Advanced multitemporal modelling and optimisation of CO_2 Transport, stOrage and utilisation Networks

ACT knowledge sharing workshop - 5th October 2023

Objectives

ACTiON aims to establish how an efficient infrastructure, connecting CO_2 sources with CO_2 geological storage and non-geological utilisation options, can be developed as part of regional decarbonisation efforts. To achieve this objective, **ACTiON aims to research and develop a multitemporal integrated assessment model** that

- will support stakeholders in the planning and design of large-scale, flexible CO_2 transport, utilisation and storage networks, and
- enable reporting on decarbonisation efforts while addressing
  - the impacts of geological and engineering constraints,
  - the effect of the economic conditions and regulatory environment, as well as
  - the unavoidable uncertainties faced in defining them.

Objectives

The term ‘multitemporal’ refers to three different time scales:

1) **short term (hours/days)**: required for safe and efficient network operability and to enable efficient CO_2 utilisation options function
2) **medium term (years/several years)**: related to dynamic storage capacity and the function of large-scale transport and storage network, connecting CO_2 supply to multiple storage and utilisation sites;
3) **long term (several decades)**: horizon planning to meet decarbonisation targets.

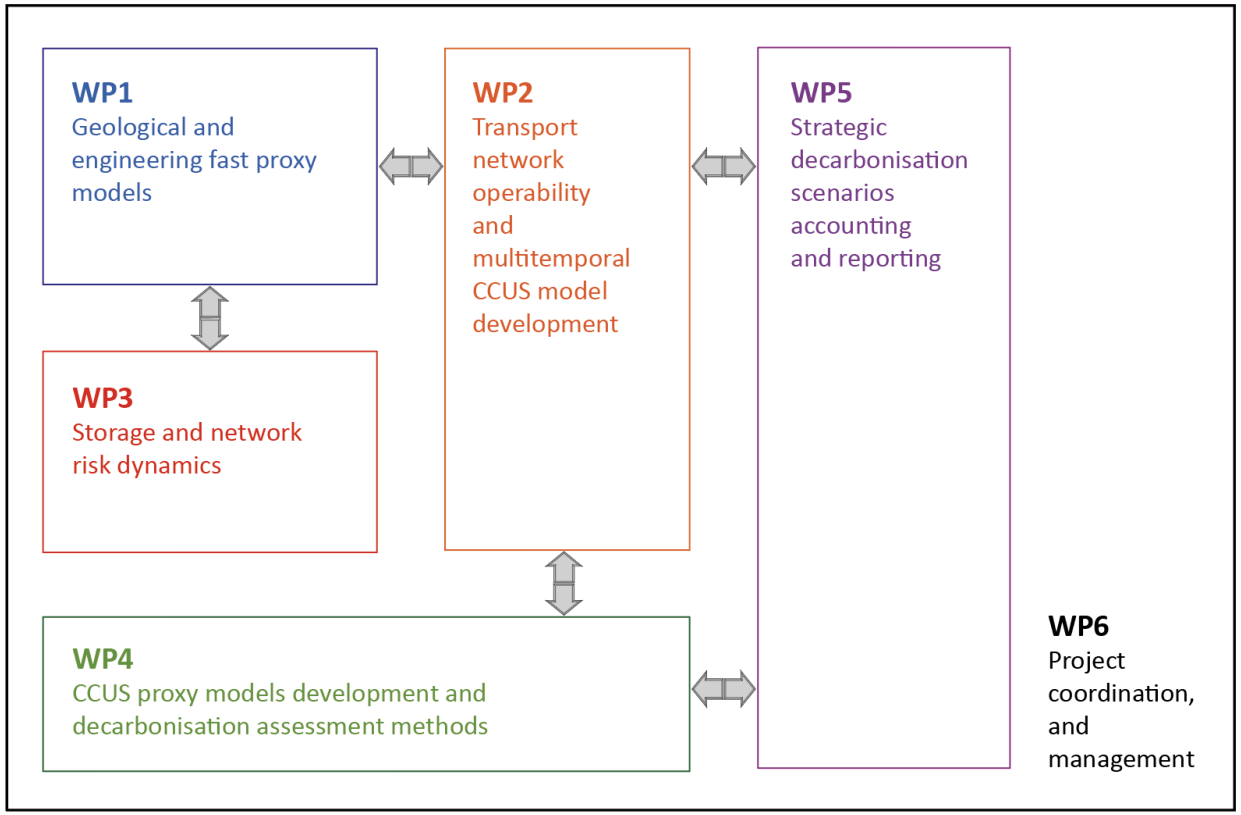
Project structure

WP1: Geological and engineering fast proxy models (lead: IFPEN)

WP2: Transport network operability and multitemporal CCUS model development (lead: TNO)

WP3: Storage and network risk dynamics (lead: UAlberta)

WP4: CCU proxy models development and decarbonisation assessment methods (lead: Imperial/LANL)

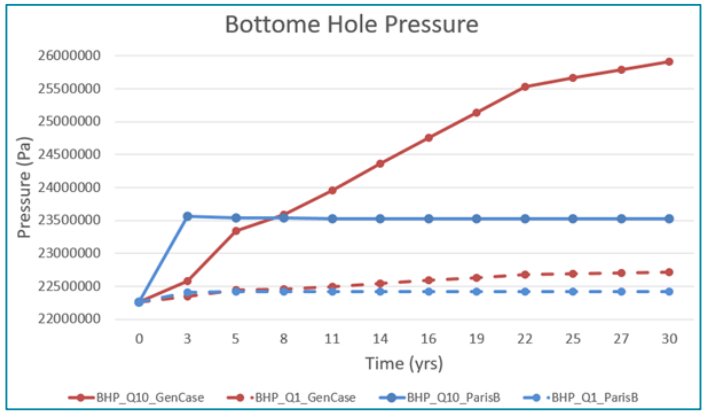


WP5: Strategic decarbonisation scenarios accounting and reporting (lead: Imperial)

WP6: Project management and dissemination (lead: Imperial)

