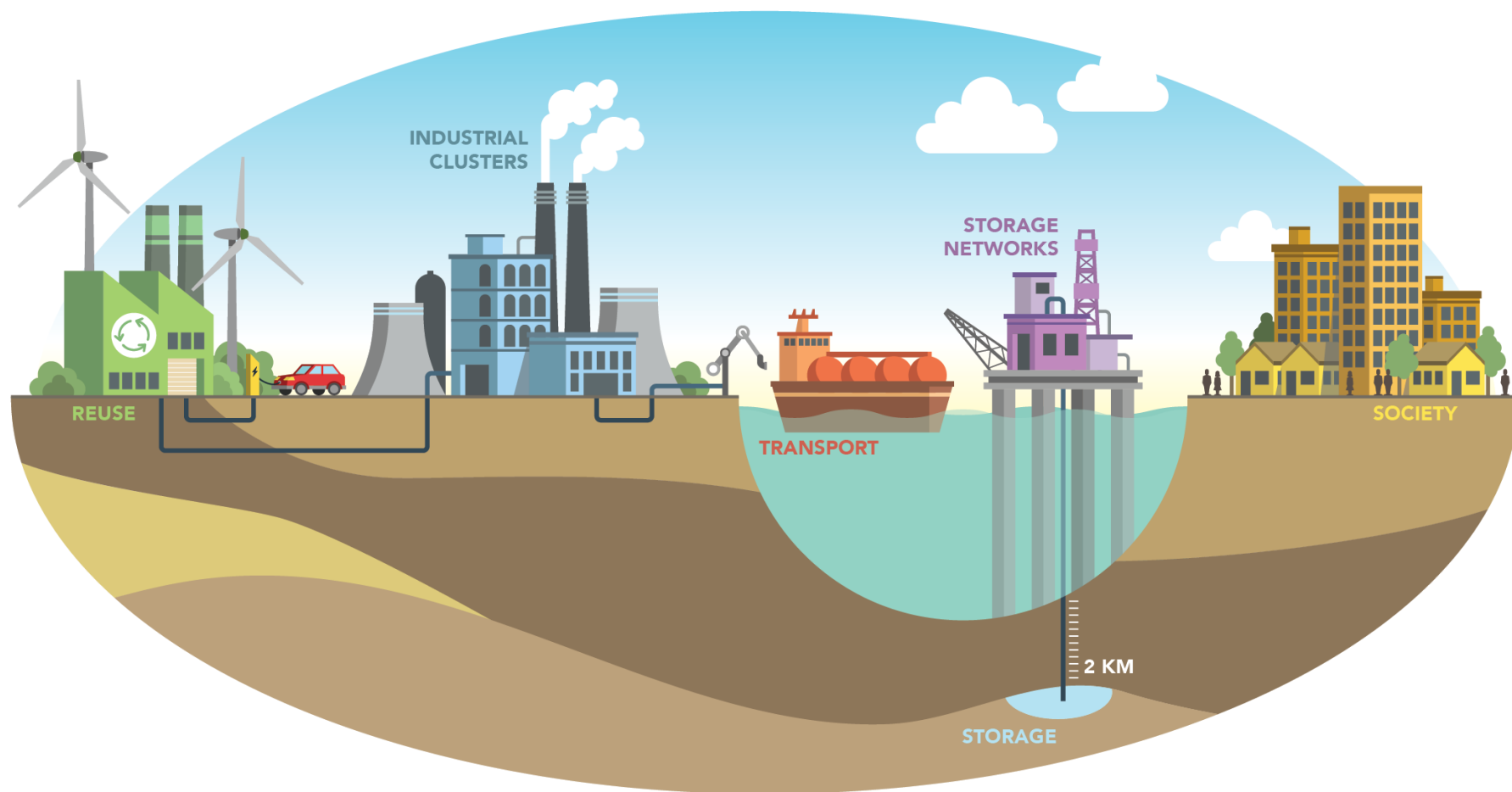


ALIGN ccus



Knowledge
sharing
workshop



Project no 271501, ACT – Accelerating CCS technology

 **Peter van Os (TNO)**

Coordinator

ALIGN CCUS

Accelerating Low Carbon Industrial Growth through CCUS 'ALIGN-CCUS'

