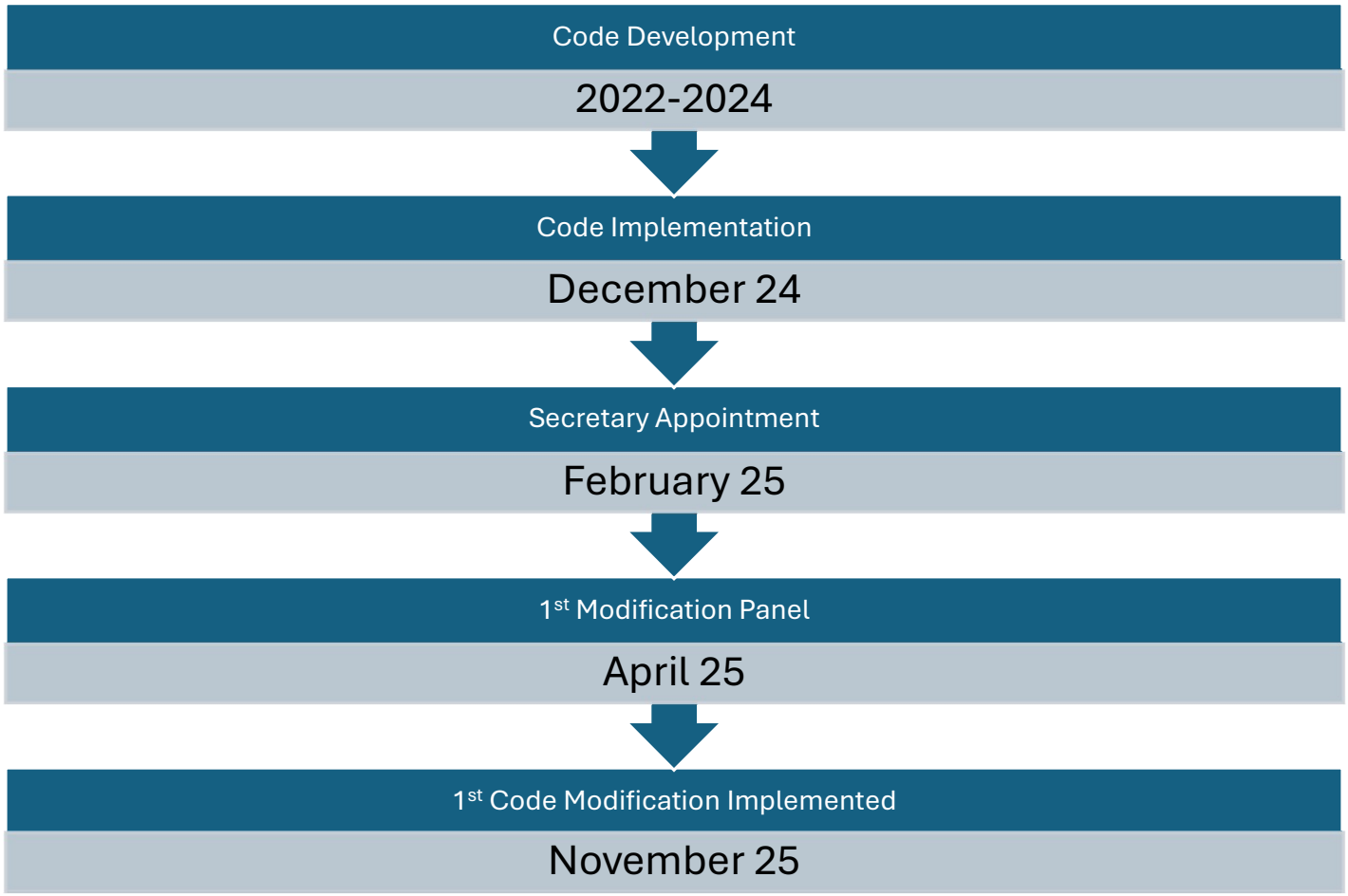
CCS Network Code Overview and Status

CCS Network Code

The CCS Network Code sets out the commercial, operational and technical interfaces between T&SCo's and Network Users. It includes:

- Governance
- User connection process
- Agreement templates
- Capacity allocation and nominations
- CO_2 specification management
- Charging methodology
- Network operation – Common Interface Procedures
- Data sharing

CCS Network Code Status



CCS Network Code Status

- Modification panel in progress. Voting members include:
  - Net Zero North Sea Storage Ltd (NEP)
  - Liverpool Bay CCS Ltd
  - Net Zero Teesside Power Ltd
  - Castle Cement Ltd
  - Protos ERF CCS Ltd
- Modifications raised so far include:
  - User venting requirements (implemented)
  - Chairperson expense management
  - Housekeeping
  - NEP annexure correction
- Website launched
- Permanent Panel Chairperson appointment ongoing

Network Code Website:

Northern Endurance Partnership

CO2 Quality Monitoring, Metering, & Measuring - LBCCS

CO2 Quality Monitoring, Metering and Measurement

CCS Networks Industry Best Practice Forum

Barry Allan – Head of Commercial and Negotiations

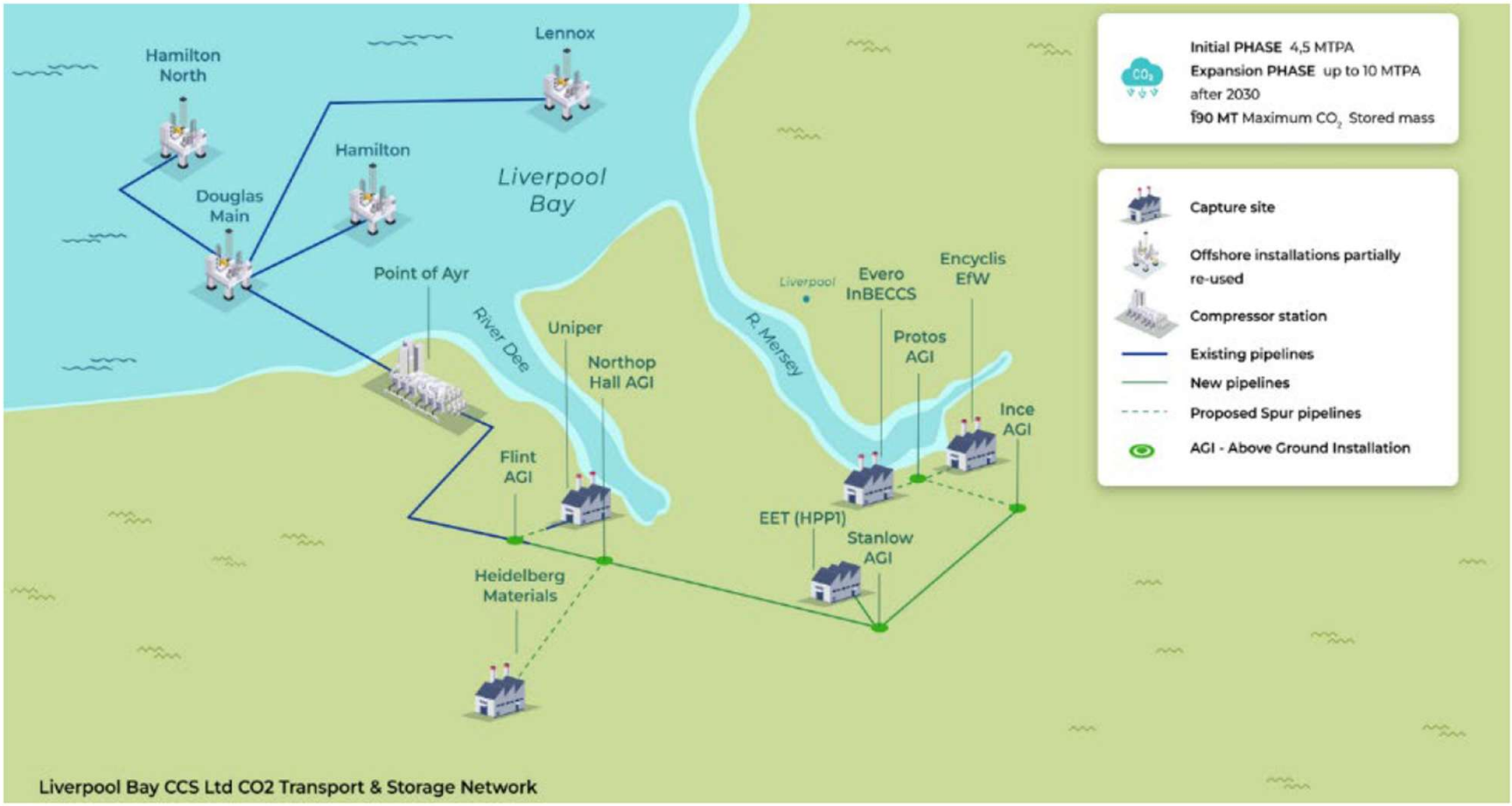
9 December 2025

Liverpool Bay CCS Limited

Agenda

- Introduction to the Liverpool Bay T&S Network
- T&Sco Regulatory and Commercial Context
- Technical Context
- Liverpool Bay T&S Measurement and Monitoring Requirements
- Reflections on Setting Requirements

Introduction to the Liverpool Bay T&S Network



Priority list users shown only.
Standby list includes EET ICC (Essar), HPP2 (EETH), Parc Adfer EFW (Enfinium), Runcorn EFW (Viridor), Silver Birch (Climeworks)

T&Sco Regulatory and Commercial Context

- Liverpool Bay CCS Limited ("LBCCS") was awarded an Economic Licence and acceded to the CCS Network Code on 22nd April 2025
- Under its Licence LBCCS must offer access to the T&S Network under the terms of the Code
- Users must also accede to the Code, and have a Connection Agreement with LBCCS, to deliver carbon dioxide to the Network
- The Connection Agreement is a template under the Code and specifies the Entry Provisions for the Delivery Point
- Users must ensure that carbon dioxide delivered to the Network is in accordance with the Entry Provisions, which include:
    - Carbon Dioxide Specifications (Code Annexure B)
    - Measurement Requirements, including the CO2 Quality Monitoring Procedure (Code Annexure C)
    - Local Requirements (Code Section F, 3.8)
- The CO2 Quality Monitoring Procedure must be in accordance with Code Annexure D (CO2 Quality Monitoring Procedure Terms of Reference)
- The LBCCS Carbon Dioxide Specifications and Measurement Requirements were incorporated into the Code at Economic Licence award
- The CO2 Quality Monitoring Procedure was implemented on 22nd July 2025, becoming part of the Code
- The Padeswood and Protos projects took FID in September 2025, acceding to the Code, and becoming Users of the Liverpool Bay T&S Network
    - Padeswood: cement project being developed by Heidelberg Materials
    - Protos: energy from waste project being developed by Encyclis

Technical Context

- It is critical for T&Sco to control and monitor deliveries to protect the integrity of the T&S infrastructure for the benefit of all Users
    - Pipelines
    - Compressors
    - Valves / wellheads / pig traps
    - Wells and reservoir
- The main sources of corrosion/erosion risk include:
    - Free water
    - Induced aqueous phase
    - Strong acids (especially sulphuric and nitic acids)
    - Solids (e.g., organic salts, elemental sulphur, ammonium carbamate)
- Chemical reactions can take place between impurities to produce:
    - Sulphuric and nitric acids (e.g., SOx, Nox, O2, water)
    - Increase in water content
    - Formation of solids
- Experimental data is limited, and real-world experience even more so
    - A very high number of chemical reactions are possible (thousands)
    - Temperature, pressure, and CO2 phase all have an impact
- For design and operation, it is important for the T&Sco to be prudent, especially where there are multiple Users with different compositions
    - There have been many examples of unexpected CCS infrastructure failures
    - More “tolerant” design solutions may be possible with higher-grade pipeline metallurgy but would be prohibitively expensive

