energy technologies institute

Programme Area: Carbon Capture and Storage

Project: System Modelling Tool Kit

Title: Dynamic modelling of CO_2 pipelines using gCCS

Context:

The two-and-a-half year, £3m project launched in September 2011 created a modelling tool-kit capable of simulating the operation of all aspects of the CCS chain, from capture and transport to storage to support the future design, operation and roll-out of cost effective CCS systems in the UK. It involved modelling technology provider Process Systems Enterprise (PSE), energy consultancy E4tech, and industrial partners EDF Energy, E.ON, Rolls-Royce and CO2DeepStore, who expected to be involved in capturing, compressing, transporting and storing CO_2 in the future. The project has resulted in a commercial product (gCCS) built on PSE's gPROMS modelling platform. The tool-kit will be used to support the initial conceptual design and eventual detailed design and operation of CCS systems by helping to identify and understand system-wide operational issues such as the effects of power station ramp-up or ramp-down on downstream storage operation, or the effect of downstream disturbances on power generation.

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EngD Presentation

Dynamic modelling of CO_2 pipelines using gCCS

OVERVIEW

- Background
- Literature Review
- Project Aims
- gCCS
- Model Development
- Model Outputs
- Shell Secondment
- QUEST
- The Quest Pipeline
- Modelling the pipeline
- Validation
- Conclusion
- ETI Projects

Carbon Capture & Storage

Carbon Capture and Storage is a method to mitigate carbon emissions from large point sources e.g. Power Stations

The process first separates the CO_2 in the flue gas from the other components.

Once ‘captured’ the CO_2 is the compressed to high pressures until the CO_2 is in either the liquid or supercritical phase.

The CO_2 is then transported deep underground to either a saline aquifer or depleted oil field where it can be sequestered.

BACKGROUND

Two methods for CO2 Transportation

Pipeline

Ideal for large quantities of CO_2 and several sources close together to form hubs.

Shipping

Ideal for when CCS starts up and for wide spreads CO_2 sources.

LITERATURE REVIEW

- Literature looking at CO_2 pipelines is limited
- Focus on pipeline modelling
- No validated models
- Extensive use of Aspen Hysys using Peng Robinson equations of state
- Most research focussed on techno-economic modelling
- Limited research looking at dynamic modelling of pipelines

PROJECT AIMS

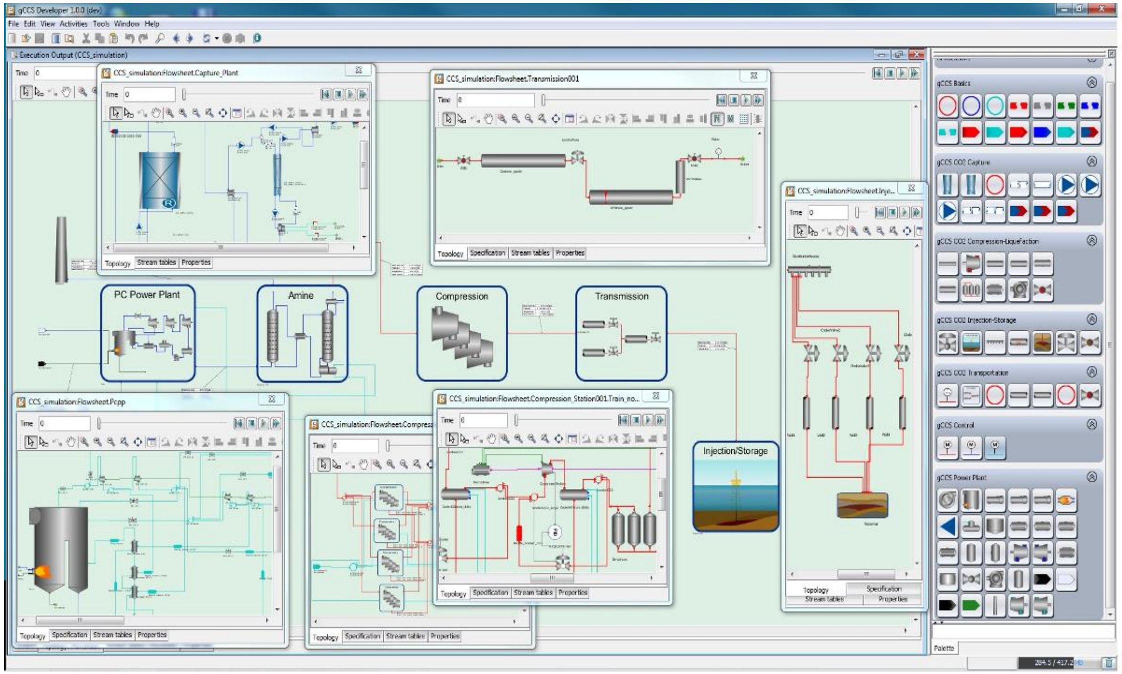
1. Understand the impact of fluctuating the flowrate at the inlet of a CO_2 pipeline on the fluid within the pipeline, looking specifically at
   - Flowrate
   - Pressure
   - Temperature
   - Density