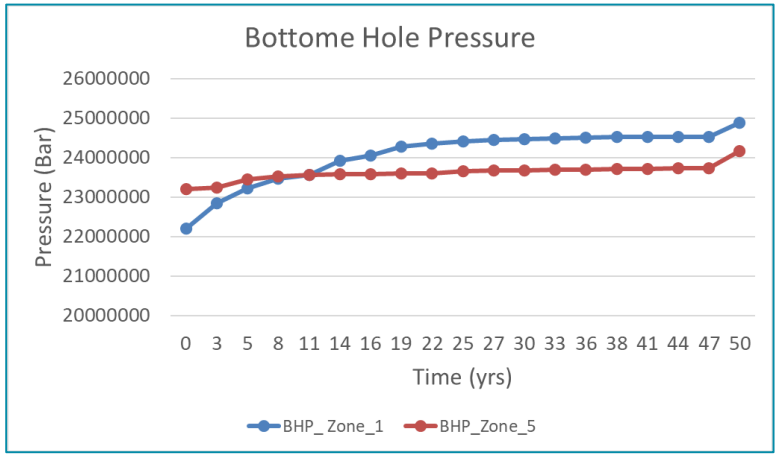
WP1: Geological and engineering fast proxy models

- Proxy models for predicting the global dynamic behavior in saline aquifer storage in response to changes in operating constraints

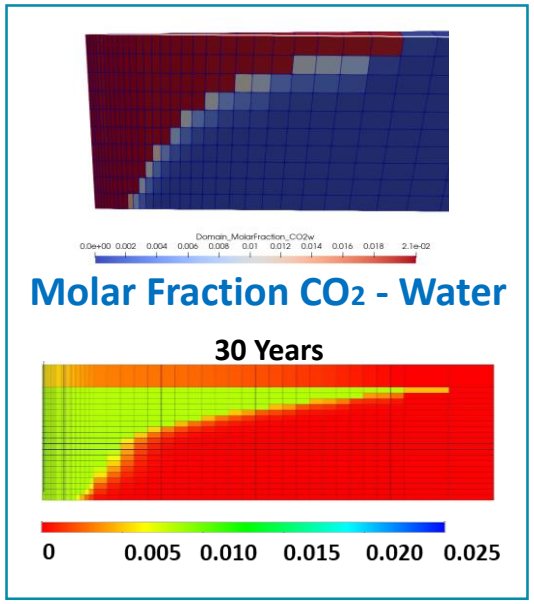


Paris Basin (France)

Numerical modeling of the Paris basin



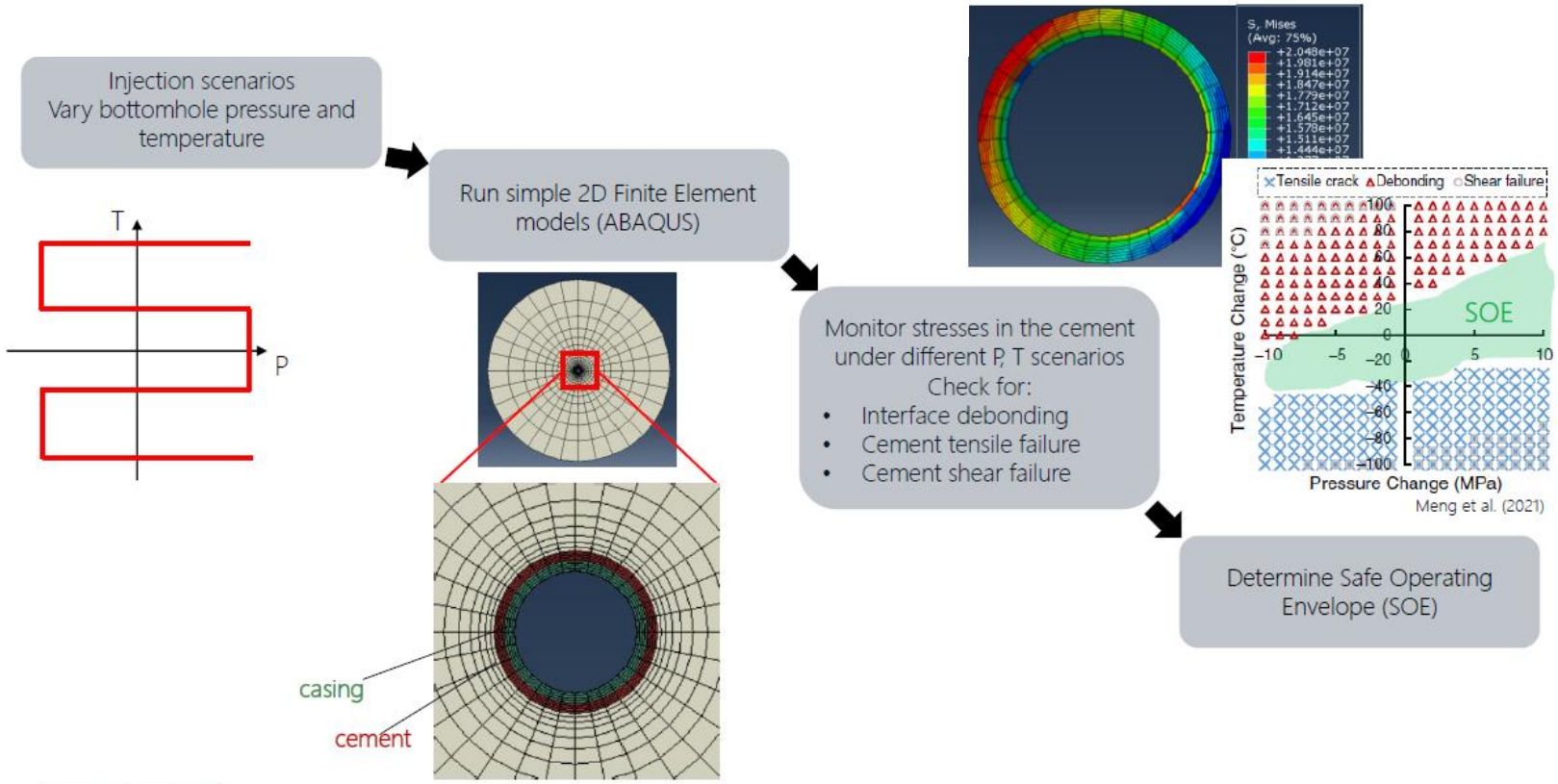
Getica site (Romania)