Liverpool Bay T&S Measurement Requirements

Key provisions include requirements regarding the following:

- Carbon dioxide stream measurement requirements
  - Equipment certification
  - Guidance on equipment selection
  - Metering uncertainty
  - Redundancy
  - Configuration
  - Calibration and verification
  - Standards
- Metering data transfer
  - Data requirements
  - Data frequency
  - Equipment requirements
  - Maintenance
- Operations
  - Commissioning
  - Maintenance
  - Verification
  - Calibration
  - Witnessing and audit
- Procedure in the case of non-compliant deliveries

Liverpool Bay T&S CO2 Monitoring Requirements

Key provisions include requirements regarding the following:

- Carbon dioxide monitoring plan
    - Minimum monitoring requirement
    - Testing frequencies
    - Non-compliance definition
    - Actions following non-compliance
- Data reporting
- Offline monitored component sampling philosophy
- Relevant standards or accreditations
- Early warning systems
- Response to non-compliant carbon dioxide
- Communication and response timeframes when non-compliant carbon dioxide is detected
- Process for user connection following isolation
- Process and requirements for derogations
- Periodic review of monitoring requirements

Reflections on Setting Requirements

- Finalising the measurement and monitoring requirements were very challenging processes for LBCCS and the cluster
    - Long, heavily-arbitrated negotiations between T&Sco, Users and DESNZ were required to resolve
- A key misalignment between T&SCo and Users was whether specification thresholds were “hard” or average limits
    - T&Sco intention is that limits are “hard”, not to be exceeded limits; Users sought more flexibility
- Business models place T&Sco and User in a win/lose situation – direct conflict between the T&S and User business models
    - Under its Licence T&SCo is incentivised to maintain Availability and minimise outages
    - User are incentivised to deliver captured carbon dioxide to the T&Sco and penalised for delivering non-compliant carbon dioxide
- Local Requirements definition in the Code is not uniformly understood – drafting is very broad and open to interpretation
- The CCS Network Code, as drafted, therefore creates a cross-chain risk, borne by T&Sco and the User, depending on the outcome of negotiations
- The Code and Economic Licence, as drafted, do not allow more flexible commercial solutions which could create win-win outcomes
- Conversations with Users on requirements should set clear expectations on requirements from project inception
- The correct sequencing is critical: alignment on User requirements should occur before design decisions are made and contracts agreed
- There is not a common understanding of best available technology for carbon dioxide monitoring
- The industry is immature: science and technology will evolve as experience is gained. The industry, and the business models in which they operate, must be sufficiently flexible to accommodate new learnings that lead to improved safeguards for system integrity

CO2 Quality Monitoring, Metering, & Measuring – Heidelberg Materials

Northern Endurance Partnership

Break

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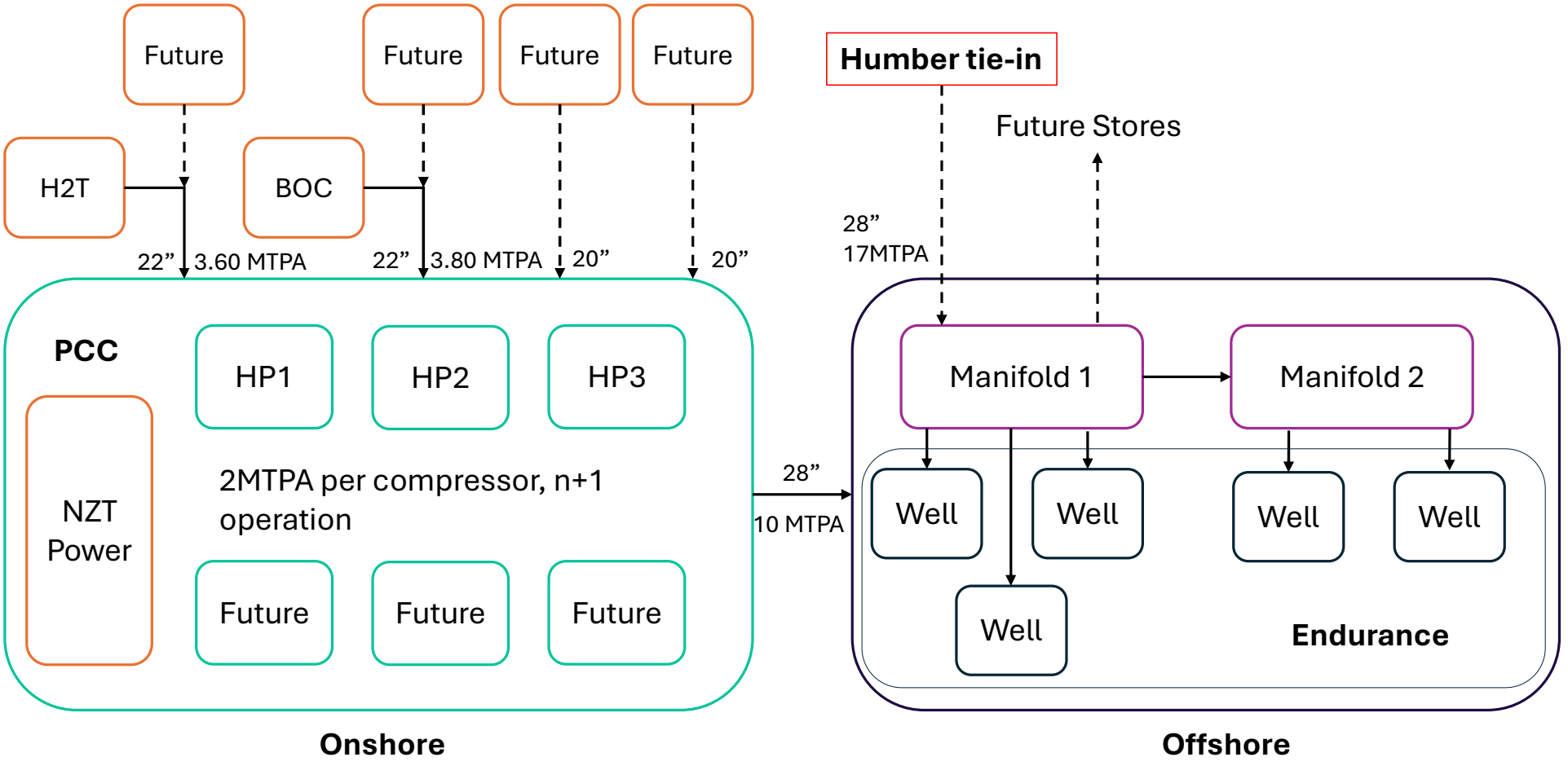
Dispatchable Operations and Opportunities for Optimising Network Capacity Utilisation