2. Compare the different responses on the system when transporting in the liquid and supercritical phase.

3. Model CO_2 with impurities to see if there is any significant impact on the dynamics

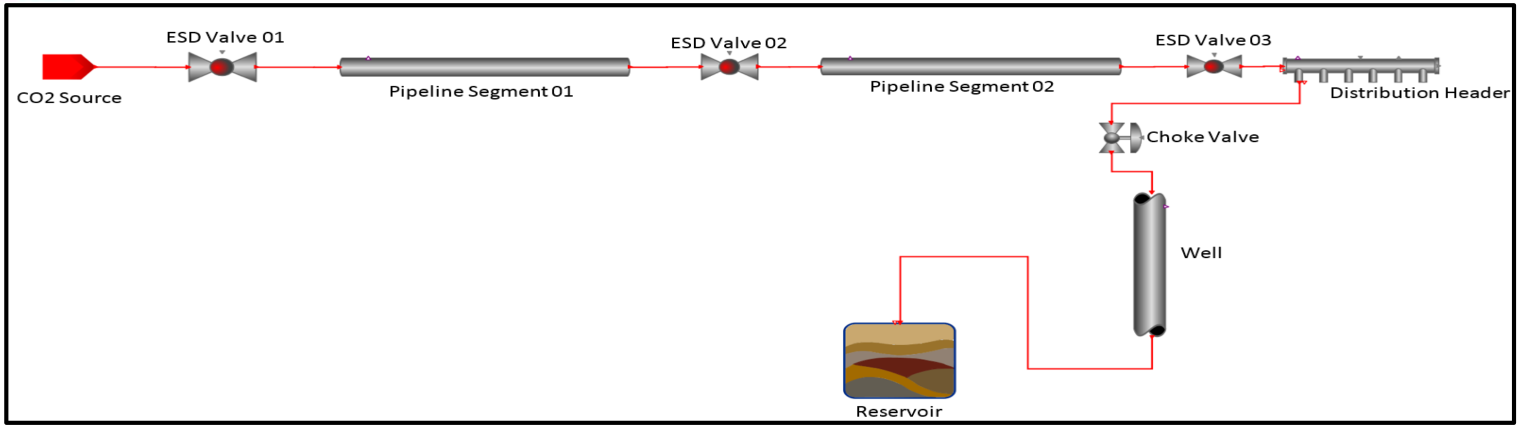
4. Validating gCCS transport model – Shell Quest secondment

GCCS



- Using the Energy Technologies Institute's System Modelling Toolkit (SMTK).
- Enables modelling of full chain CCS system. Including Power generation, capture, compression, transport and storage.
- Will focus on using the transport and storage models which utilises SAFT to predict thermodynamic values of the fluid.

