



## Advanced multitemporal modelling and optimisation of CO<sub>2</sub> Transport, stOrage and utilisation Networks

Feb 2022 – Jan 2025

ACT knowledge sharing workshop 9<sup>th</sup> June 2022





## Rationale

Large-scale implementation of CCUS requires the **availability and flexible utilisation of a transport and storage network** that can handle varying CO<sub>2</sub> supply rates from different sources avoiding potential high emission costs of venting.

### From the network operator's

**viewpoint**, the overall cost of storing or the benefit of utilising a contracted amount of  $CO_2$  needs to be considered in a dynamic, time dependent

framework that respects **complex** engineering, economic and regulatory constraints.



From **strategic decarbonisation view point**, must be able to determine decarbonisation

### performance at operation and cluster level

(annual resolution, multiyear, planning horizon) that may be used to verify  $CO_2$  credits, use this for

## CO<sub>2</sub> accounting and reporting and have the

means to devise stage-gates and communicate progress towards the longer term decarbonisation agenda of the industry operators and regional clusters.

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## **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<sub>2</sub> transport, utilisation and storage networks,
- 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.

The term 'multitemporal' refers to three different time scales:

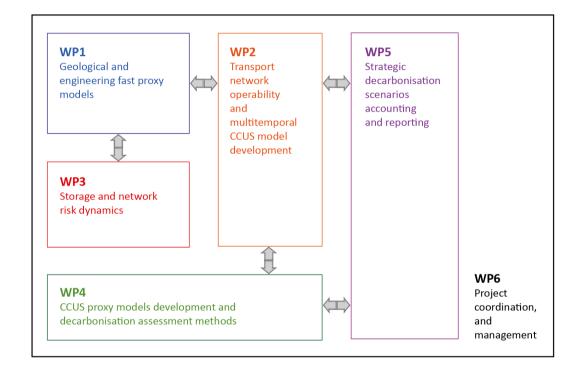
- 1) **short term (hours/days)**: required for safe and efficient network operability and to enable efficient CO<sub>2</sub> utilisation options function
- 2) medium term (years/several years): related to dynamic storage capacity and the function of large-scale transport and storage network, connecting CO<sub>2</sub> 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 (lead: IFPEN)

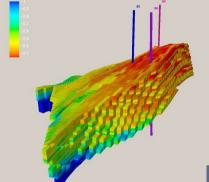
Develop computationally efficient proxy models that capture static geological reservoir characteristics and dynamic reservoir responses to be used for (near) realtime monitoring and decision support, especially those requiring demanding workflows (sensitivity analysis, optimisation under uncertainty).

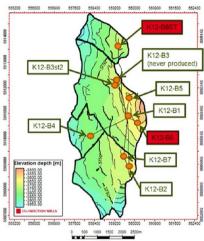
These will be implemented as modular, computational building blocks for integration with the models developed in **WP2**, **WP4** and **WP5**.

Previously validated reservoir models of a number of sites and the experience gained from long-term research by the project partners will be used in the development of reservoir performance, well/near wellbore and storage system integrity proxy models in WP1.

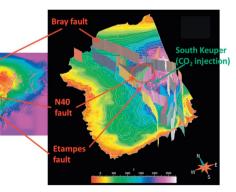
Structural map (faults and Triassic top layer) of the Paris Basin

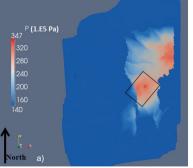
Compartment structure of the K12-B gas field with the CO2 injection wells in compartments K12-B8ST and K12-B6ST





Dynamic reservoir model of the centre compartment of K12-B, indicating water saturation68





Basin scale simulated pressure map in 50 years 7



## **WP1**: Geological and engineering fast proxy models

#### Task 1.1 - Reservoir Performance Proxy Models

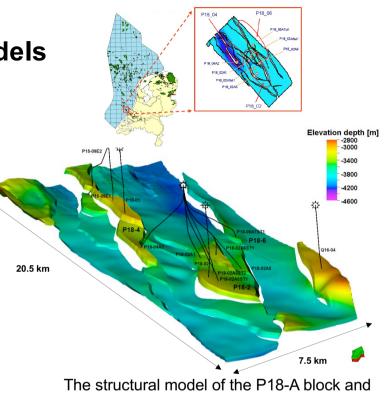
Subtask 1.1.1 - Saline aquifer storage performance

