CCUS T&S: Operability Challenges

22 FEB 2023

DR MURRAY ANDERSON

AGENDA

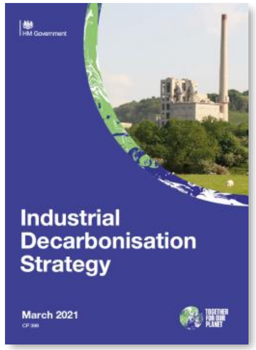
- Context
  - UK Decarbonisation Strategy
- CCUS Transportation and Storage
  - Carbon Dioxide Streams
  - CCUS System Design
  - Industrial Carbon Emissions
- Operability Challenges
  - Gas Phase and Dense Phase – Problems in Steady Operation
  - Source Gas – Problems in Transient Operation
  - System Stability and Interim Storage
- Conclusions

Crondallenergy

UK DECARBONISATION

Key UK Government policies are set out in the UK Industrial Decarbonisation Strategy (March 2021):

Industrial Decarbonisation Policy	Policy Aims	Policy Impact
Industrial Decarbonisation Challenge (IDC)	The IDC aims to accelerate the cost-effectiveness of decarbonisation across industrial clusters by supporting the development of low carbon technologies such as CCUS and hydrogen at scale. The IDC will demonstrate and validate decarbonisation measures through funding the uptake of engineering plans; business plans; the demonstration of cost-effective technologies and processes; and enabling deployment of core infrastructure.	**Government spending:** £170 million from 2019 – 2024. **Net zero contribution:** Through the rollout of the decarbonisation of industrial clusters, development of industrial cluster decarbonisation roadmaps and the creation of the Industrial Decarbonisation Research and Innovation Centre (IDRIC), the Fund will directly support the facilitation of four low-carbon industrial clusters by 2030 and at least one net zero cluster by 2040.

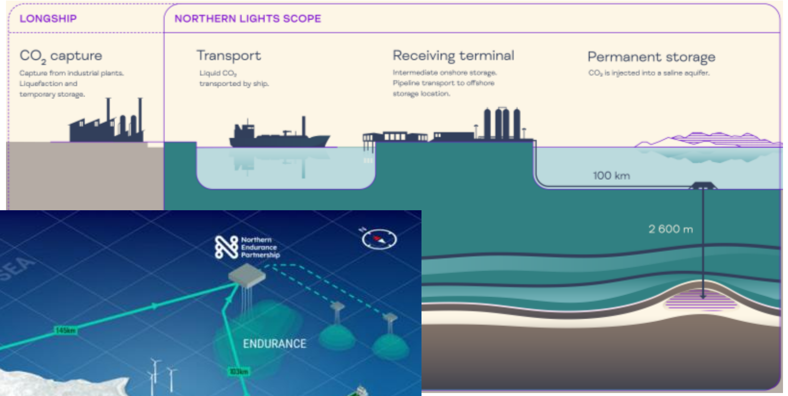


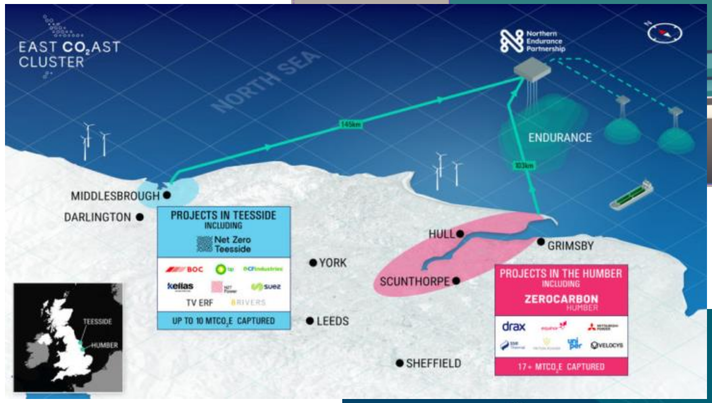
Industrial Decarbonisation Policy	Policy Aims	Policy Impact
Deployment and Infrastructure Funding		
CCUS Infrastructure Fund	The fund aims to support the development of business models and enable the deployment of Carbon Capture Usage and Storage (CCUS) across energy-intensive industries to enable organisations to remain economically competitive while reducing carbon emissions. Decarbonisation will be achieved through stimulating future private sector investment in CCUS, driving scale-up and market development to support initial carbon capture projects and catalysing deployment during the 2030s.	**Government spending:** £100 million per year. Total of £1 billion from 2021 - 2030. **Net zero contribution:** The fund will facilitate the delivery of CCUS at four clusters, two by the mid-2020s and a further two by 2030. (HM Government, *Ten Point Plan*, 2020). This will enable the fund to directly support deployment of at least 3 $MtCO_2$ of CCUS on industrial sites in clusters by 2030 and up to 14.3 $MtCO_2$ by 2050.

