Carbon Capture, Utilisation and Storage (CCUS)–Operational Challenges

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Agenda & Introduction

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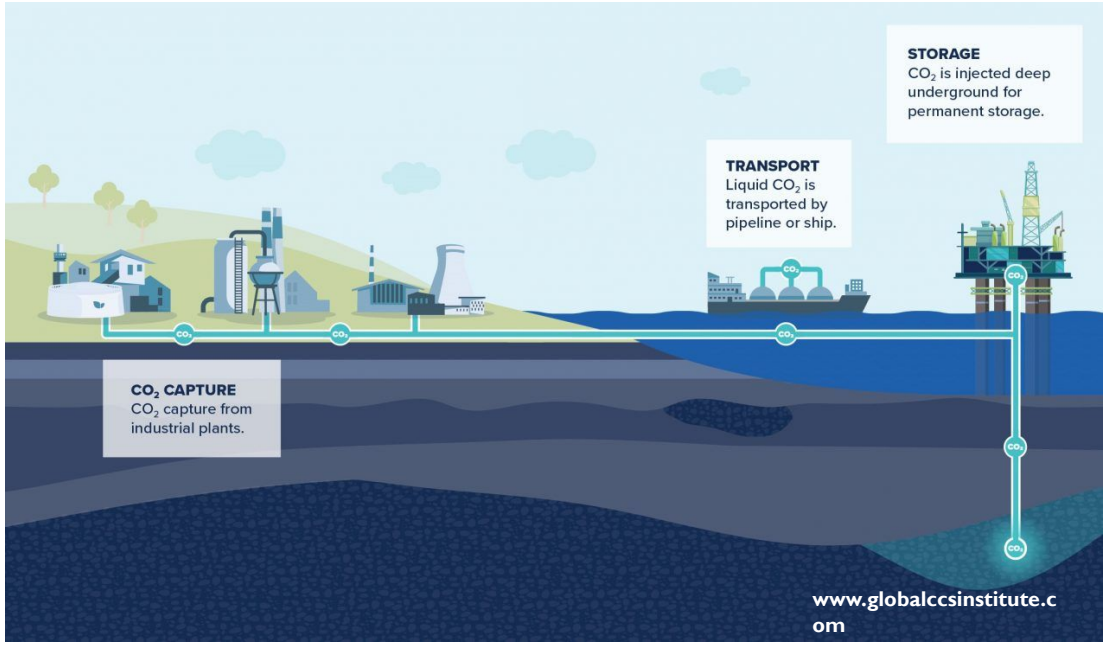
Agenda

- CO_2 Sources and Composition
- Phase Behaviour and Transportation
- CO_2 Specification Considerations
- Variable Output and System Control
- Conclusions



Introduction

Carbon sequestration is essential for reducing CO_2 levels and combating climate change but has various barriers and operational challenges to overcome. This presentation will address and discuss some of the key operational challenges associated with the development of CCUS industrial clusters and CO_2 transportation networks, covering:

- Depleted O&G reservoirs & saline aquifers
- New infrastructure & re-purposed infrastructure
- Pipeline transport and shipping
- Full chain system operability.

CO_2 Sources And Composition

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CO_2 emitter impurities, capture requirements and flow 'stability' vary by emitter type.

- Onshore industrial sites – consistent emissions but shutdowns occur.
- Onshore power generation – intermittent for dispatchable power generation.
- Distributed sources – difficult to capture and accumulate.
- Offshore industry – accumulation and transport.

Impurities impact phase behaviour

- SO_x, NO_x, H_2S and O_2 – can react to form corrosive acids or deposit sulphur.
- Non-condensables:
  - Expand multi-phase region of phase envelope.
  - Can impact compression requirements.
  - Impact shipping design and pressure required to ensure liquid phase

Specification crucial for system design:

- Early agreement, impact across full value chain.
- Emitters: impact on selection and capture technology.
- Transportation: impact on materials and system operability.
- Shipping: impact on transportation pressure.