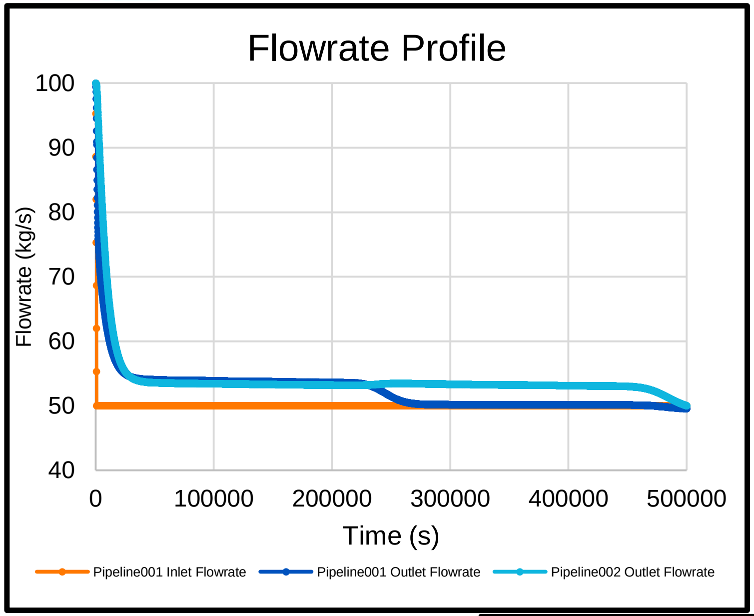
Model development

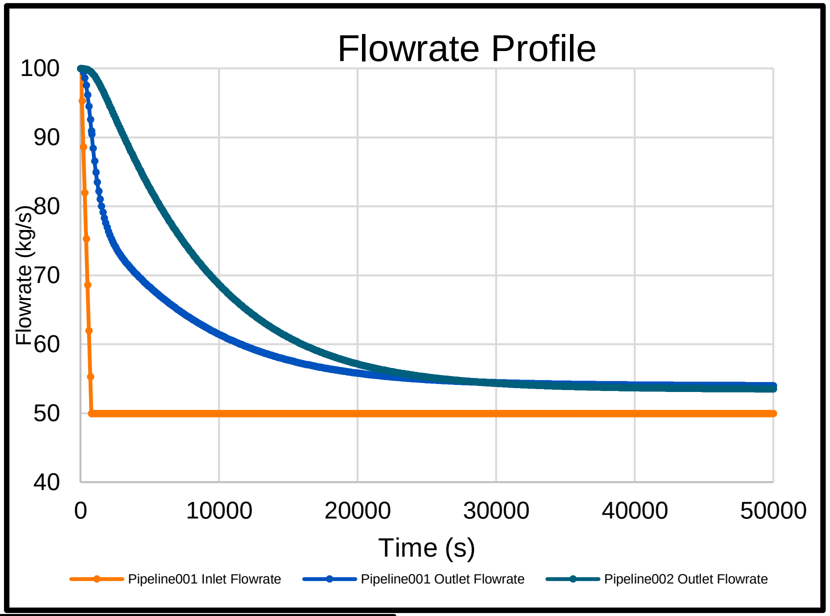


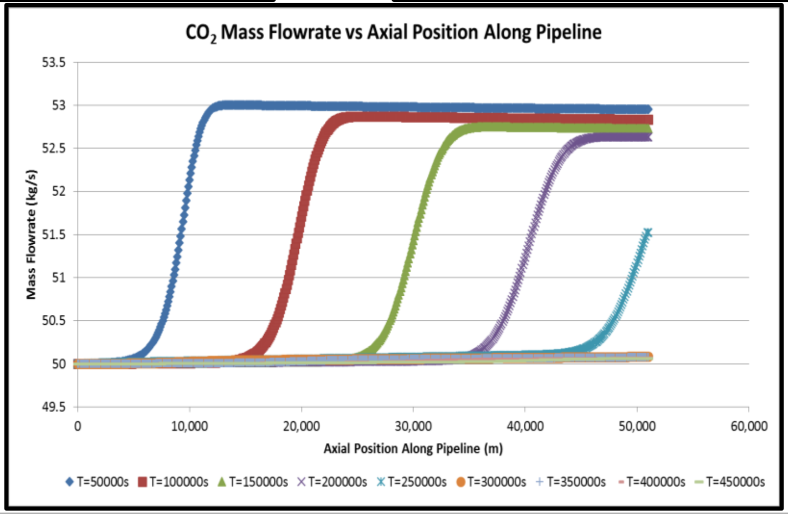
Process Input	Value
Initial Mass Flowrate	100 kg/s
Final Mass Flowrate	50 kg/s
Ramp Rate	-4 kg/s/min
Ramp Time	750 s
Total Simulation Time	500,000 s

Model Input	Value
Pipeline1 length	52,000 m
Pipeline2 length	52,000 m
Well depth	1,200 m