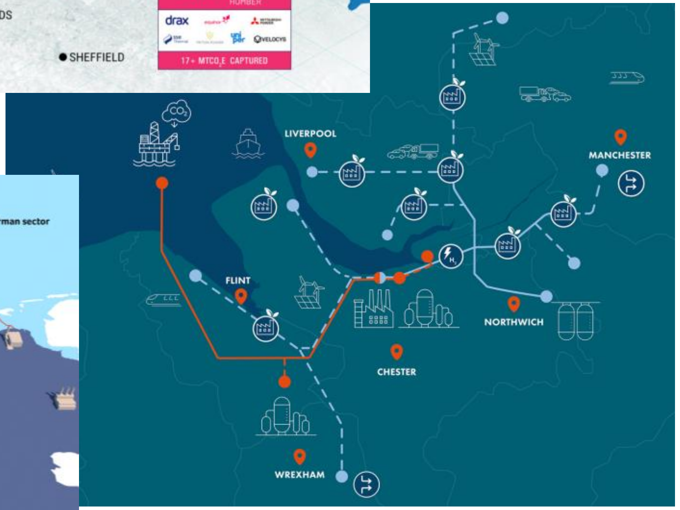
https://www.gov.uk/government/publications/industrial-decarbonisation-strategy
https://www.gov.uk/government/publications/energy-white-paper-powering-our-net-zero-future
https://www.gov.uk/government/publications/review-of-net-zero
https://www.gov.uk/government/publications/deep-geological-storage-of-carbon-dioxide-co2-offshore-uk-containment-certainty

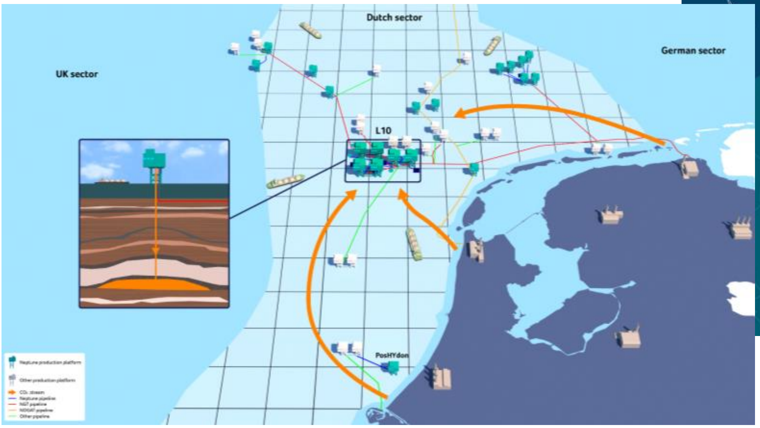
NORTH SEA CARBON CAPTURE

- Norway
  - Project Longship - Northern Lights (Equinor, Shell, TotalEnergies)
- UK
  - East Coast Cluster – Northern Endurance Partnership (bp, Equinor, National Grid, Shell, Total)
  - HyNet (ENI)
- Netherlands
  - L10 CCS Hub (Neptune Energy, EBN Capital, Rosewood Exploration, XTO Netherlands)