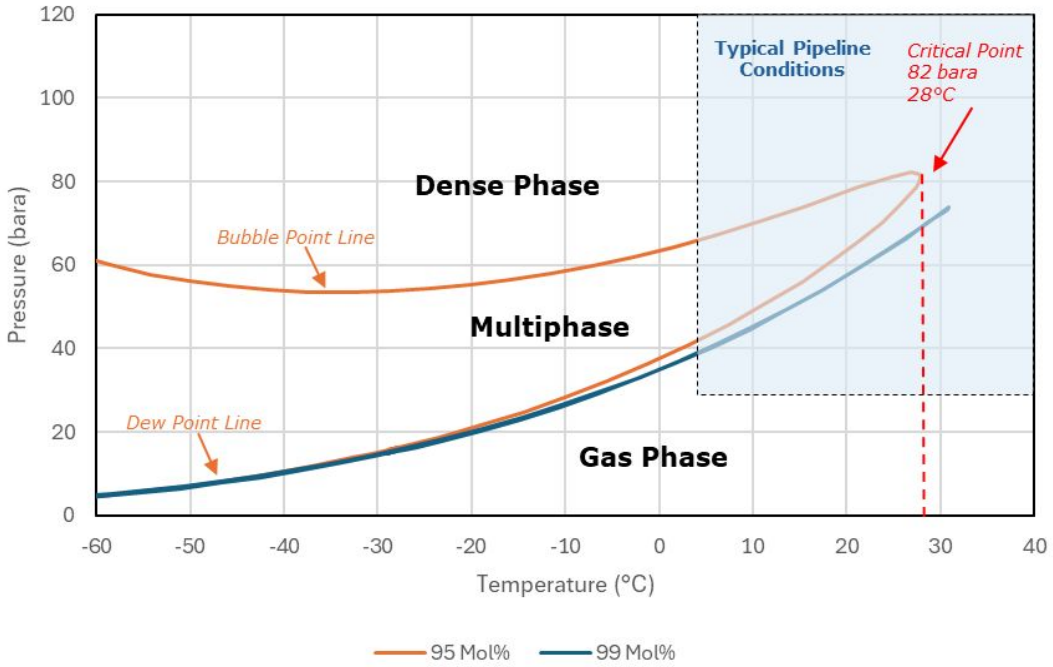
		Stream 1	Stream 2	Stream 3	Stream 4	Stream 5
CO2 Stream	**Carbon Dioxide**	min 96mol%	≥95.0%	max 100%	99.4vol%	min 91% gas min 96% dense
Non-condensable	**Hydrogen**	≤20,000ppmv (2vol%)	≤10,000ppmv (1vol%)	≤20,000 (2%)	≤5,000ppmv	≤20,000 (2mol%)
	Carbon Monoxide	<2,000ppmv	<1,000ppmv	≤2,000ppmv	≤1,000ppmv	not specified, see non-condensables
	Total volatiles (non-condensable) N_2, Ar, CH_4	<40,000ppmv (4%) including H_2	<40,000ppmv (4%) including H_2 and CO	saturation pressure not to exceed 80barg	≤6,000ppmv including O_2, H_2 and CO.	saturation pressure not to exceed 80barg
Trace Impurities	**Water**	<50ppmv	≤50ppmv	≤50ppmv	≤50ppmv	≤50ppmv
	Oxygen	<10ppmv	≤10ppmv	≤10ppmv	≤20ppmv	≤10ppmv
	SO_x/NO_x	≤100ppmv each	≤30ppmv each	≤100ppmv each	≤10ppmv each	≤100ppmv SO_x <20ppmv NO_x
	Hydrogen Sulphide	<19.56ppmv	<5ppmv in total	≤80ppmv (gas) ≤20ppmv (dense)	≤10ppmv	≤20ppmv (dense)