Pipeline Diameter	0.6096 m
Inlet Temperature	293 K
Reservoir Pressure	150 Bar

MODEL OUTPUTS







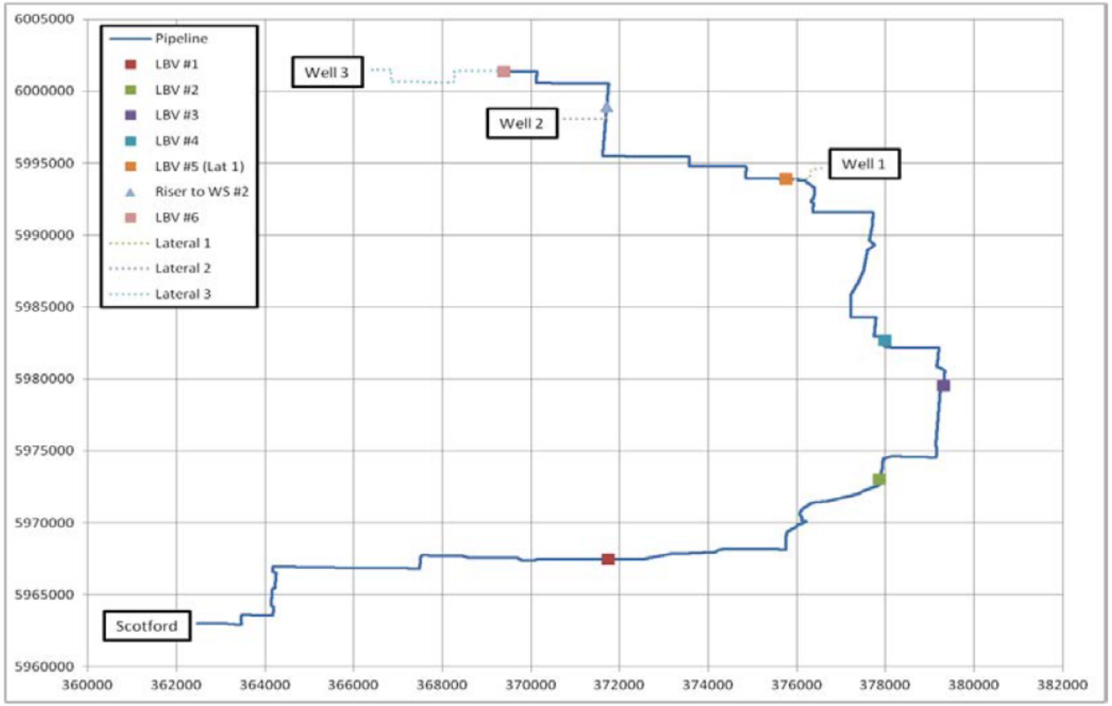
SHELL SECONDMENT

- 8 month secondment from November 2015 to June 2016
- Work with Shell to model the Quest CCS pipeline
- Validate gCCS transport model
- Model possible scenarios that could occur with the pipeline
- Provide support on modelling the Quest compressor