CO_2 SOURCES

- Onshore Industry
  - "Hard to Abate" Industrial Users
    - Steel, petrochemicals, aluminium, cement, fertilizers
  - Power
    - Gas fired power, bio-mass, coal
  - Distributed sources
    - Domestic heat, transport and aviation
- Offshore Industry
  - Oil and Gas Production
    - Gas sweetening, local power generation (heat and power)

Localised consistent emission but significant swings on shut-downs

Localised but intermittent emission for dispatchable power generation

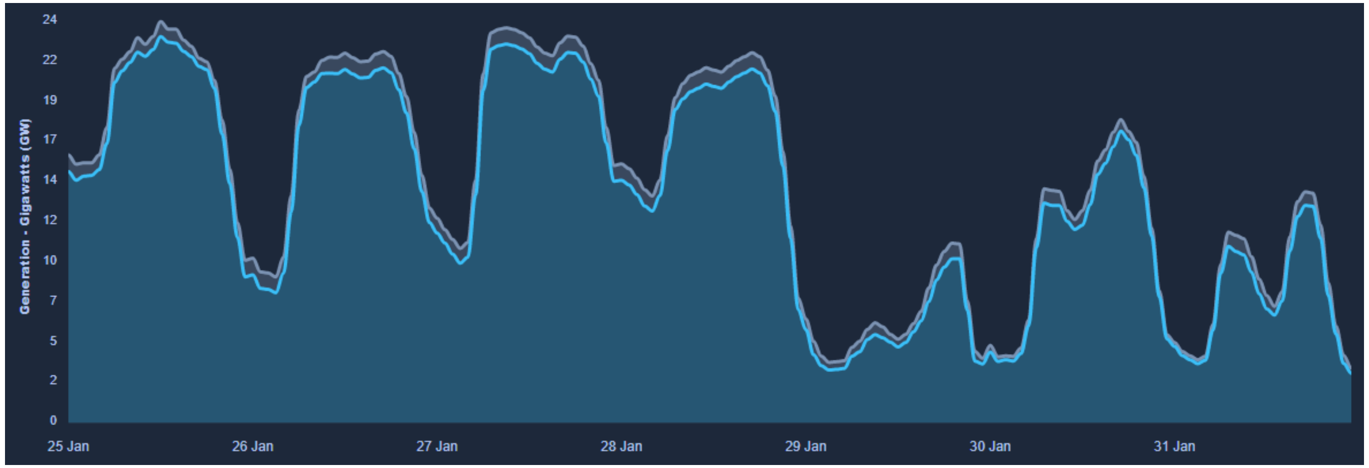
Distributed emissions difficult to capture and accumulate