Phase Behaviour & Transport

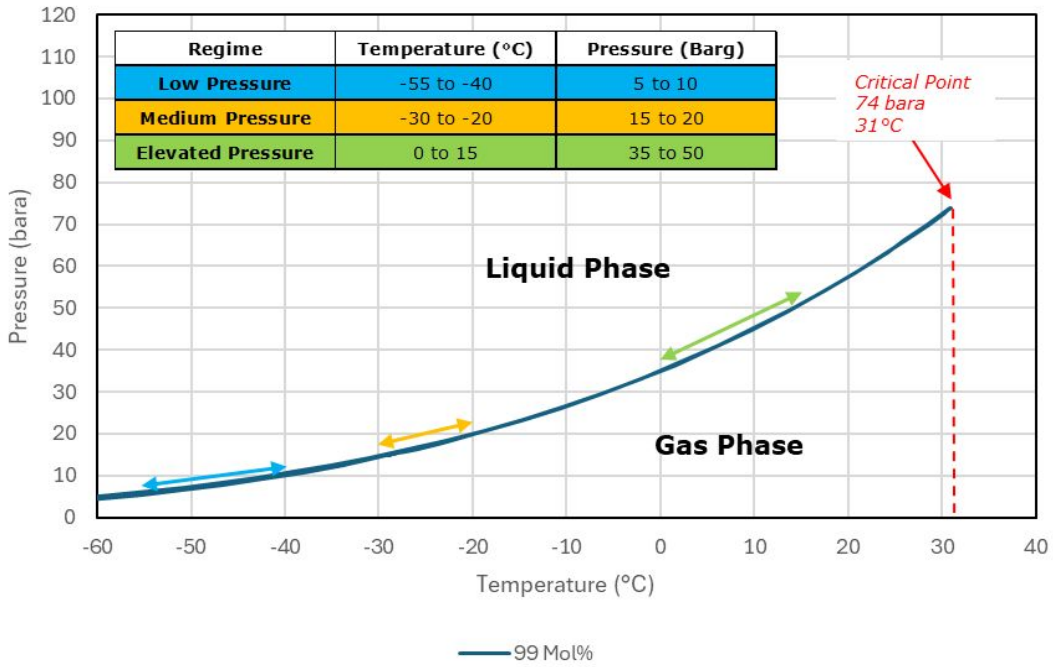
Phase Behaviour

- **Onshore Gathering Networks** – Lower pressure operation ☐ Gas phase
- **Offshore Pipelines** – Either gas phase or dense phase, dependent on store conditions.
  - Can initially be **Gas Phase** for depleted oil and gas reservoir with later switch to dense phase as store pressure increases.
  - **Dense Phase** for saline aquifers ☐ efficient transport.
  - Key driver to **avoid multiphase** flow regime.
- **Shipping** – Liquid state but key considerations on shipping pressure, liquefaction and conditioning.