Paris Basin, Shell Quest, PTRC Aquistore, Forties and Nelson, Getica case histories to be used for proxy model benchmarking and validation

Subtask 1.1.2 Depleted gas reservoirs

P18, K12B case histories to be used with convolutional NN and machine learnine assisted proxy model for injectivity, P/T dependence and coupling wellbore model

Subtask 1.1.3 CO<sub>2</sub>-EOR in siliciclastic and carbonate reservoirs



well locations

Weyburn-Midale, Pembina Cardium Pilot and Romanian field case histories for proxy models using multi-objective evolutionary optimisation algorithms to maximise CO<sub>2</sub> utilisation under geological and operation uncertainties.



## **WP1**: Geological and engineering fast proxy models

#### Task 1.2 - Well and Near-Wellbore Proxy Models

Subtask 1.2.1 Dynamic well injectivity in saline aquifers

Paris Basin, PTRC Aquistore, Getica case histories to be used for proxy model development based on machine learning trained from available simulation results

#### Subtask 1.2.2 Well integrity proxy model

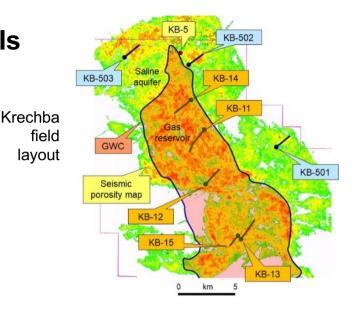
**P18**, **K12B** and **PTRC** Aquistore case histories used to enable the proxy model to be developed estimate a safe operations window

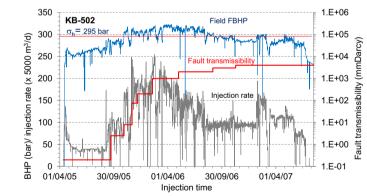
### Task 1.3 - Storage System Integrity Proxy Models

Subtask 1.3.1 Fault reactivation

InSalah case histories used and implement the NRAP response surfaces methodology for fault reactivation proxy model development







History matching of KB-502 Injection (BHP during the injection period between April 2005 and July 2007)

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

Build new and adapt existing proxy models (used in O&G) to support the design and management of

- CO<sub>2</sub> transport networks (pipelines and shipping),
- multitude of CO<sub>2</sub> emitters (e.g. power plants, cement industry, steel industry, chemicals),
- CO<sub>2</sub> users (EOR and industrial processes that use CO<sub>2</sub> as feedstock) and
- **storage reservoirs** (depleted fields and saline aquifers),

accessed through several offshore platforms or intermediate storage facilities and multiple wells at the scale of **days to weeks**.



Potential future CO<sub>2</sub> transport network



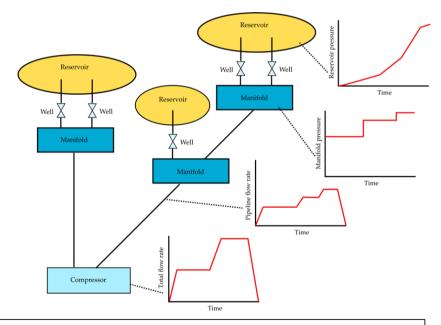
**WP2**: Transport network operability and multitemporal CCUS model development

Then, design a modular multi-disciplinary workflow for evaluation of the whole chain of CO<sub>2</sub> transport, utilisation and storage networks, which can be tailored to the specifics of any case study region.

This will be tested and demonstrated for the ACTION case study regions in WP5.

