

Carbon Capture and Storage Forum

Behaviour of CO₂ in Transportation Systems

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- CO₂ Sources
- Transport Options & Challenges
- UK Clusters
- CO₂ Properties & Quality
- Design Principles
 - Pipelines
 - Shipping
- Carbon Capture & Storage Chain
- Conclusions

Potential Sources of Captured CO₂

The logo for COSTAIN, featuring the word "COSTAIN" in white capital letters on a blue rectangular background.

- Large scale power generation
 - Coal vital for future energy mix & current focus for CCS
 - Gas fired power also important
- Industrial – many significant point sources
 - Oil & gas – upstream, refineries, etc.
 - Iron & steel
 - Cement
 - Chemicals
 - Glass, paper, food & drink, etc
- Pre-combustion, post-combustion & oxy-fuel capture routes

CO₂ Transport Options

COSTAIN

- Shipping
 - Compression & liquefaction
 - Storage & marine loading facilities
 - Liquid transportation
 - Refrigerated temperatures

- Pipelines
 - Compression
 - Dense phase transportation
 - Ambient temperature



Enabling Legislation

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- London Protocol – Amended 2007
 - Allowing “CO₂ streams for CO₂ capture processes for sequestration” to be considered for licensed disposal
- OSPAR Convention – Amended 2008
 - Allowing storage of CO₂ under sea-bed
- EU Directive 2009/31/EC
 - Legislative proposals to regulate CCS

Transportation Challenges for CCS

The logo for COSTAIN, featuring the word "COSTAIN" in white, uppercase letters on a blue rectangular background.

- Development of large integrated networks
- Pre-investment in transportation infrastructure
 - Initial demonstration
 - Commitment to wider adoption of CCS
 - Understanding the 'end game'
- Highest levels of safety in operation

UK Cluster Development

COSTAIN

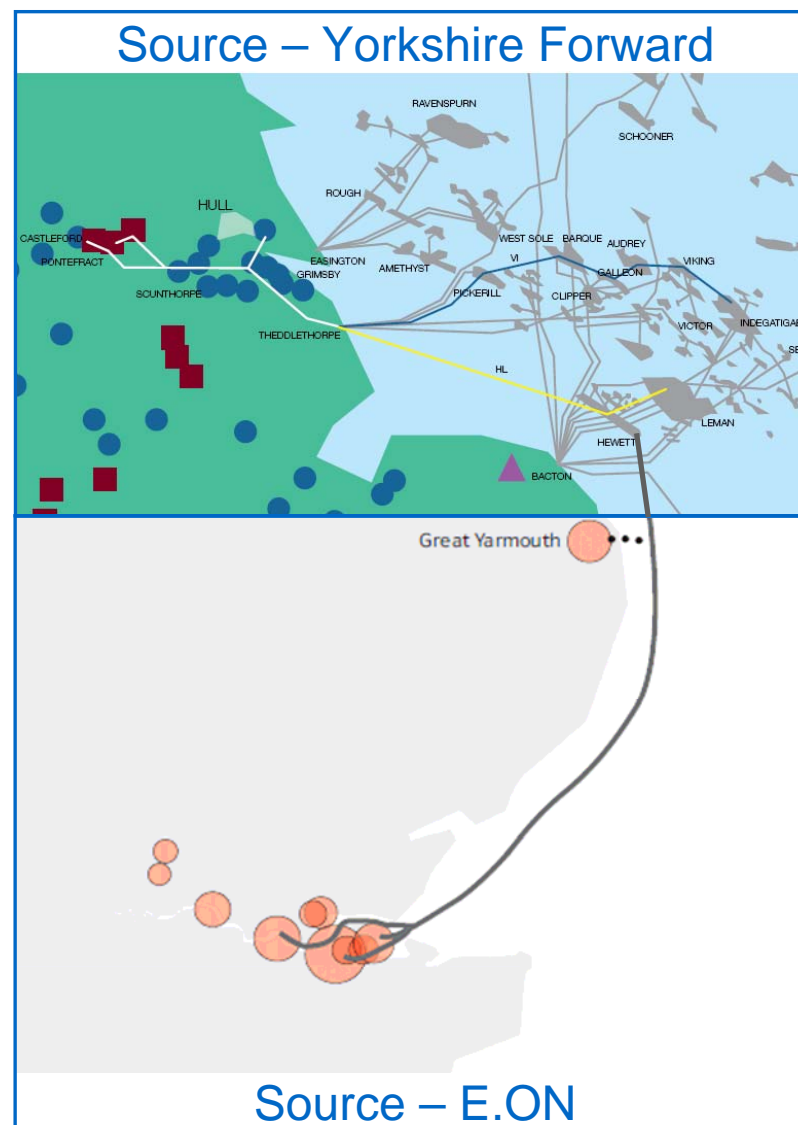
- Groups of large point sources
- Access to North Sea
 - Depleted oil and gas fields
 - Deep saline aquifers
- Common infrastructure
- Economies of scale
- Pre-investment – over sizing
- Strategic