Offshore from brownfield facilities not local to storage sites

RWE Pembroke B gas fired power station

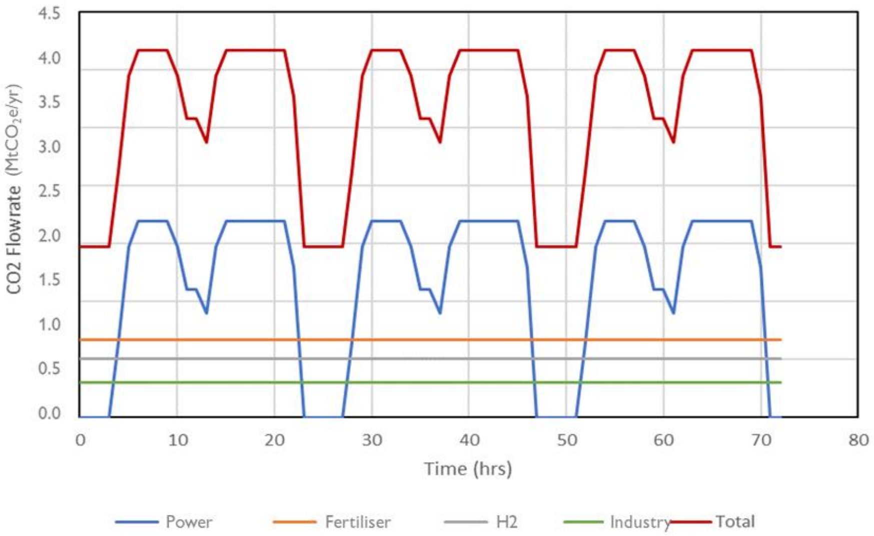
EMISSIONS PROFILES

- UK gas fired power (Jan 2023):
  - Max ~23 GW (80 $MtCO_2e/yr$)
  - Min ~2 GW (7 $MtCO_2e/yr$)
- Average daily swing:
  - ~12 GW (42 $MtCO_2e/yr$)



https://www.energydashboard.co.uk

- Industrial Cluster:
  - Max 4.2 $MtCO_2e/yr$
  - Min 2.0 $MtCO_2e/yr$



Carbon footprint for combined cycle gas turbines estimated between 365 and 488 gCO2eq/kWh

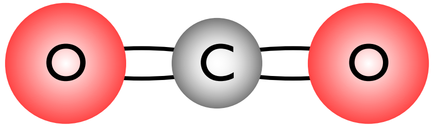
https://www.parliament.uk/globalassets/documents/post/postpn_383-carbon-footprint-electricity-generation.pdf

Crondallenergy

CARBON DIOXIDE

Carbon Dioxide:

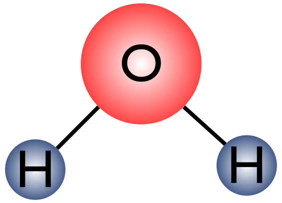
Chemical Formula CO_2
Colourless, odourless gas
Soluble in water to from carbonic acid
Atmospheric concentration 410 ppm (global average)



Molecular Wt. 44 g/mol

Water:

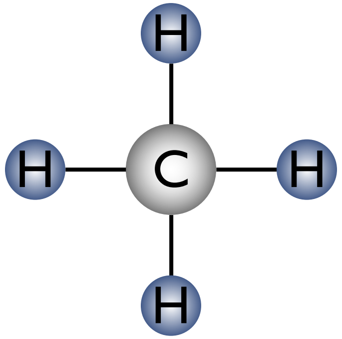
Chemical Formula H_2O
Colourless, odourless liquid/vapour
Atmospheric concentration 0 to 40,000 ppm



Molecular Wt. 18 g/mol

Methane:

Chemical Formula CH_4
Colourless, odourless gas
Atmospheric concentration 0 to 1.87 ppm