#### Task 2.1: Well – pipeline proxy model

- Subtask 2.1.1 Develop pipeline model to calculate the pressure and temperature drop in pipelines
- Subtask 2.1.2 Develop pressure model including heat transfer for the injection well from choke valve to perforations
- Subtask 2.1.3 Develop pressure drop model for sub-critical and critical-flow of flow through a choke control valve
- Subtask 2.1.4 Derive reduced models of pipeline and well models



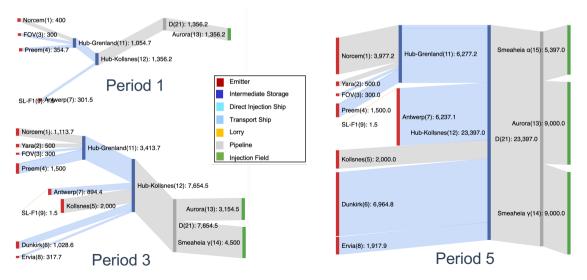


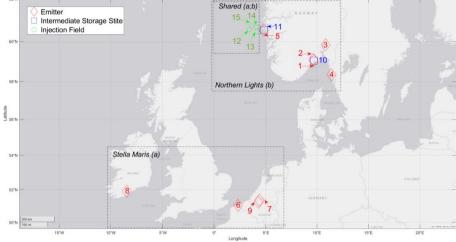
The proxy reduced models will be designed/selected to be suitable for implementation in the network model. Will be validated against the base models and results from commercial tools such as OLGA.<sup>11</sup>

## WP2: Transport network operability and multitemporal CCUS model development

## Task 2.3 Source and sink matching and multimode transport network design

The multi-period multi-mode CCUS value chain model developed in ALIGN CCUS, will be used as a basis, adding trucks for onshore scenarios and a rail transport component (for onshore CO<sub>2</sub> utilisation) and will be used in WP5.





#### Stella Maris (e.g. Ireland, France, Belgium, and Wales), Northern Lights concepts (e.g. Norway and Sweden)

The model includes: Conditioning (compression and liquefaction); Intermediate storage; Transport (transport ship, direct injection ship, onshore and offshore pipeline, and lorry); Injection (i.e. umbilical to platforms, subsea templates, and satellite wells). Stochasticity is added to every emission profile and to initial storage capacity from injection sites

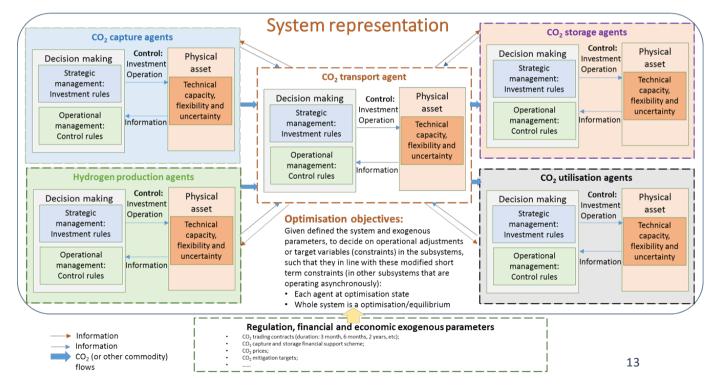
## WP2: Transport network operability and multitemporal CCUS model development

#### Task 2.4 Multi-agent system modelling of CCUS systems

The multi-agent based optimisation tool will be developed as a decentralised system to reflect accurately the physical assets of the system, but also the regional regulation, markets and economic reality that the ACTiON regional studies are set in.

Each agent element will be configured on the basis of the proxy model metrics from the respective WPs and designed to enable decision/optimisation to maximise facility profits (based on own perspective on markets, economics, physical asset operation conditions and limitations).





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

Characterise the integrated storage and network risk dynamics through modelling and risk assessments at hub and inter-hub level, addressing the inherent geological variability and uncertainties associated with the subsurface and its response to temporally variable demands on capacity ( $CO_2$  supply accommodation). Within ACTiON, risk will be considered in the context of system operability only.

**Performance indicators**, acting as system controls or constraints, will be established based on these risks and used to regulate the proxy models in WP1.

This work focuses on the relationship between **subsurface system risk** and **network risk at short temporal scales**, which has been largely ignored in earlier CCUS supply chain risk and optimisation studies.

In addition, techniques will be developed that provide fast constraints for network optimisation, based on (user-specified) acceptable limits on risk ranking.



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

#### Task 3.1 Risk-based key performance indicators

Will identify a suite of risks that can be informed by outcomes from proxy models (WP1, WP2) using case histories (Aquistore, In Salah, NRAP) and define key performance indicators for tracking the dynamic operations of a CCUS network.