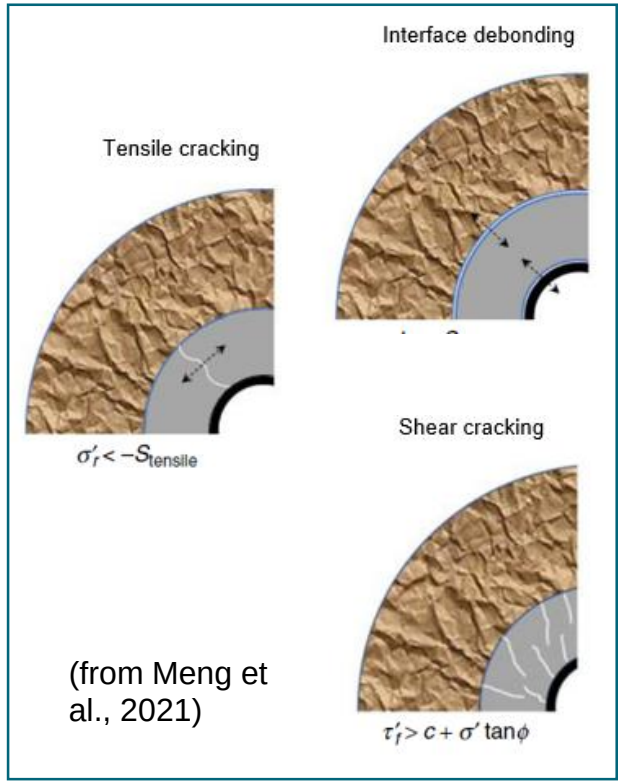


Case derived from Aquistore field data (Canada)

WP1: Geological and engineering fast proxy models

- Development of a fast proxy model for estimating a Safe Operating Envelope of pressure and temperature for assuring well integrity (TNO)
  - Application of the workflow to a case study inspired by Dutch assets in the North Sea

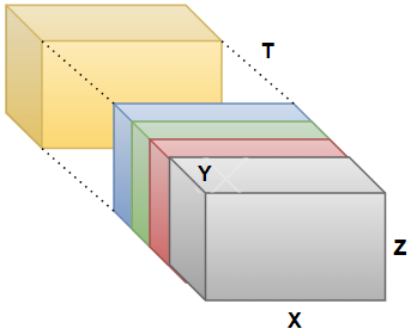




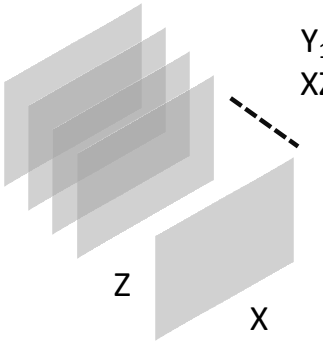
WP3: Storage and network risk dynamics

ANN-based Proxy Model for 3D Pore Data Prediction

- Predicts pore pressure, temperature and gas saturation, estimate the dynamic storage capacity
- Used in optimisation to determine the mass flow rates that minimise fracture pressure and maximise storage