Typical Pipeline Conditions



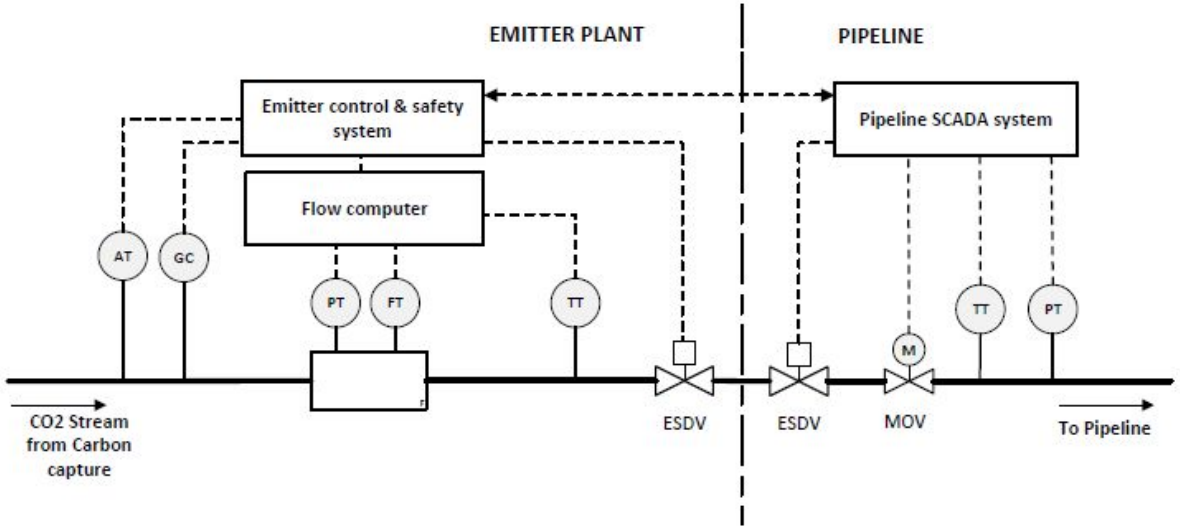
Typical Shipping Conditions



Specification Considerations

'Off Spec' considerations:

- Key impurities are water (corrosion and hydrate risk) and non condensables (multiphase/compressor power).
- Key decision to be made on location of analysers.
- What if off spec excursion occurs only for a short period?
  - Potential corrosion rates and water evaporation rates.
  - Water more soluble in dense phase than gas phase.
- Pipeline in-line inspection important for pipeline integrity management
  - Development ongoing for CO2 service and large pipe diameters.
  - Project decision on ILI requirements, 'initiating events', base frequency.
- Off-spec management philosophy requires careful consideration.



Pipeline Pre-Commissioning – Dewatering/Drying

- Stringent dryness criteria.
- Potentially long duration.

Variable Output & System Control

Variable Flow

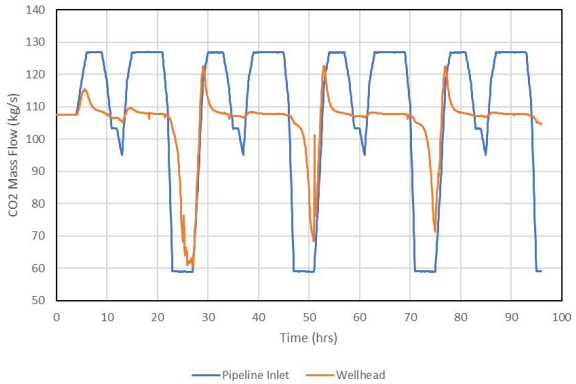
- **Challenge** – Intermittent flow from emitters, turndown/shutdowns.
- **Impact** – Pipeline pressure fluctuations, pressure control to maintain phase. Potentially frequent cyclic operations → increased risk of choke or completion damage, halite formation (saline aquifers)
- **Solutions** – Design and qualification of valves/chokes, well flexibility, wash water facilities, buffer storage, flexible compressor operating strategy.

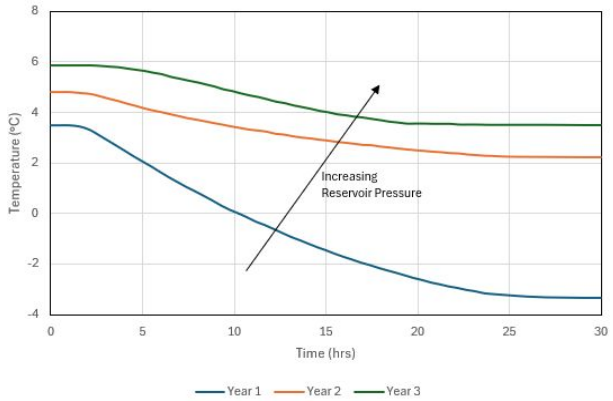
System Control (early life)