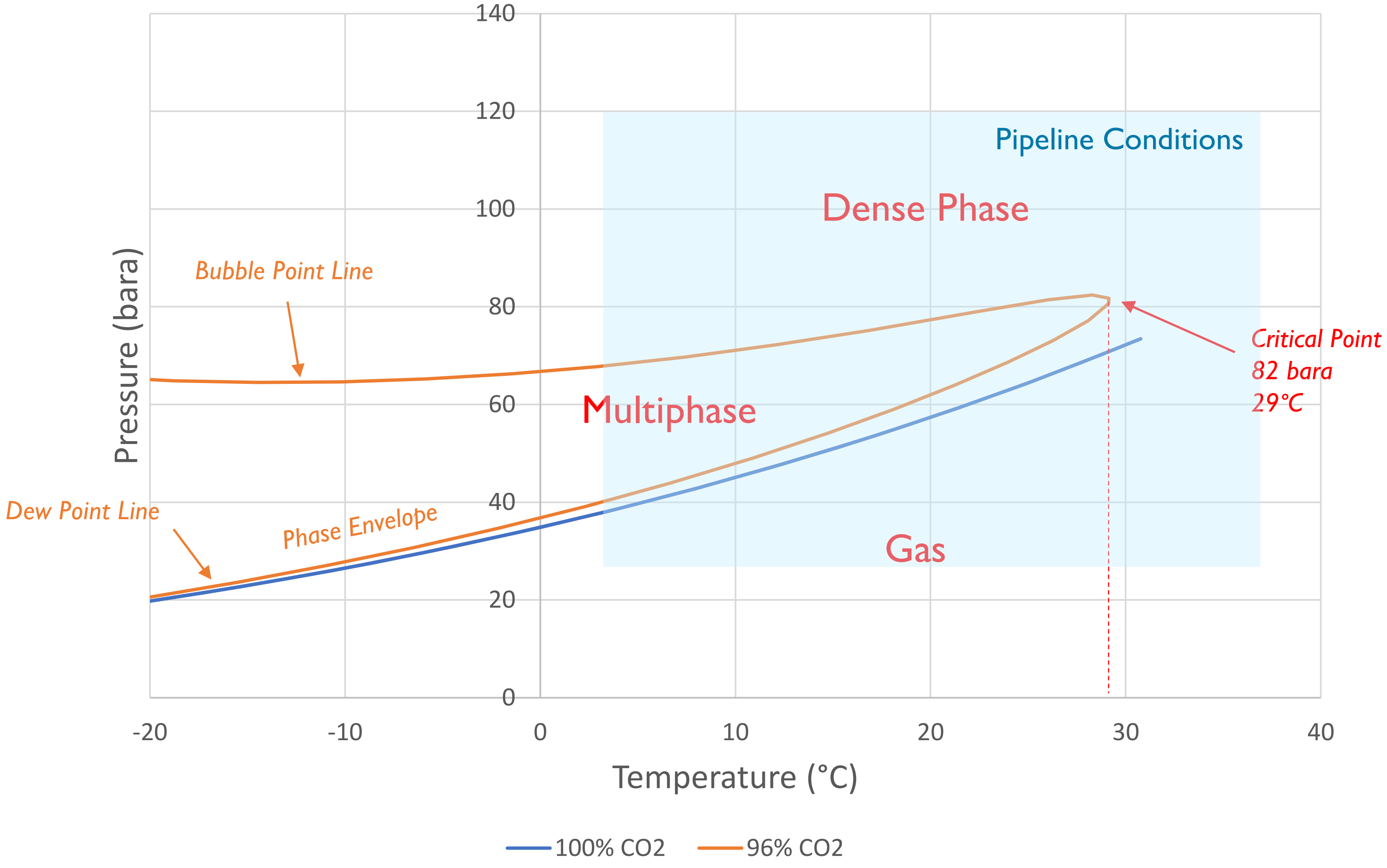
Molecular Wt. 16 g/mol

Crondallenergy

EMITTER STREAMS

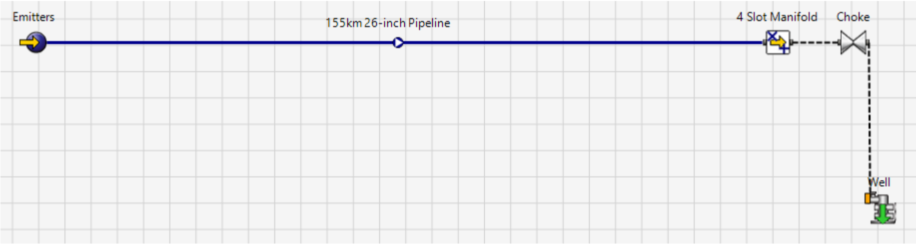
		Stream 1	Stream 2	Stream 3	Stream 4	Stream 5
CO2 Stream	**Carbon Dioxide**	min 96mol%	≥95.0%	max 100%	99.4vol%	min 91% gas min 96% dense
Non-condensable	**Hydrogen**	≤20,000ppmv (2vol%)	≤10,000ppmv (1vol%)	≤20,000 (2%)	≤5,000ppmv	≤20,000 (2mol%)
	Carbon Monoxide	<2,000ppmv	<1,000ppmv	≤2,000ppmv	≤1,000ppmv	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)