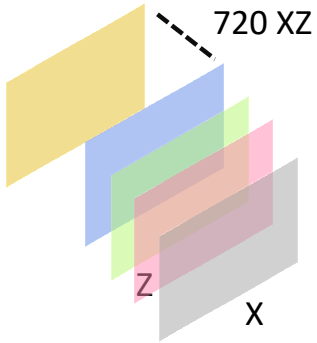


Complete XYZ-T 3D Spatiotemporal Snapshots*



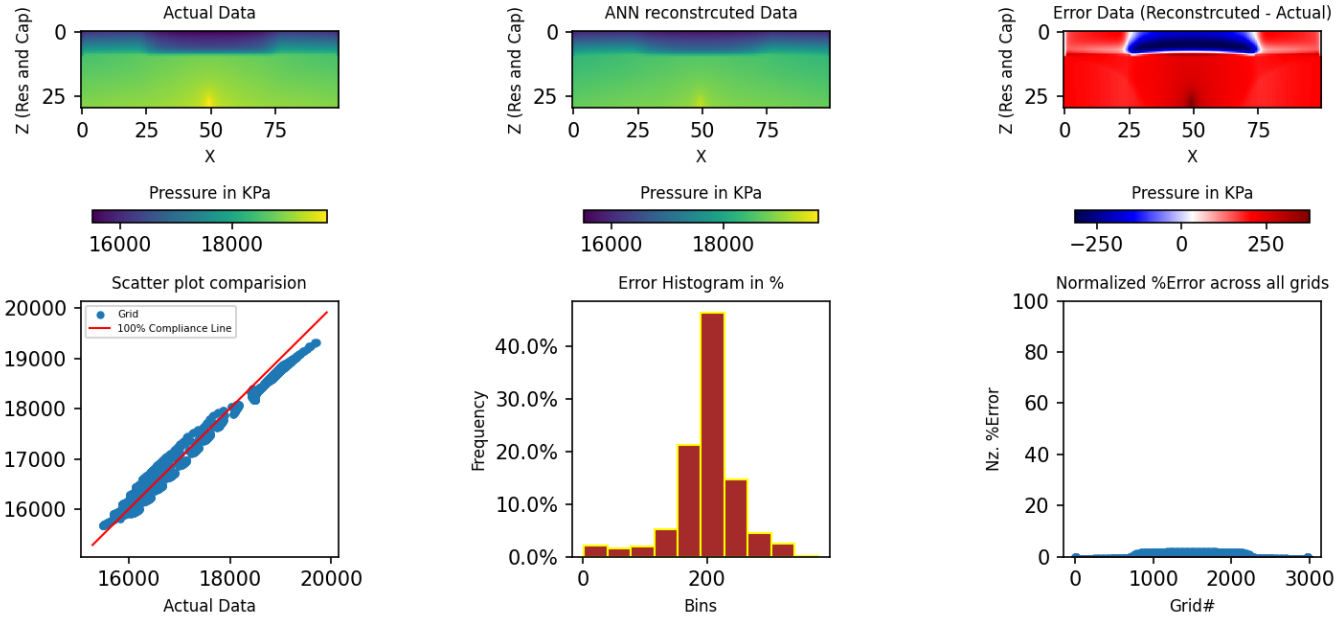
Y_1 - Y_{100} XZ Slices at T_k

100 XZ Slices in Y direction at k^{th} time instant



720 XZ Slices

i^{th} Y frame Y_i (i from 1 to 100) at every time instant*

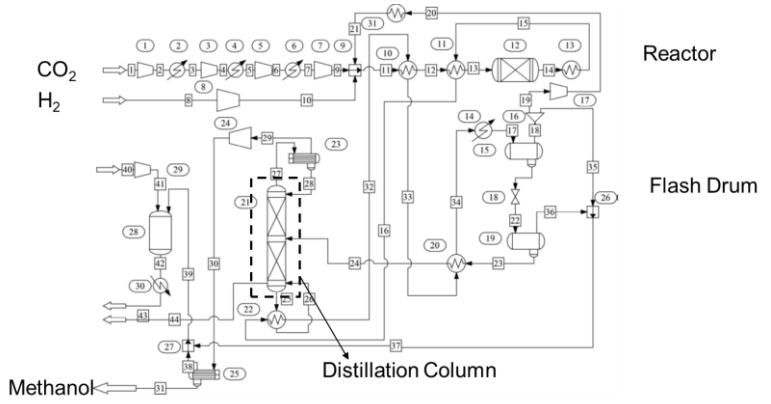


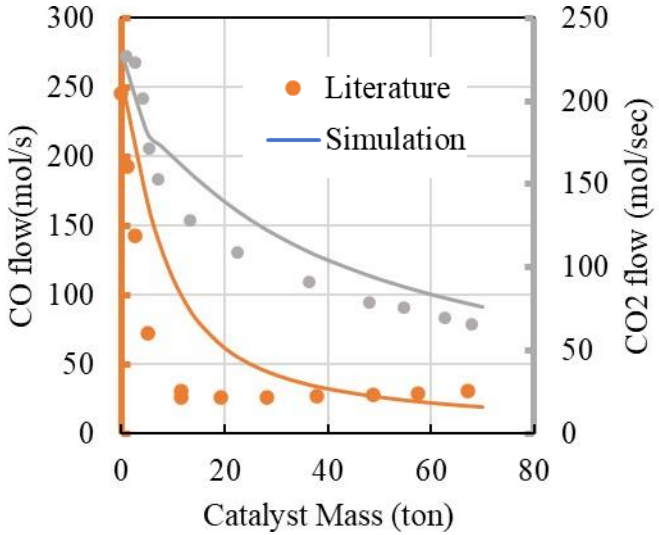
Pressure Center Frame Y_{50} at a time

WP4: CCU proxy models development and decarbonisation assessment methods

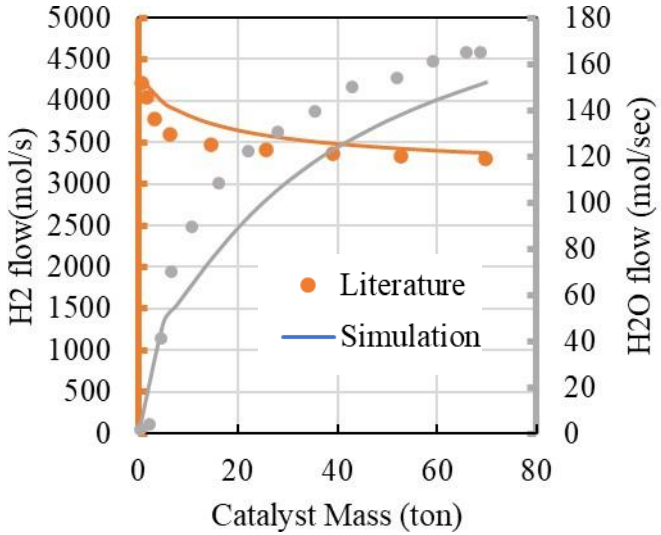
Proxy model for methanol production from CO_2

Empirical correlations (Wahid et.al., 2018) are used to calculate the net conversion of CO_2 to CH_3OH, the proxy model is validated using Lurgi-type industrial reactor model data

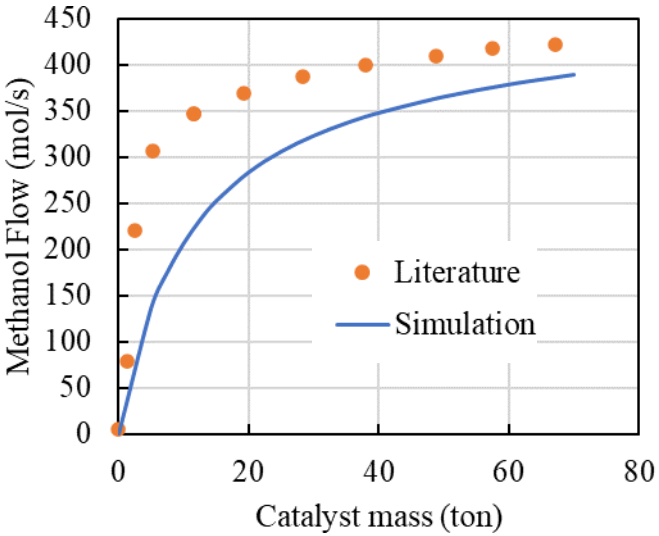




Effect of catalyst weight on CO and CO_2 flowrates in the reactor.



Effect of the catalyst mass of H_2 and H_2O flowrate.