QUEST

- First CCS project for an oil sands operation in the world
- Reduce CO_2 emissions from Shell's oil sands project by over 1 million tonnes
- CO_2 is captured from the process gas streams of the three hydrogen manufacturing units
- Capture of CO_2 using Shell patented amine technology
- Compressed and dehydrated to a dense phase state for easy transportation
- Transported via pipeline
- CO_2 is stored in an onshore saline aquifer

QUEST PIPELINE



Transporting 1.2 Mtpa of captured CO_2

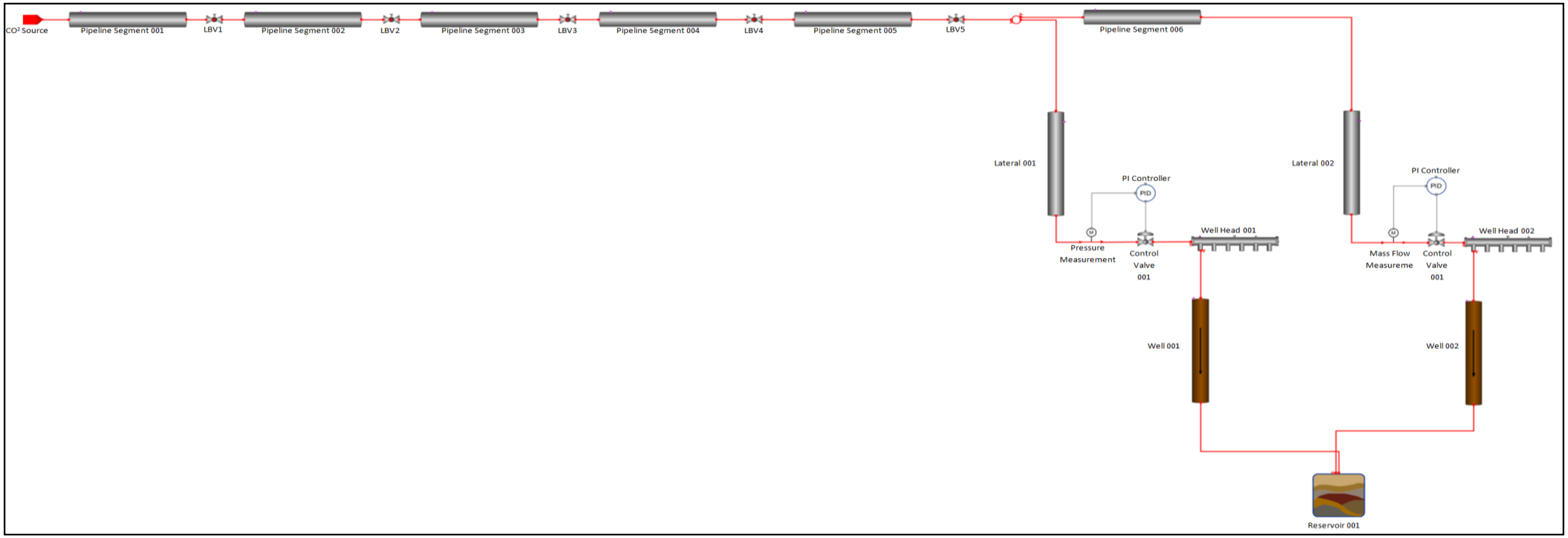
Transported in the supercritical phase

12” pipeline from Scotford to a series of three injection wells

Furthest injection well is located 65km away from the upgrader

Pipeline is buried approximately 1.5m underground

PIPELINE MODEL



Only 2 wells are currently in operation, with a constant flow of CO_2 to well 2 and well 1 absorbing any fluctuations in flowrate.