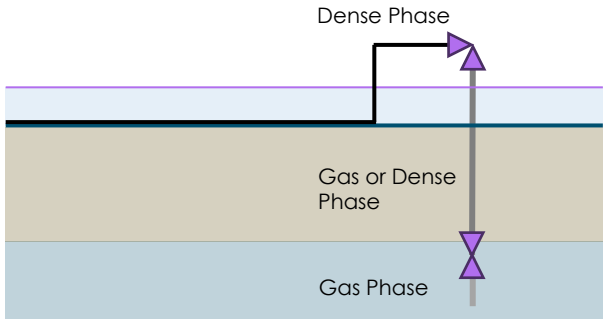
- **Challenge** – Low storage site pressure, (depleted O&G reservoirs).
- **Impact** - JT cooling risk for gas phase, low bottomhole temperatures increase the risk of reservoir damage → exacerbated by temp loss of well(s) / increased injectivity elsewhere.
- **Solutions** - Offshore heaters to ensure bottomhole temperature limits are not exceeded.

System Control (late life)

- **Challenge** – Increasing pressure through life → switch from Gas to Dense phase operations
- **Impact** – Pipeline suitability for dense phase operation. Choking to maintain pipeline in dense phase but injection gas phase at low reservoir pressure → JT cooling.
- **Solutions** – Offshore pressure control (WH choke or D/H choke), Potential increased heating requirement.



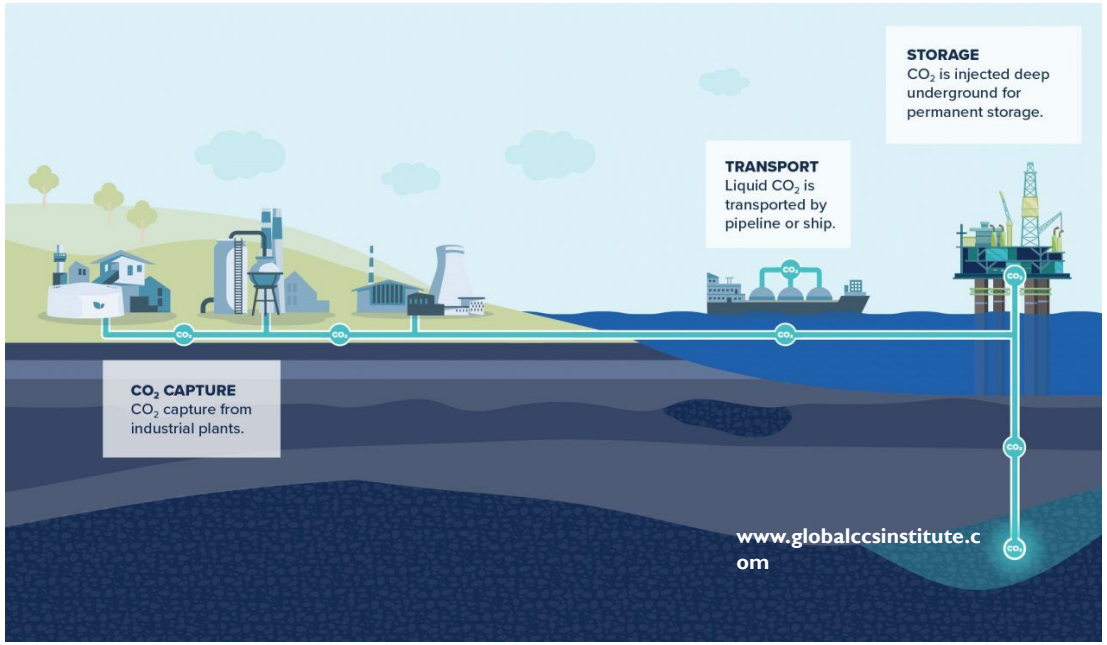




Summary

A feasible CCUS T&S system must demonstrate:

- Operation within transportation system pressure and temperature limits
- Stable pipeline and well operation in steady state
  - Phase transitions and choke designs are identified and addressed
- Clear understanding of the operating limits of individual wells
  - Maximum and minimum flows and tolerance to cycling
- Design for "profile" and operability limits
  - Management of initial flows
  - Overall maximum and minimum flows
  - Operating and management strategy for excursions:
- Complete system integration
  - Emissions profile, emitter/T&S interfaces & control, compression, pipeline transportation, well control and storage



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