Effect of catalyst mass on methanol formation

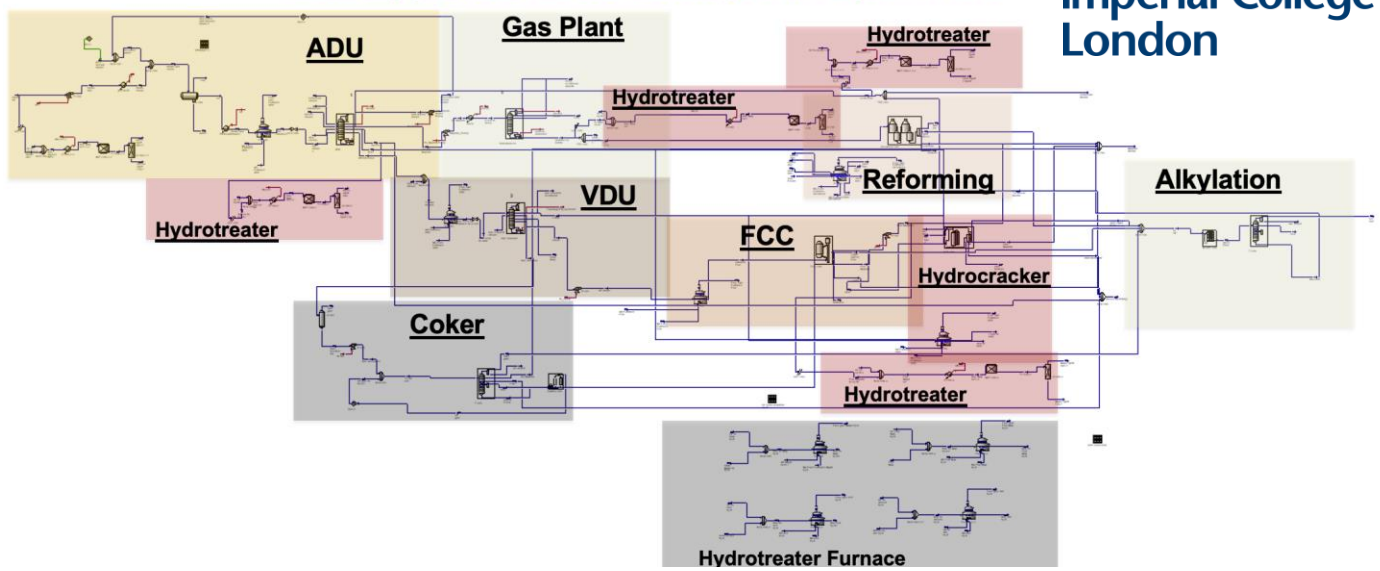
WP4: CCU proxy models development and decarbonisation assessment methods

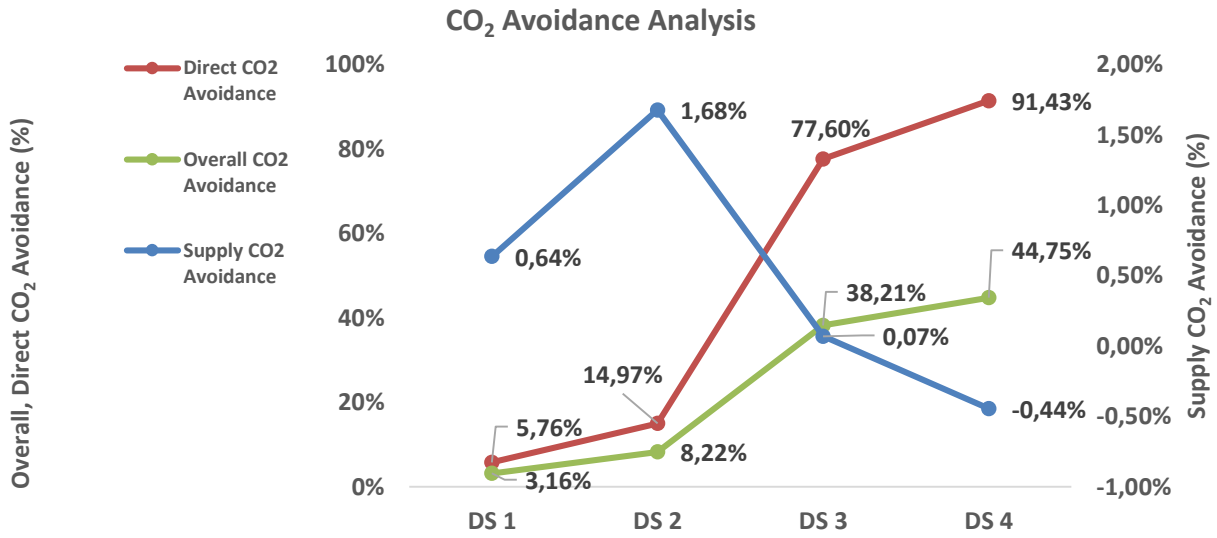
Term	Focus	Description
BAU		Refinery process with electricity and steam are imported from the grid
BAU1	Baseline (typical refinery system)	Refinery process with internal combined power and heat generation (CCGT+NG Boiler)
DS1	Efficiency improvement	Utilisation of excess heat from intermediate products (Diesel, Atmospheric Residue, and Reformate) for preheating crude oil
DS2	Efficiency improvement	Utilisation of excess heat from flue gases for power and heat generation to support the additional utilities (energy supply for refinery processes and post combustion CO_2 capture)
DS3	Carbon Abatement	Post combustion CO_2 capture using MEA for 80% of the direct CO_2 emissions (from top emission sources, i.e. CHP, Reforming, ADU, FCC Regenerator, VDU)
DS4	Carbon Abatement	Post combustion CO_2 capture using MEA for all direct CO_2 emissions

Plant/facility level decarbonisation versus hub/regional level performance may be competing objectives