	Risk	SSubsystem <sub>a</sub>	Risk nature <sup>b</sup>	Nature of consequences <sup>b</sup>
1*	Project permits not obtained	W	L	P, P/S
2 *	Technology scale-up	W	Т	P, P/S, T
3 *	Public opposition	W	S	P, P/S, L
4 *	Lack of knowledge/qualified resources for operating the unit	W	Т, О/Н	P, P/S, HSE, O/H, T
5	Corrosion	w	т	Т, Р
6	Using the existing facilities (specially pipelines)	w	т	Т, Р
7	CO <sub>2</sub> out of specification	W	Т	T, P, HSE
8	CO2 plumes exceed the safe zone	W	Т	P, T, HSE
9 *	Legal uncertainties	W	L	P, P/S, T, L
10	Safety related accident	W	т, 0/н	T, O/H, P, HSE, S
11 *	Uncertainties in stakeholders requirements/perceptions - communication problems	w	P, P/S, HSE, O/H, T, S, L, F/E	P, P/S, HSE, O/H, T, S, L, F/E
12 *	Public availability of sensitive information	w	O/H, P/S	P, P/S, S, O/H
13 *	Change in policies/priorities	w	P/S, L	P, P/S, L
14 *	Financial crisis impact on financial support of CCS projects	W	F/E	P, P/S, F/E
15 *	Unavailability of a monetary mechanism for CO2	W	F/E, L	P, P/S, F/E, L
16	Construction field conditions	W	т	Р, Т
17 *	Geographical infrastructure	W	Т	T, P, P/S, S, HSE
18	Proximity to other industrial plants	W	Т	T, P, HSE
19	Energy consumption	W	Т	P, P/S, T
20	Maintenance and control procedures (including ESD system)	w	т, о/н	T, O/H, P, HSE
21	Boiling Liquid Expanding Vapor Explosion (BLEVE)	w	т	P, T, HSE
22 *	Lack of financial resources	W	F/E	P, P/S, F/E
23 *	Lack of political support	w	P/S	P, P/S, O/H, S, L, F/E
24	Phase change & material problems	W	Т	Ρ, Τ
25 *	High cost of project 3	W	F/E	P, P/S, F/E
26	Lower capture efficiency due to the upstream plant flexible operation	с	т	Ρ, Τ
27	CO2 leakage from compression unit	С	Т	T, P, HSE
28	Pipeline construction	Т	т	P, T
29	CO2 leakage from pipeline	Т	Т	T, P, HSE
30 *	Unavailability of regulations regarding different types of storage (offshore/ onshore)	S	L	P, P/S, L



				Nature of
	Risk	SSubsystem <sub>a</sub>	Risk nature <sup>b</sup>	consequences
31	Leakage through manmade pathways such as abandoned wells	S	т	Р, Т
32	Well integrity	S	т	Ρ, Τ
33	CO <sub>2</sub> migration	S	т	T, P, L, S
34	Injectivity reduction over time	S	т	Ρ, Τ
35 *	Uncertainties regarding the storage performance (capacity/injectivity/ containment)	S	т	P, P/S, T
36	CO <sub>2</sub> leakage from storage to the surface	S	т	T, P, P/S, HSE
37 *	Model and data issues	S	т	P, P/S, T
38 *	Uncertainties related to storage monitoring	S	т	P, P/S, T, HSE, S, L
39	Soil contamination	S	Т	Р, Т

aW=Whole CTSC chain, C=Capture, T = Transport, S=Storage bT = Technical, P=Project, S=Social, P/S=Policy/Strategy, HSE = Health, Safety, Environment, L = Legal, O/H=Organizational/Human, F/E = Financial/Economic \*Major risk affecting project progress in the **first phases** 

- Subsystem Storage Risk

**Conformance Risks** 

**Containment Risks** 

- Methodology for Assessing Transport Properties of Wells Used in the Geological Storage of CO<sub>2</sub>
- Work flows for Dynamic Analysis of Safety Key Performance Indicators for CCUS (e.g. STAMP)

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

Develop proxy models for  $CO_2$  utilisation and conversion technologies likely to be part of future CCUS systems. Many are already fully/partially developed by the team (natural gas processing, natural gas power generation with  $CO_2$  capture; steam methane reforming of natural gas for H<sub>2</sub> production with  $CO_2$  capture; syngas production from deep coal resources for methanol production with  $CO_2$  capture). Others will be reconfigured using components of the process models available (fermentation, cement, iron and steel production) and new ones will be developed (biological conversion, additional chemical conversion processes and  $CO_2$  mineralisation options).