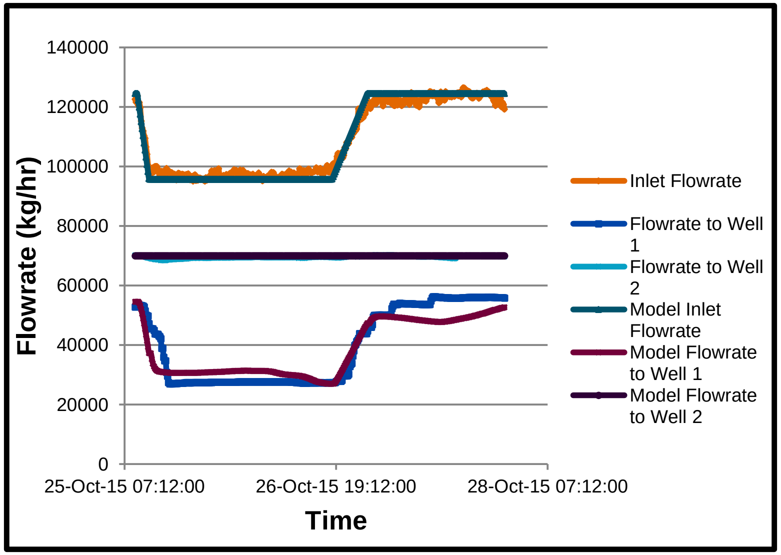
Inlet fluid temperature is kept constant at 43^{o}C to ensure that the CO_2 is in the supercritical phase when it enters the pipeline

Pressure is controlled at the well head to maintain a pressure above the critical point

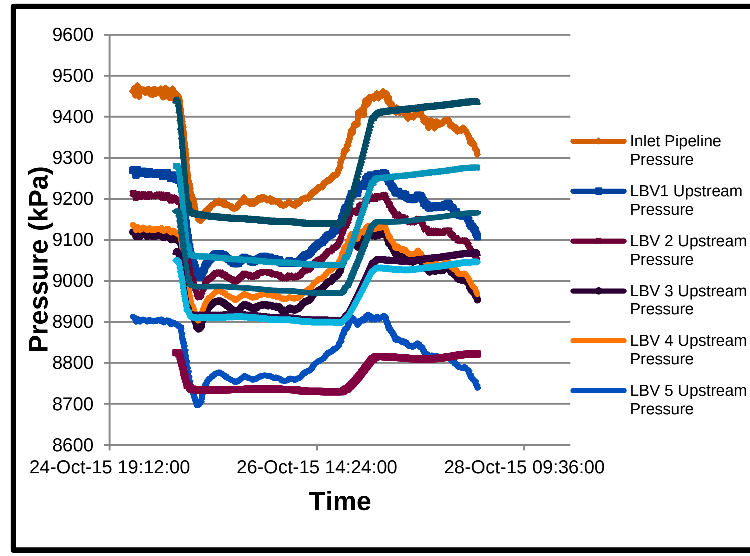
Pipeline is buried 1.5m underground with wet soil as the surrounding material used within the model