Refinery process model developed in Aspen HYSYS®

Imperial College London

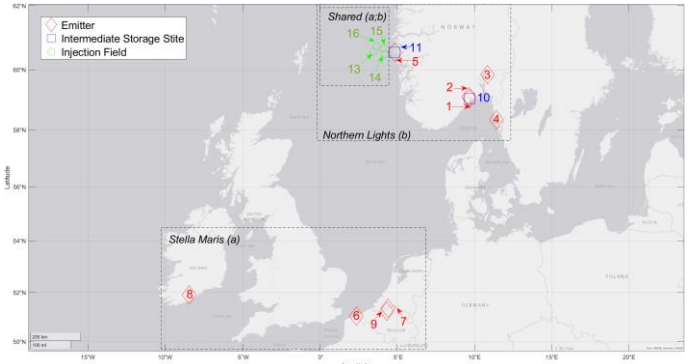




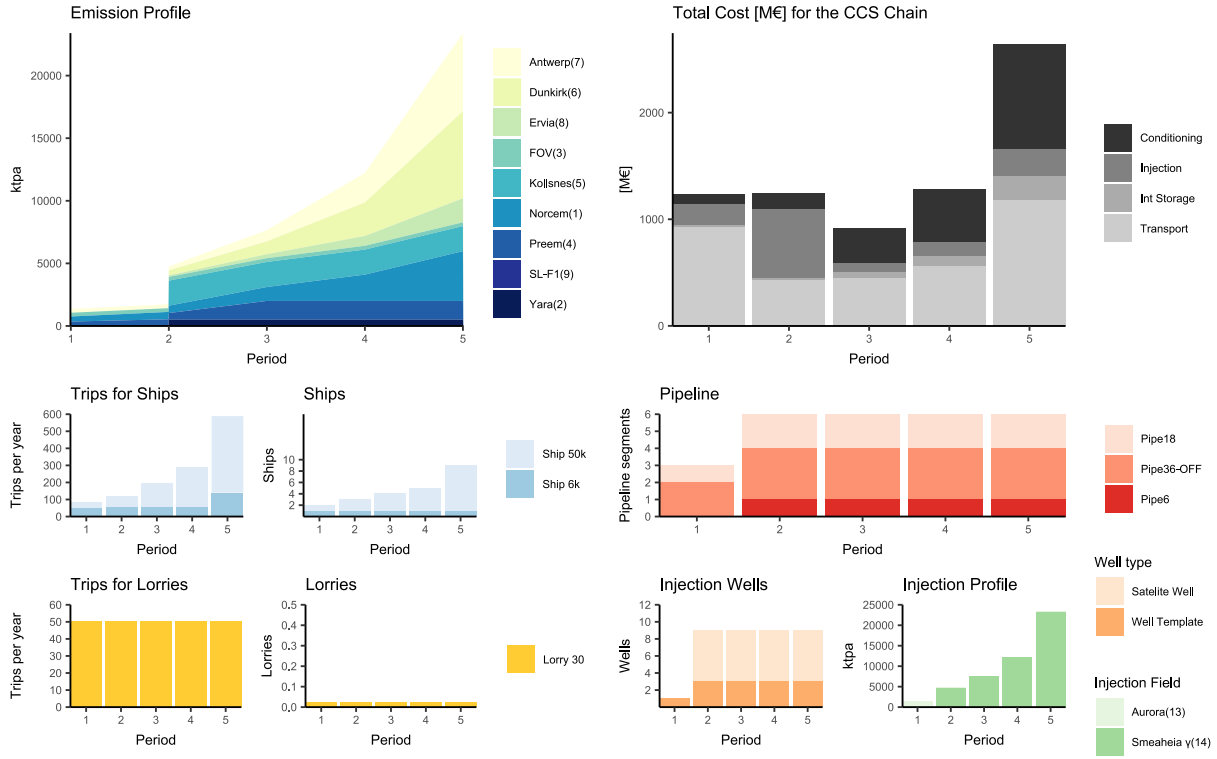
WP2: Transport network operability and multitemporal CCUS model development

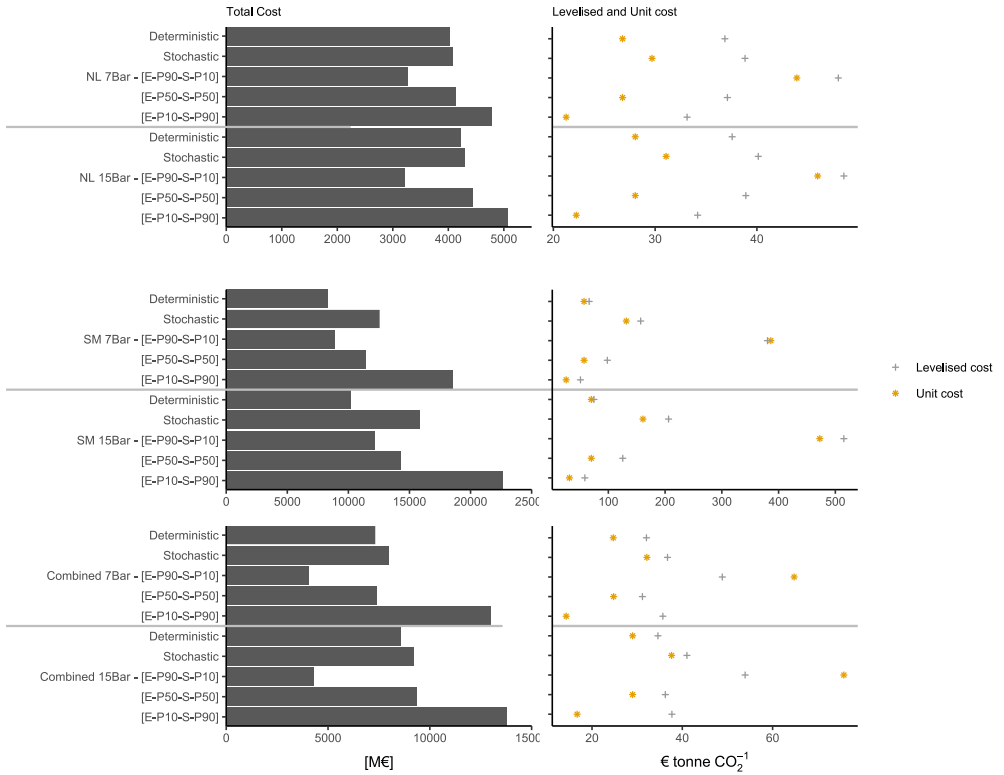
Deterministic and Stochastic Mixed Integer Linear Programming (MILP) cost optimisation model for CCS chains

Imperial College London



Implemented for the Northern Lights (NL), Stella Maris (SM) and the combined concepts for both 7 and 15 bar pressures and analysed trade-offs