NEP

NEP Design & Capacity Overview



NEP Obligated Network Capacity (ONC)

The ONC is the network capacity that must be made available to Users on aggregate. It has expressed in terms of:

- Maximum instantaneous flow
- Maximum annual cumulative flow
- Minimum instantaneous flow
- Overall store capacity

Component of ONC	Value
Maximum Instantaneous Flow Rate	4.21 MTPAi
Maximum Annual Cumulative Flow	4.00 Mt
Minimum Instantaneous Flow Rate	0.2 MTPAi
Overall Store Capacity	100 Mt

Maximum Annual Cumulative Flow – Endurance Permit

Annex 4

Operational Requirements

1. Earliest start date for commencement of CO_2 injection: 1 October 2027
2. The latest date that CO_2 injection may commence is twenty four calendar months from the date in paragraph 1 of this Annex.
3. Maximum period of injection: 25 Years from the date at of commencement of injection.
4. Maximum quantity of CO_2 authorised to be stored: 100 Million Tonnes ('**MT**')
5. Composition of CO_2 stream: ≥ 96 mol % CO_2, ≤50 ppm mol water
6. Maximum average reservoir pressure: 226 bar absolute ('**bara**') (3273 pounds per square inch absolute ('**psia**')) at datum depth 1300m True Vertical Depth Subsea
7. Maximum injection rate: 4 Million Tonnes Per Annum ('**MTPA**') average for the gross CO_2 stream for the storage site
8. Maximum injection rate per well: 1.5 MTPA
9. If maximum well rates as per paragraph 8 of this Annex are sustained for periods of longer than 90 days, then regularity of tubing inspection and well integrity reviews must be re-assessed and discussed with the OGA
10. Maximum well head injection pressure: 156 bar (2263 psia) at flowing bottom hole pressure of 259 bara (3753 psia)
11. Maximum bottom hole pressure (datum depth ref needed): 259 bar (3753 psia) at datum depth 1300m TVDSS
12. Perforation Strategy: Minimum 50m True Vertical Thickness stand-off below the base of the Rot Clay within the Bunter Sandstone interval

Development must balance rate, total storage volume and pressure to demonstrate "no significant risk of leakage"

Maximum quantity stored: 100 Mt

Maximum reservoir pressure: 226 bar

Maximum quantity stored per year: 4 Mt

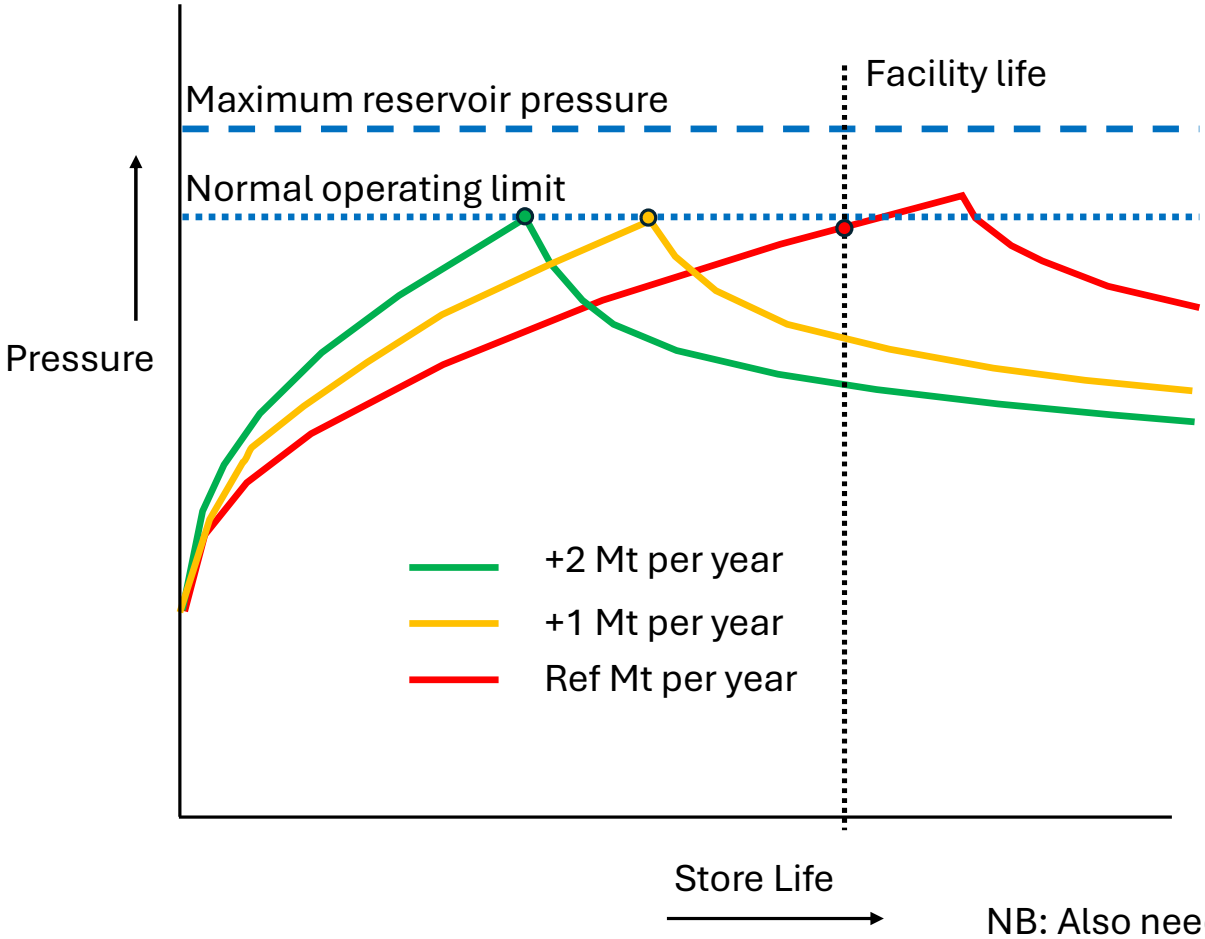
Maximum injection rate per well: 1.5 Mtpa