#### Task 4.1 Proxy models development for utilisation/conversion technologies

#### Task 4.2 Proxy models for CO<sub>2</sub> capture from power, the steel and cement industries

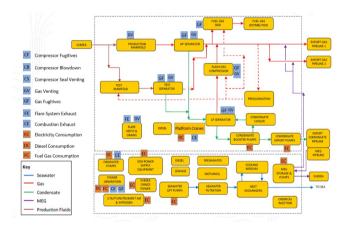
The new process models will be converted to Life Cycle Assessment (LCA) and Life Cycle Cost (LCC) models to complement the existing ICLCA inventory models already developed by IMPERIAL, to be used for the decarbonisation accounting and reporting in WP5.

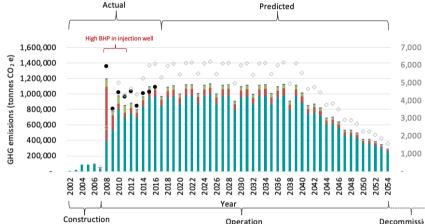


## **WP4**: CCU proxy models development and decarbonisation assessment methods

#### Task 4.3 LCA / LCC model development for decarbonisation assessment

(ICLCA) will be used and expanded with appropriate functionality to cover the individual value chain specifics for all the transport, utilisation and storage options considered



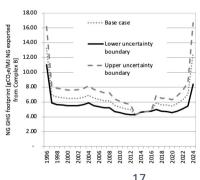




Fugitive CO<sub>2</sub> eq emissions Venting CO<sub>2</sub> eq emissions Flaring CO<sub>2</sub> eq emissions Combustion CO<sub>2</sub> eq emissions Reported CO<sub>2</sub> eq emissions LNG production

#### Task 4.4 Consequential LCA development

A background model, taking into account relationships between markets, will be produced in order to derive the cascading effects (physical or market-mediated) of the decision on the concerned markets and the related environmental impacts. C-LCAs will be performed for the Dunkirk, Western Canada and Netherlands regions





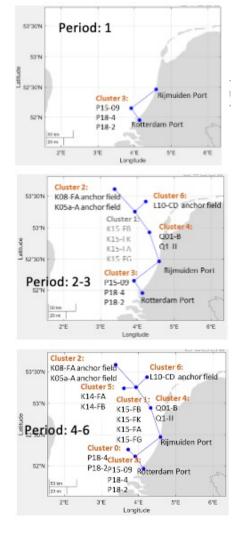
## WP5: Strategic decarbonisation scenarios accounting and reporting (lead: Imperial)

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.

### A scenario development task followed by six region

**specific ones** dedicated to the tailored implementation of the multitemporal CCUS network modelling tools developed in ACTiON with the purpose to assess strategic decarbonisation scenarios relevant for each region and to provide the means for GHG emissions reductions accounting and reporting at operation, cluster and regional, and national level.

The learnings from these implementations, drawing the conclusions and assessment from the regional studies together, will be explored in the final project workshop and be presented in a publishable report.



ACTON

WP6: Project management and dissemination (lead: Imperial)



Work package descriptions         Project Neutre           WPL Geological and Engineering Fast Proxy Models         Image: Control Pro	Year         2nd Year         2           7         8         9         10         11         12         13         14         15         16         17         18         19         20         21         22         23         24         25         26         27	3rd Year		
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About ACTiON

ACTION aims to establish how an efficient infrastructure connecting CO<sub>2</sub> sources with geological storage and utilisation options can be developed. The three-year project, which brings together researchers and industrial partners from seven countries, will help accelerate industrial decarbonisation by minimising the risks and costs associated with moving and storing or utilising captured CO<sub>2</sub>.

Learn more

Website: <u>www.action-act.org</u> Twitter: @ACTiON\_ACT



# ACTON



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Prof Anna Korre (ACT!ON coordinator) a.korre@imperial.ac.uk