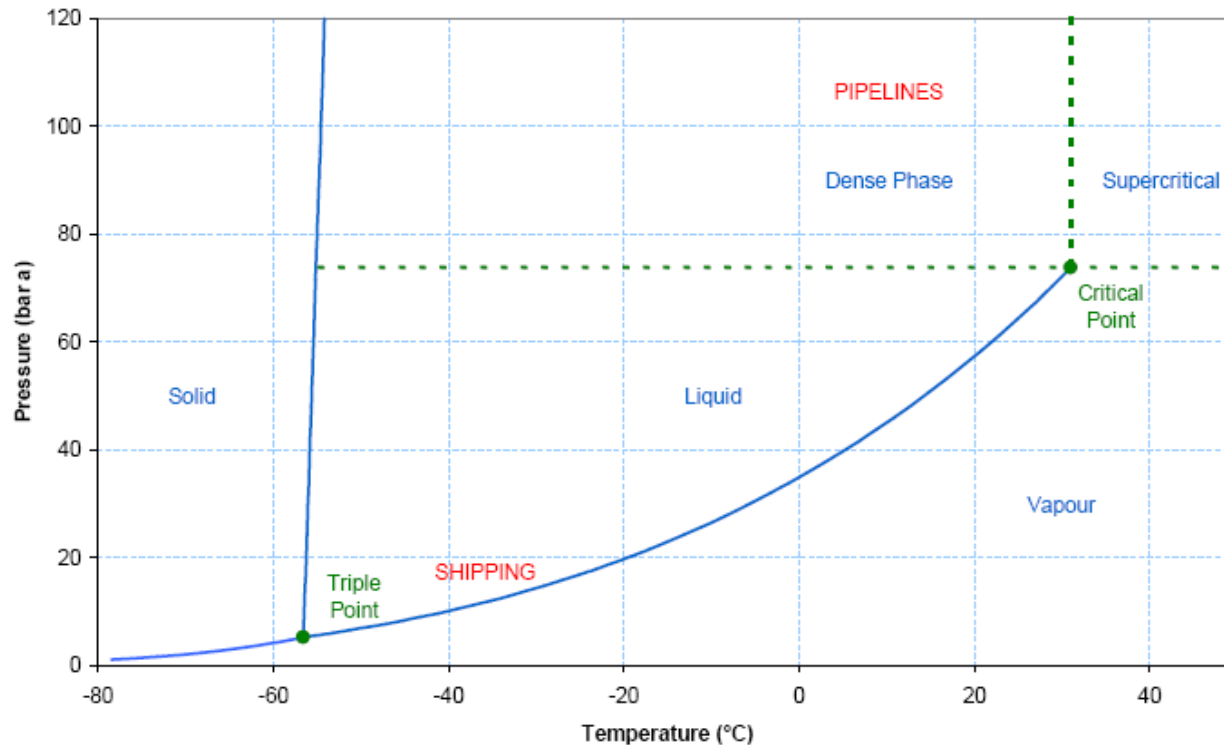
UK Cluster Development

COSTAIN

- Yorkshire & Humber
 - Twelve emitters > 1 MT/Yr
 - Make up 95% of total
 - Total potential > 60 MT/Yr
- Thames
 - Eight emitters > 1 MT/Yr
 - Planned Kingsnorth and Tilbury >16 MT/Yr
 - Total potential 28 MT/Yr
- Depleted oil and gas fields
 - Hewett, Viking and others



CO₂ Phase Properties



- Dense phase pipelines. 10 x natural gas density
- Liquid phase shipping. Pressurised & refrigerated
- Low temperature & solidification on pressure reduction
- Contaminants affect critical temperature & pressure

CO₂ Properties & Hazards

COSTAIN

- Clear odourless gas
- Denser than air
- Expands - large volumes on release
- Potential to accumulate
- Asphyxiant at high concentrations
- Toxic effects at lower concentrations
- In presence of water
 - Corrosive to pipe materials
 - Can form hydrates
- Low temperature on depressurisation



Lake Nyos, Cameroon
Natural disaster CO₂ release



Gas Hydrate
(source: Heriot Watt University)

CO₂ Stream Quality

- OSPAR and London Protocol
 - Streams to be “overwhelmingly of CO₂”
- Transport and storage specifications to be developed:
 - Corrosion & integrity – H₂O, H₂, H₂S
 - Storage – impact uncertain – O₂ in particular
 - Health & safety – CO, H₂S, SO₂, NO_x
 - Loss of energy value of components – H₂S, CH₄, H₂
 - Transportation & storage cost for non-CO₂

Delivery to Pipeline

COSTAIN

- CO₂ sources at low pressure
- Compression
- Dehydration
- Purification
- Dense phase, above critical pressure (120 – 200 bar)
- Pressure sufficient for injection
- 12"-24" pipelines for major sources
- 36"+ pipelines joining clusters