so maximum injection with 5 wells: 7.5 Mtpa

Maximum bottomhole well pressure: 259 bar

Storage permit based on the subsurface model that gives 90% chance of delivering outcome

Maximum Annual Cumulative Flow



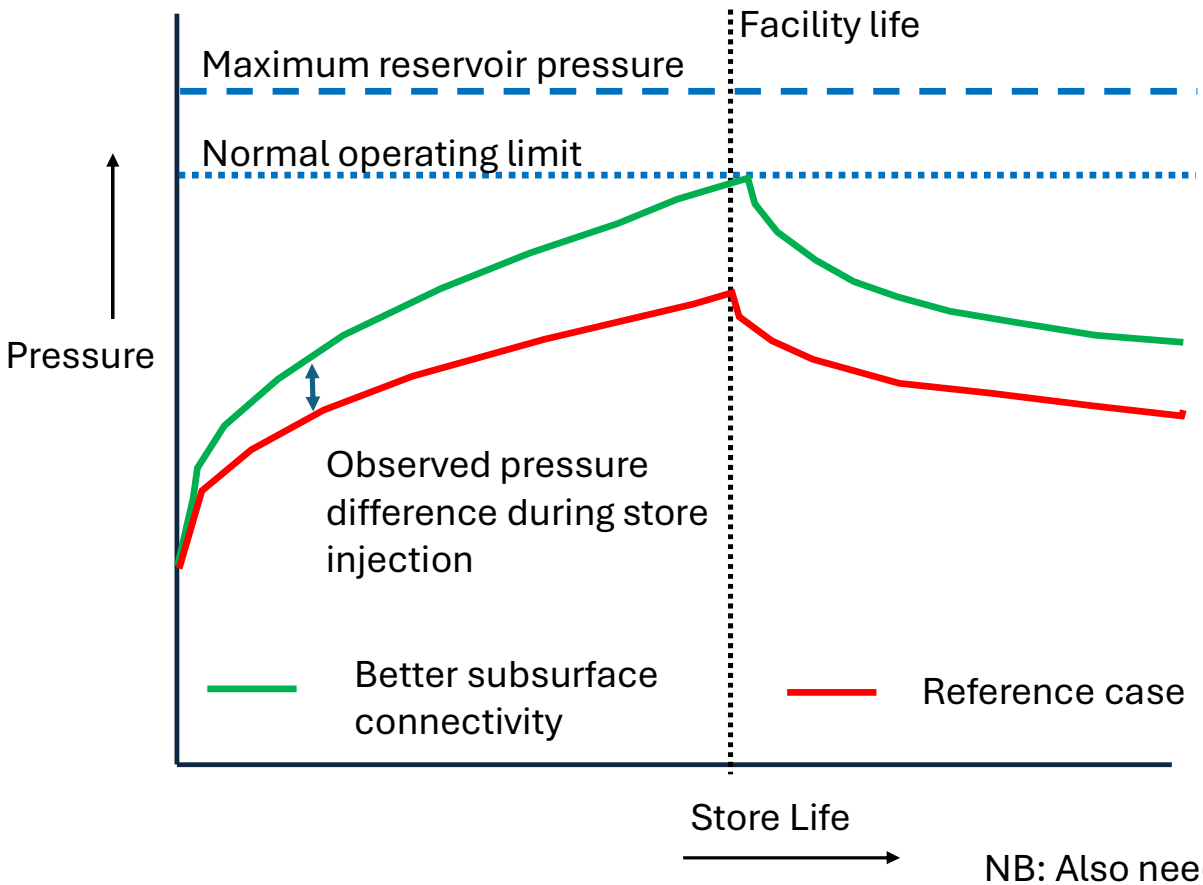
For the same subsurface outcome in a saline aquifer:

If annual storage rate increases:

- Pressure increases faster to pressure limit
- Life of field shortens when pressure forces shut in resulting in decrease in volume stored

NB: Also needs to consider well injectivity and pressures

Maximum Annual Cumulative Flow



For different subsurface outcome in a saline aquifer:

If subsurface connectivity is better than forecast:

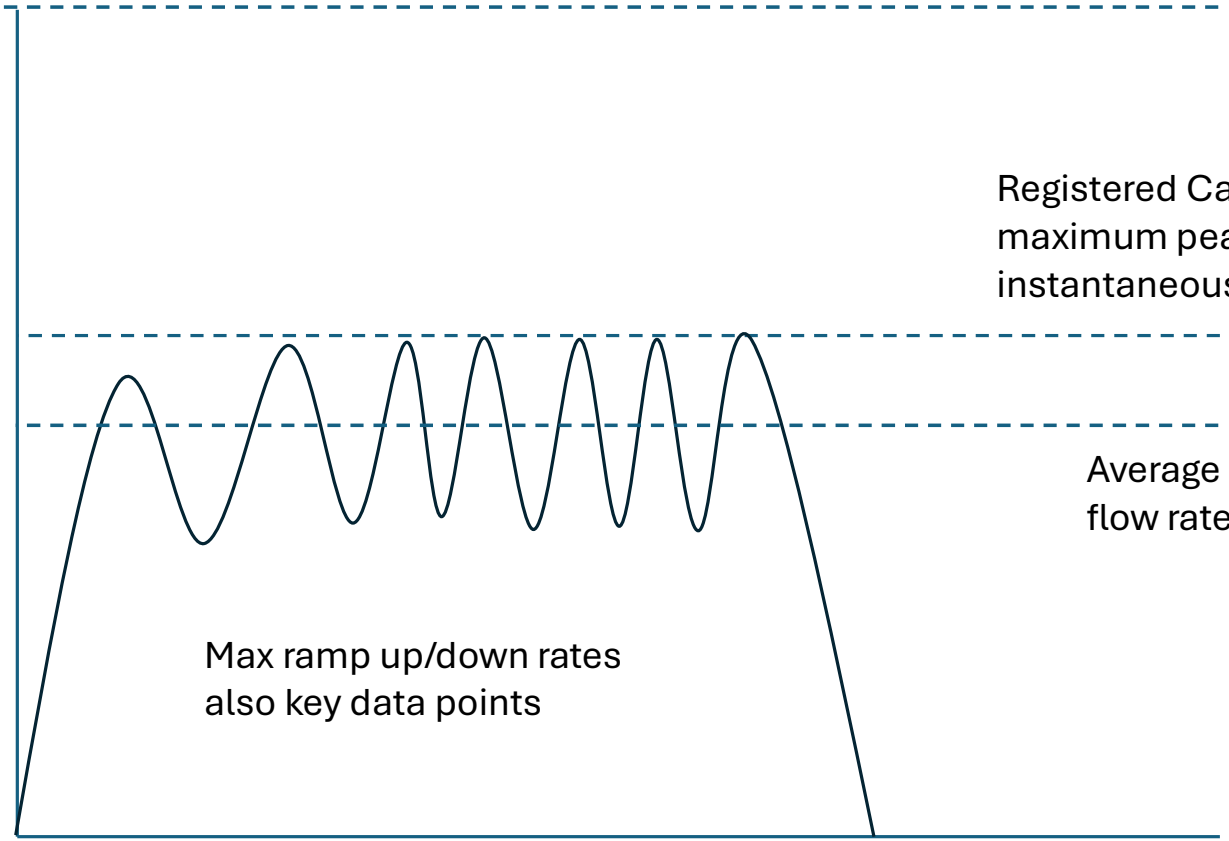
- Pressure increases more slowly to pressure limit
- Total storage and injection rates can be increased (with storage permit update)