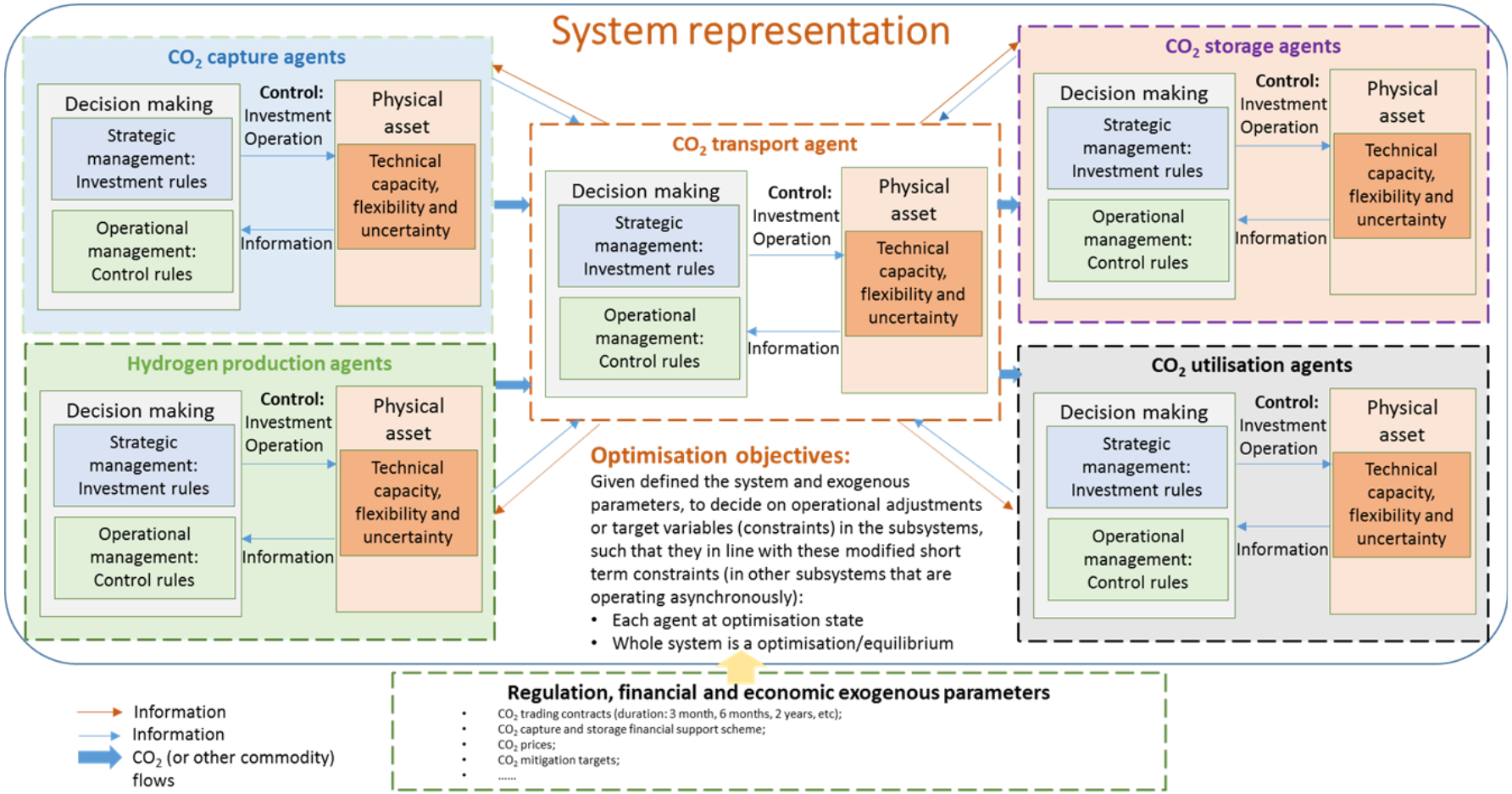




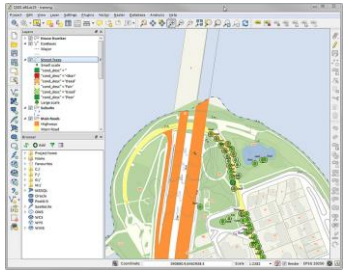
ACTION

WP2: Transport network operability and multitemporal CCUS model development

Multi-agent system modelling of CCUS systems



GIS Toolkit



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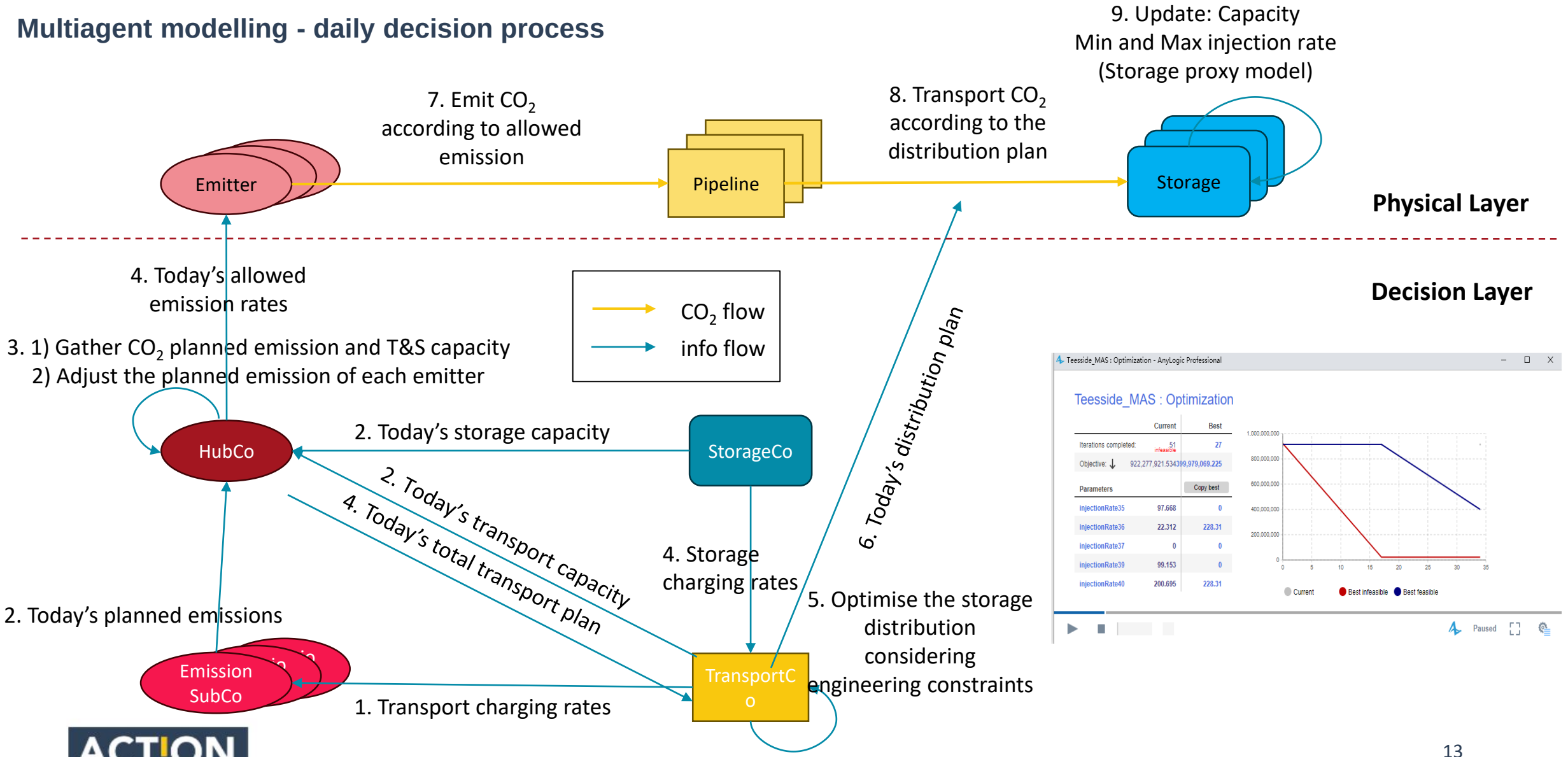
MATLAB