Pipeline Safety Considerations

COSTAIN

- Routing both over land & sub sea
- Burial depth & wall thickness
- Block valves in over land sections
- Pipeline materials
- Design to avoid fracture propagation
- Failure, release & dispersion consequence modelling
- Fabrication & construction
- Monitoring – dehydration, leakage
- Inspection
- Emergency plans



CO₂ Shipping

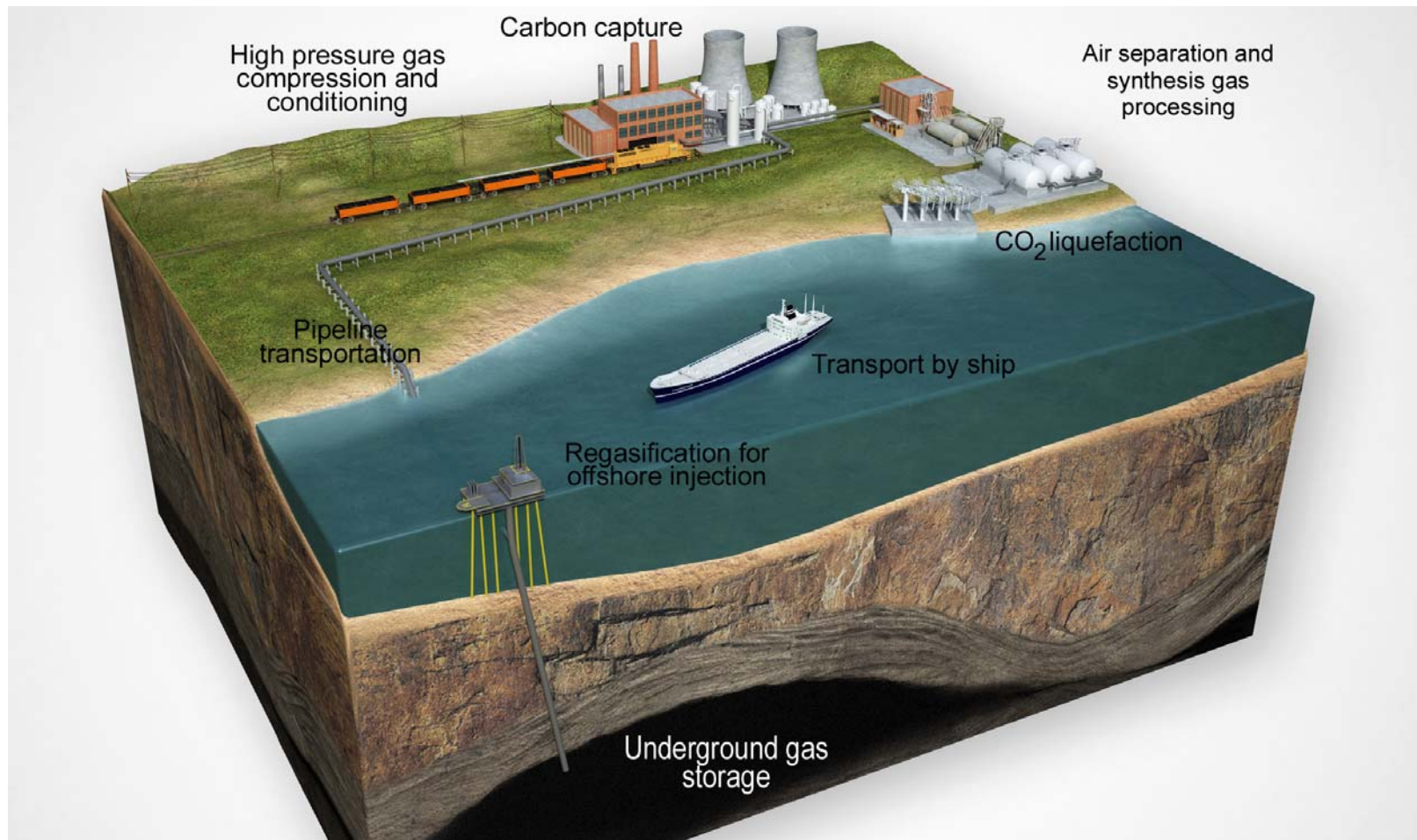
COSTAIN

- Alternative to pipeline for
 - Small scale
 - Long distance
- Similarities with LNG chain
- Source – compression, liquefaction, liquid storage, loading
- Sink – pumping & conditioning for injection
- No experience of CO₂ shipping at scale needed
- Shipping conditions economic optimum



Carbon Capture and Storage Chain

COSTAIN



Conclusions

The logo for COSTAIN, featuring the word "COSTAIN" in white capital letters on a blue rectangular background.

- Conditioning for transportation – conventional & proven
- CO₂ not as hazardous as natural gas
- Unique safety & design challenges
- Short term demonstration – shipping & pipeline
- Long term integrated networks
- Major clusters with good access to North Sea
- Large strategic investments