NB: Also needs to consider well injectivity and pressures

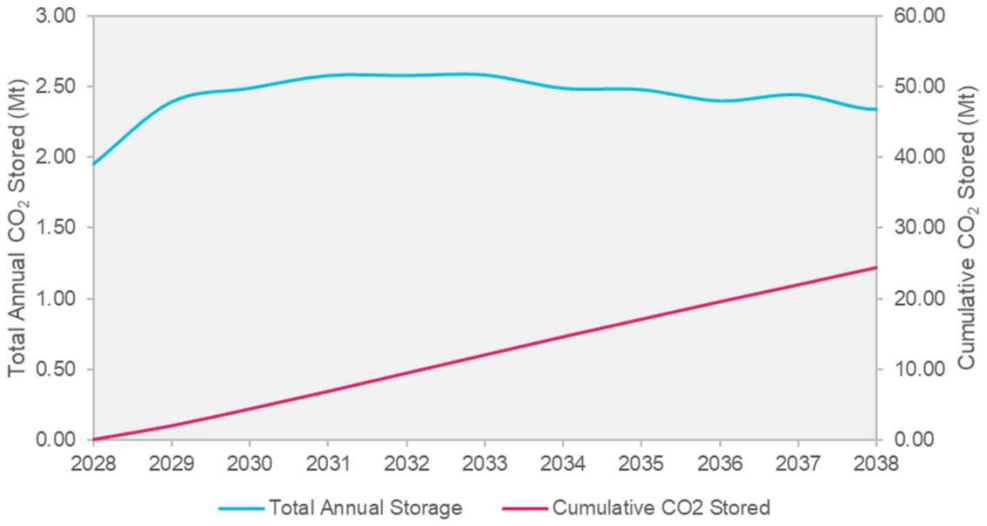
Maximum Instantaneous Flow Rate

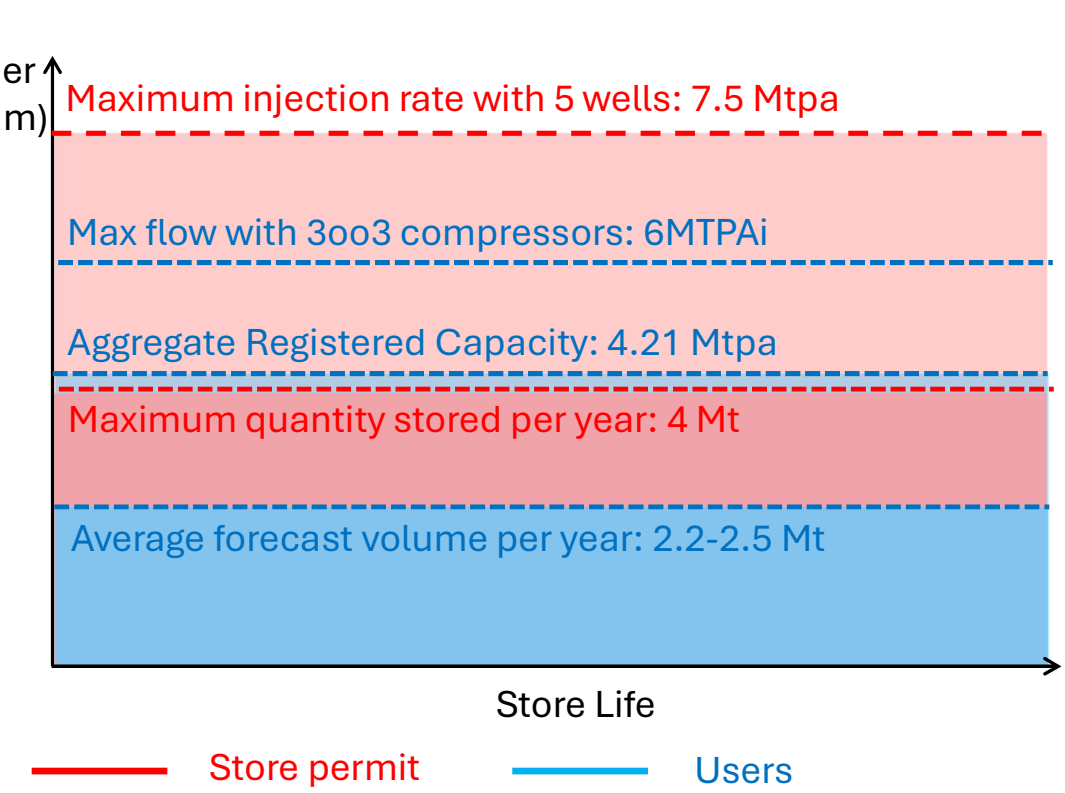
ONC - 4.21 MTPAi is the aggregate of registered capacities