Validation

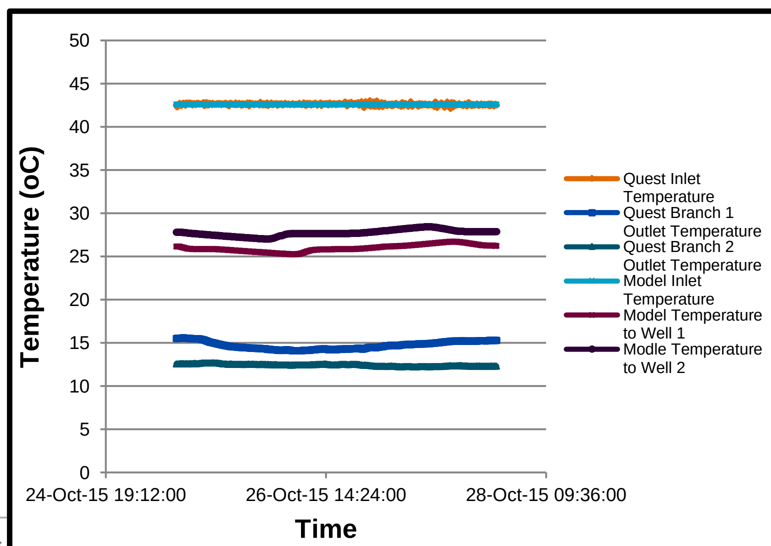
Flowrate



Pressure

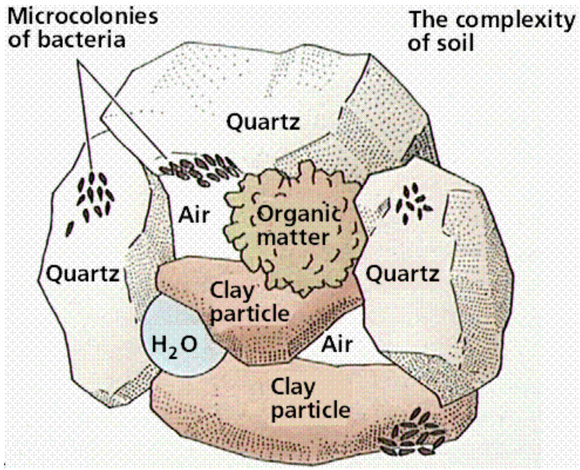


Temperature



Discrepancies

- Parameter that seemed to be the main cause of the discrepancy is the SOIL THERMAL CONDUCTIVITY
- Model contains specific values for thermal conductivity based on soil specified
- Thermal conductivity can vary based on several parameters
  - Soil composition
  - Volume
  - Density
  - Porosity
  - Water migration



CONCLUSION

- Due to the physical properties of CO_2 the dynamics of a pipeline system are more complicated than for other fluids.
- It takes a significant amount of time for the effects of any changes in the system to be felt down stream.
- It has been understood that this occurs due to the physical properties of CO_2, more specifically the compressibility.
- This will be important to understand when CO_2 may be bought and sold i.e. EOR
- Impurities only start to have a significant effect on these dynamics when they exceed the limits
- gCCS is capable of modelling the pressure changes in a system with good accuracy even during modelling of scenarios such as valve closure or compressor trip.
- Difficulty in modelling the temperature drop along the pipeline, however this is likely due to the limited choices of soil thermal conductivity given within gCCS.
- The model shows the flowrate develops a wave like profile when it approaches the set point. This however was found not to occur, so is an error within the model itself.

ETI PROJECTS

- Exhaust gas recycle for thermal power plants review
- Hydrogen storage project
- Review of North Sea oil and gas fields for CO_2 storage
- Gas pipeline repurposing project
- Technical study on CO_2 removal from sea water
- NET Power modelling review

Thank you!