MAS Toolkit – GAMA **G**IS **A**gent-based **M**odelling **A**rchitecture)

WP2: Transport network operability and multitemporal CCUS model development

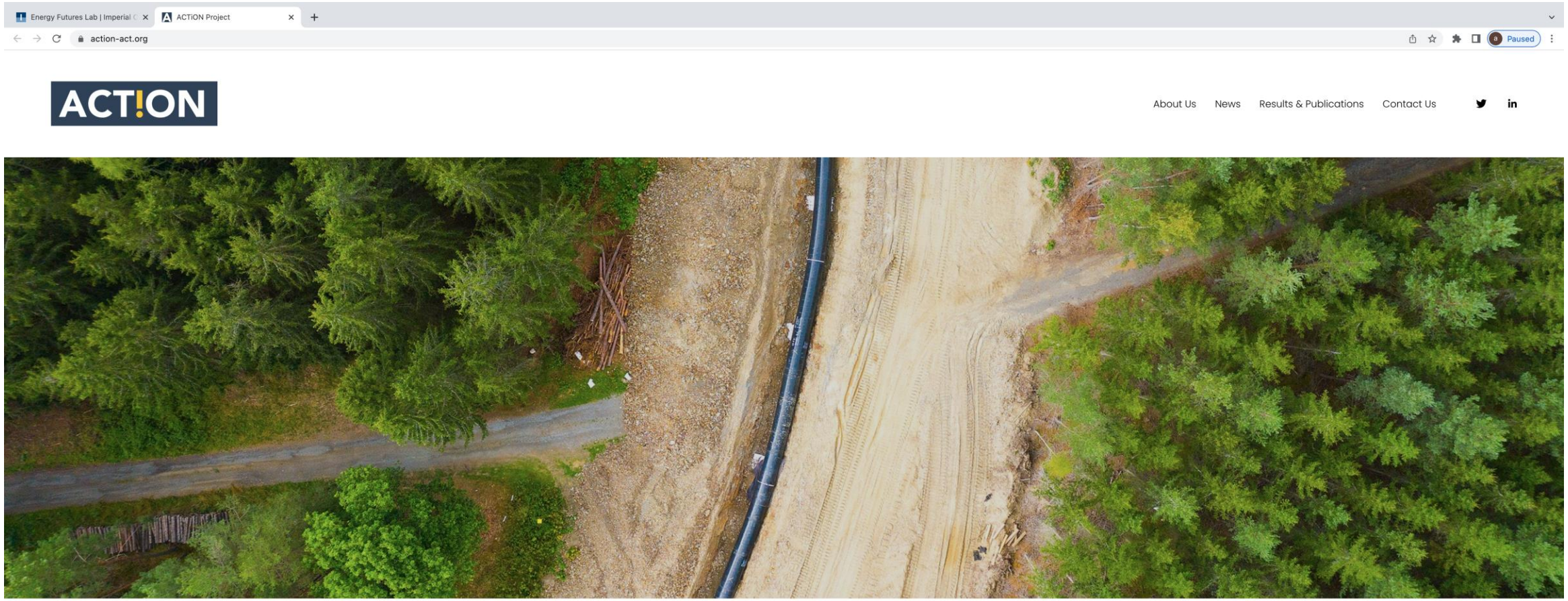
Multiagent modelling - daily decision process



WP5: Strategic decarbonisation scenarios accounting and reporting (lead: Imperial)

A WP dedicated to advancing the strategic decarbonisation of CCUS in six industrial regions across EU countries, the UK, Canada/Alberta Region and the US centred around developing full-chain CCUS projects.

UK:	BP Net Zero Teesside (NTZ) and Northern Endurance (NEP); South Wales Industry cluster (SWIC)
The Netherlands:	Neptune Energy, EBN (Porthos, Aramis), Netherlands-North Sea CCS cluster
USA:	Chevron, HeidelbergCement, Chemvita, Enchant Energy (CCU at Intermountain West region of US)
Canada:	Alberta Carbon Trunk Line (ACTL); PTRC (Weyburn Midale CO_2 Monitoring & Storage Project, Saskatchewan; Pembina Cardium CO_2 Monitoring Pilot (Alberta), Aquistore (Saskatchewan), Cvīctus utilisation (Alberta)
France:	Total - Gas Renewables and Power (Dunkirk-North Sea CCS cluster)
Romania:	PicOil, Getica (Romanian cluster)



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Acknowledgements

This project is funded through the ACT - Accelerating CCS Technologies programme. Financial contributions by the Department for Business, Energy & Industrial Strategy UK (BEIS); the Ministry of Economic Affairs and Climate Policy, the Netherlands; Department of Energy-Office of Fossil Energy (DOE-FE); Emissions Reduction Alberta (ERA); the French Agency for the Environment and Energy Management (ADEME); the Executive Agency for Higher Education, Research, Development and Innovation Funding (UEFISCDI) are gratefully acknowledged. We also thank all our industrial partners for their contributions and the funding they provide towards ACTiON.

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