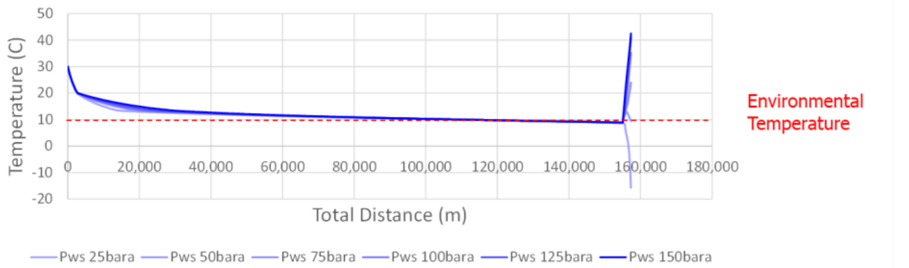
PHASE BEHAVIOUR

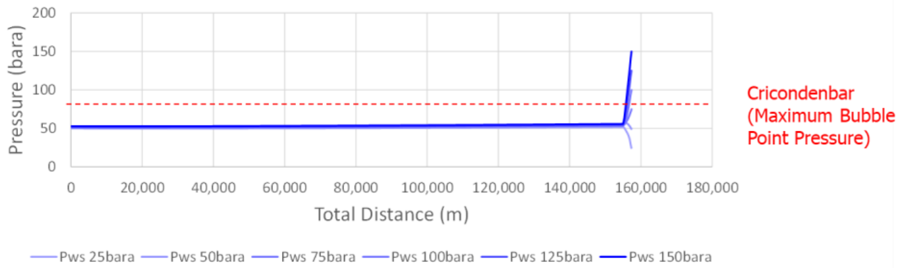


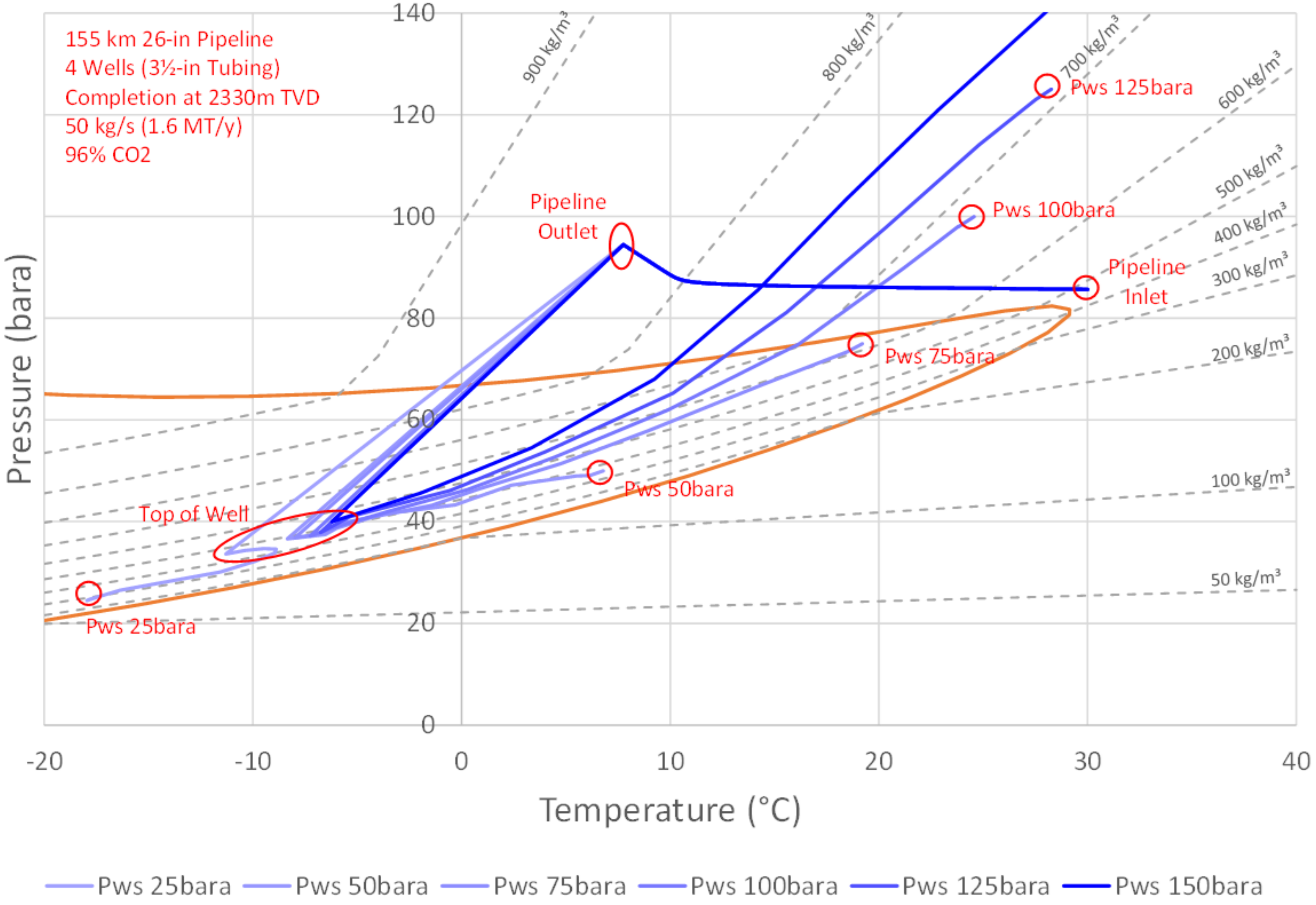
Crondallenergy

STEADY STATE MODELLING

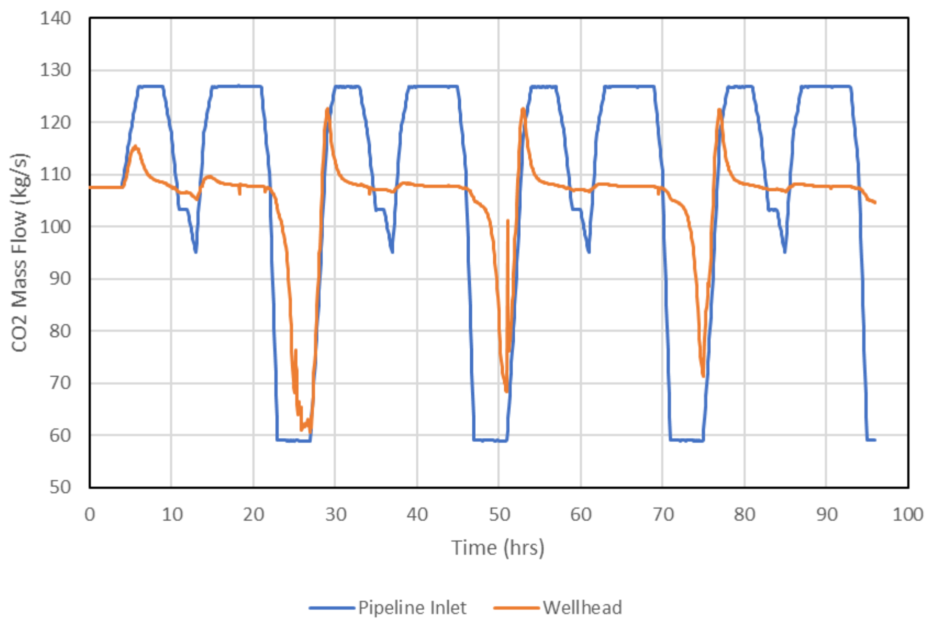


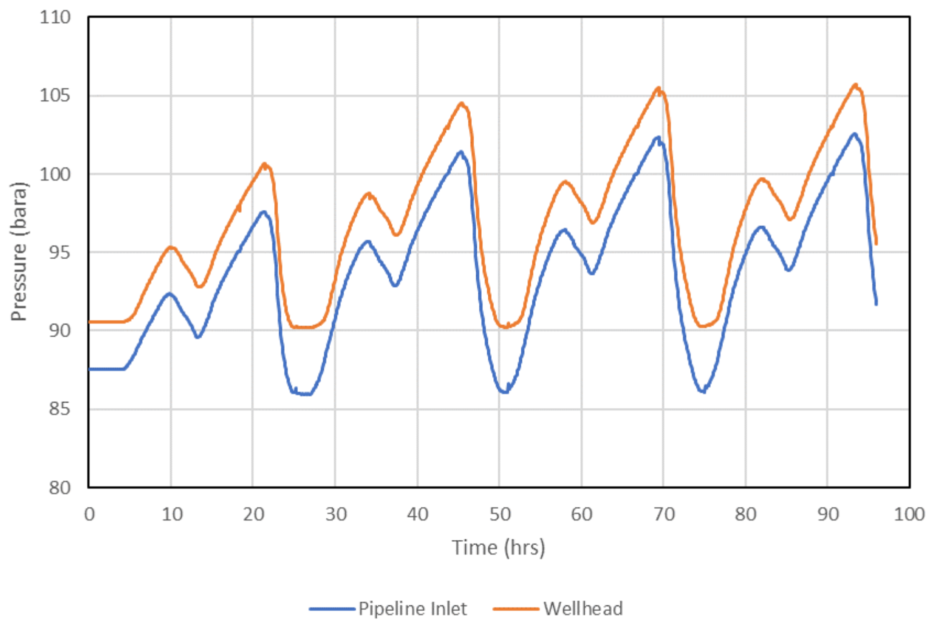






TRANSIENT MODELLING





- OLGA model with 96% CO_2 / 4% non-condensable, 28-in 123km offshore pipeline operating in dense phase (>85 bar)
- As flowrate from dispatchable power plant stops, pipeline pressure and flowrate at wellhead drop within 4 hours
- Storage buffer in the pipeline is too limited to avoid shut-down/turn-down of wells
- Short (mid-day) fluctuations in dispatchable power can be accommodated by line pack/unpack
- Pressure fluctuations in the pipeline are of the order of 15 bara

OPERATIONAL CHALLENGES