Planned Initial User Registered Capacities



Capacity Utilisation

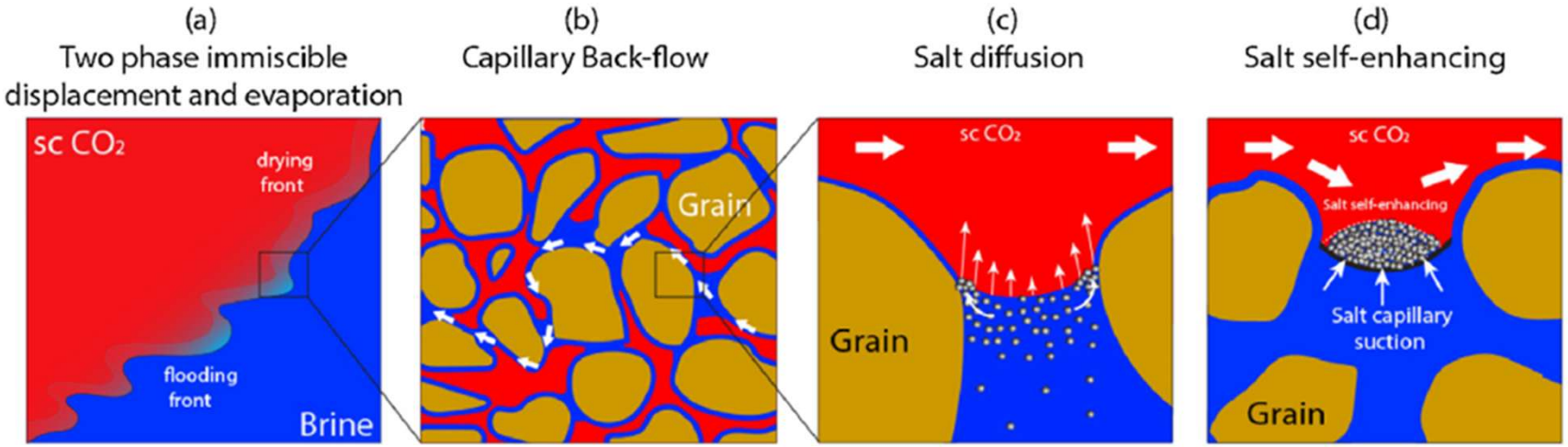




Minimum Instantaneous Flow Rate

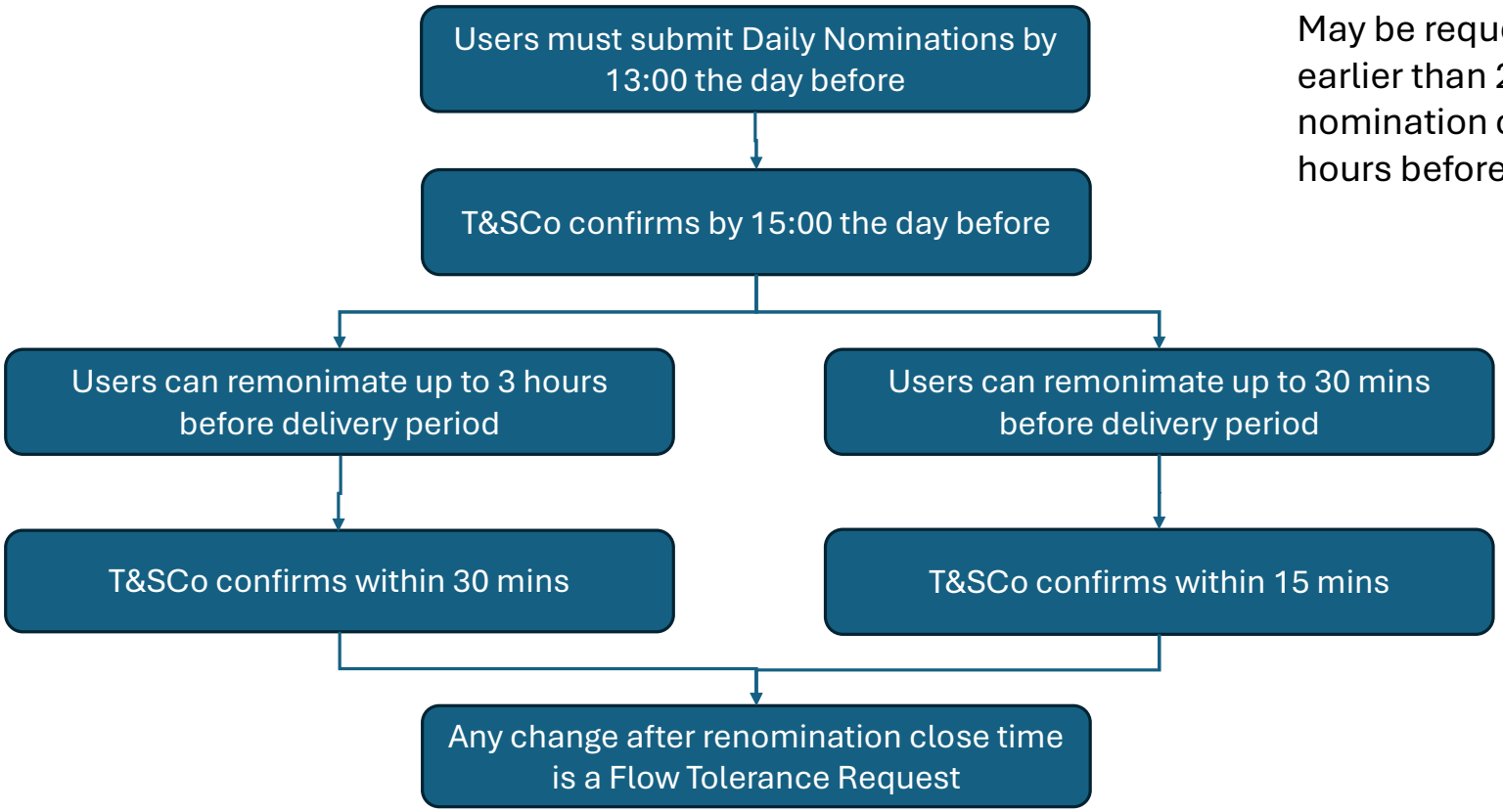
Driven by lowest rate users' minimum instantaneous rate

- CO_2 has a drying effect that leaves salt (halite) behind when it is in contact with the high salinity formation water
- The rate (and associated velocity) controls how the salt is distributed near wellbore
- Halite precipitation is **reduced with continuous injection at high rate** as the brine is pushed away from the wellbore



Schematic illustration of different physical mechanisms contributing to the process of salt precipitation
(Please note that the length scale has been for the sake of clarity exaggerate in these drawings)

Enhanced Response Service



May be requested by users no earlier than 24 hours before nomination close time and up to 3 hours before delivery period.

Dispatchable Network Operation

Standard Response Service — >3 hours notice

Spare compressor(s) will be maintained in “warm” mode:

- Compressor not energized
- Auxiliary systems in operation

Enhanced Response Service — >30 mins notice

Spare compressor(s) will be maintained in “hot” standby mode:

- Compressor will be energized and pipework pressurized.
- All systems operational (e.g. lube oil, seal gas etc.)

Dispatchable Network Operation

NEP is designed to operate in a dispatchable mode, though it introduces additional considerations.

No network flow

- Compressors maintained at requested readiness level

CO_2 Flow Commences

- Compressor start-up
- Injection into wells commences

CO_2 Flow Ceases

- Compressor shutdown and placed on standby
- Subsea injection valves close to maintain pressure.

Increased compressor starts/stops	• Increased maintenance
Increased well cycling	• Increased fatigue loading • Increased requirement for water washes

Why Optimise Network Capacity?

1. Increased store capacity utilization, thereby greater climate impact.
2. Connect additional users to network
3. Reducing user tariff per tonne
4. Earlier realization of Endurance store upside potential
5. Lower opex per tonne
6. Mitigate challenges of intermittent operation

Potential Opportunities for Optimising Network Capacity

Category	Approach	Considerations
No/limited overbooking - Bring new users on to backfill dispatchable users going offline	User comes online once dispatchable user comes offline – no-overbooking.	• Intermittent network operation • Potentially significant code changes • Potential for discounted tariff rates.
	Short-term overbooking to manage switch-over smoothly	• Potentially significant code changes • Potential for discounted tariff rates.
Overbooking - Increase maximum instantaneous flowrate part of ONC to permit higher total aggregate user registered capacity	Operate additional (3rd) compressor to increase total network instantaneous capacity.	• Potentially minimal code changes • Overbooking may increase risk of user curtailment • Additional costs of 3rd compressor and potential impact on operational availability if operating spare is utilised.

List is indicative, may not be exhaustive and is intended to generate discussion.

Capacity Optimisation Discussion Points

- What constraints do you see on capacity utilisation?
- What are the benefits/risks of overbooking network capacity?
- What kind of projects may be able to provide ‘flexibility services for networks’?
- How could such dynamic capacity management be managed under the code?

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Central Data Service

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Reflections & Synthesis

Learning for next time

- What went well or could be improved?
- What kind of topics do you want to see covered in future forums?
- How would you like to see future forums run?

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Closing Remarks