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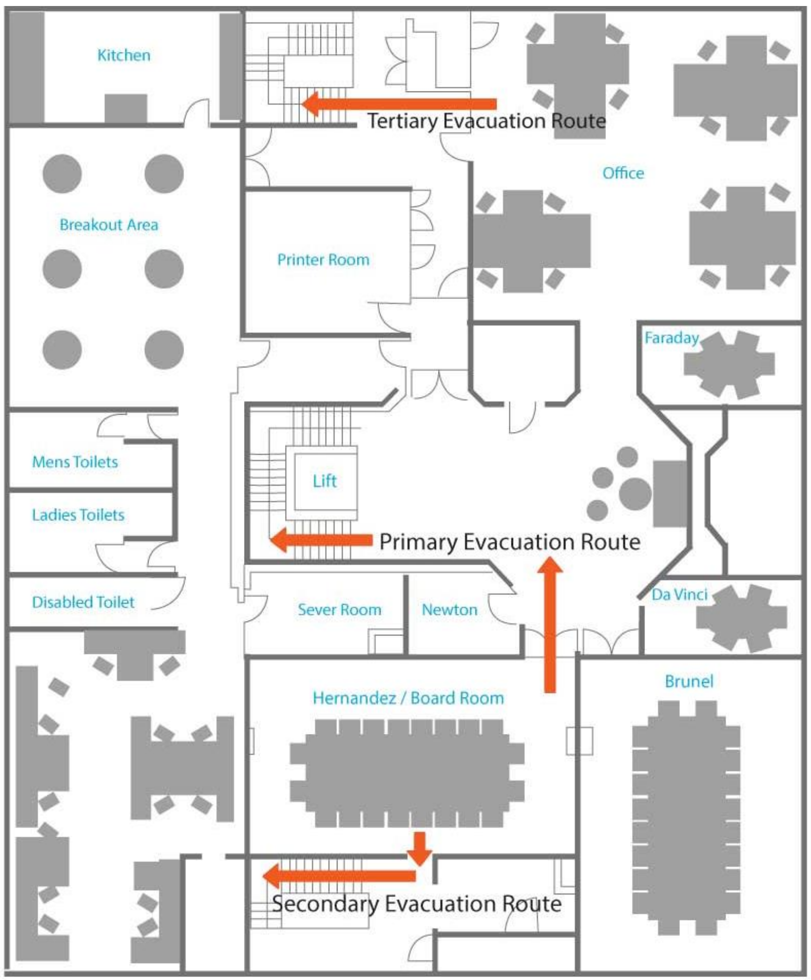
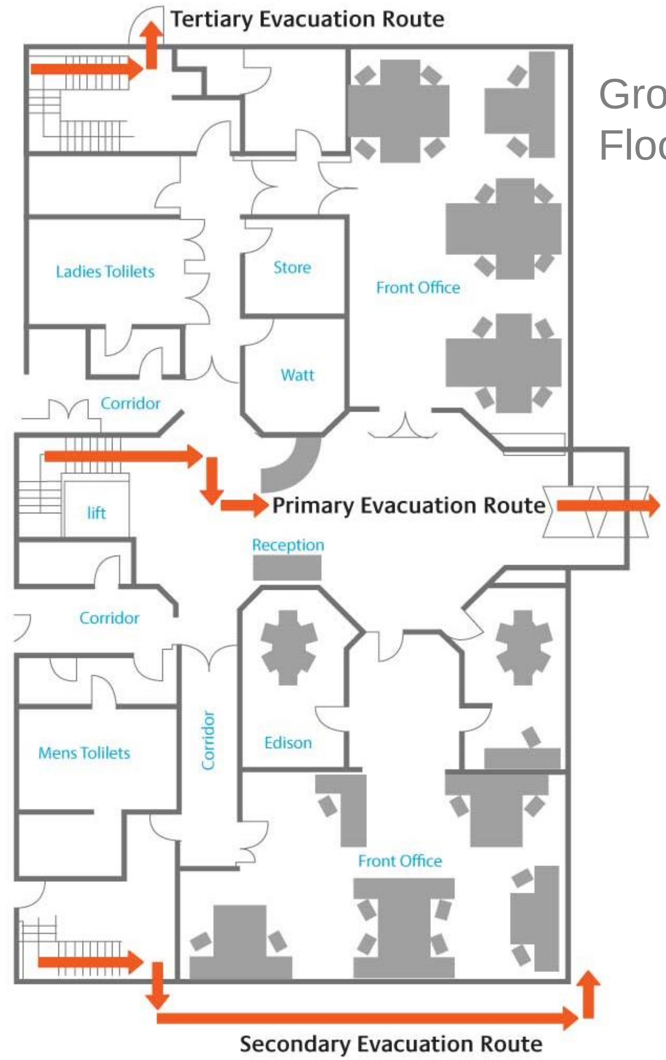
First Floor



Ground Floor



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For more information about the ETI visit www.eti.co.uk

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