- Flow variations (dispatchable power) will cause frequent pressure fluctuations
- Frequent cycling on this scale is not typical of offshore oil and gas production networks
  - Design and qualification of subsea tree valves for appropriate service
- Wellbore pressure cycling increases the risk of completion damage and loss of injectivity
  - Increased risk of halite formation in the near wellbore region
  - Requirement for permanent wash water facilities
- Storage capacity in dense-phase pipeline network is limited
- Dedicated storage can smooth out pressure fluctuations
  - ~5,000 tCO_2 would cover the peak flowrates in the scenarios analysed (half the capacity of a Longships transport vessel)
- Interfaces (between multiple emitters and T&S) are challenging…

https://norlights.com

Crondallenergy

KEY MESSAGES

- A feasible CCUS T&S system must demonstrate:
  - Stable pipeline and well operation in steady state
    - Phase transitions and choke designs are identified and assessed
  - Clear understanding of the operating limits of individual wells
    - Maximum and minimum flows and tolerance to cycling
  - Design “profile” and operability limits
    - Management of initial flows (small baseload)
    - Overall maximum and minimum flows
    - Operating strategy for excursions:
      - System turn-down or well shut-down?
      - Storage
- A feasible system must demonstrate complete system integration:
  - Emissions profile, emitter/T&S interfaces, sequestration, compression, pipeline transportation, well control and storage

CONTACT US

www.crondall-energy.com

enquiries@crondall-energy.com

www.linkedin.com/crondall-energy