ALIGN CCUS is a full chain project



Objectives (1)

- ALIGN addresses specific issues across the CCUS chain for industrial regions in ERA-NET ACT countries, enabling large scale, cost effective implementation of CCUS by 2025. To reach the overall aim of ALIGN, the project encompasses a number of focused but interlinked objectives:
 - **Capture:** Enable near-term deployment of CO₂ capture by improving performance and reducing costs
 - **Transport:** Optimising large-scale CO₂ transport
 - **Storage:** Reduce uncertainty in the provision of large-scale storage networks
 - **Utilisation:** Establish the contribution of CCUS as an element for large-scale energy storage and conversion
 - **Social acceptance:** Implementing CCUS in society

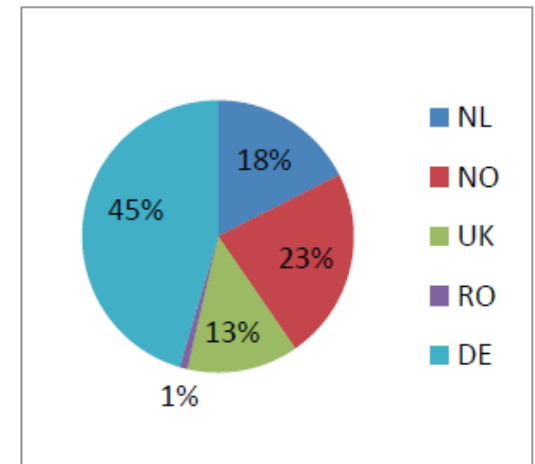
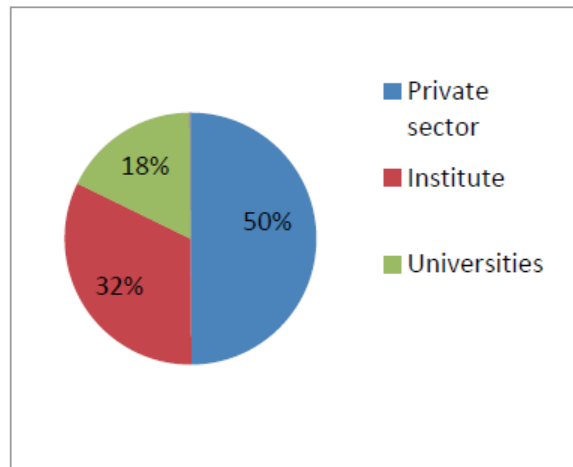
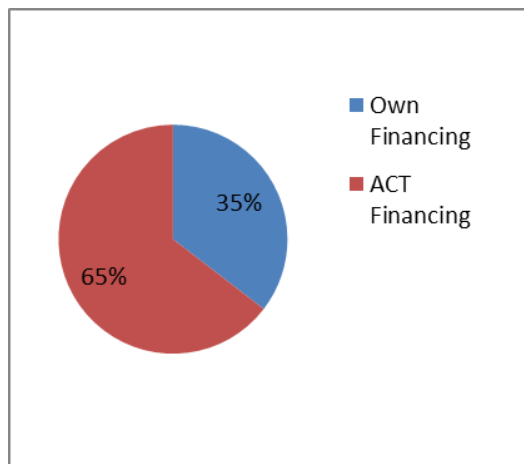
Objectives (2)

- ALIGN will combine the results from each of these objectives to deliver actionable blueprints in ERA-NET ACT countries: Teesside and Grangemouth (UK), Rotterdam (NL), North Rhine-Westphalia (DE), Grenland (NO) and Oltenia (RO, in which CCUS enables low-emission industries, through geological storage or through utilization of CO₂).



Key Figures

- 31 partners in the project from Germany, Norway, Romania, United Kingdom, The Netherlands
- ~23 Million Euro project budget, ~15 Million Funding
- September 1st 2017 until September 1st 2020
- Budget division as below



ALIGN CCUS

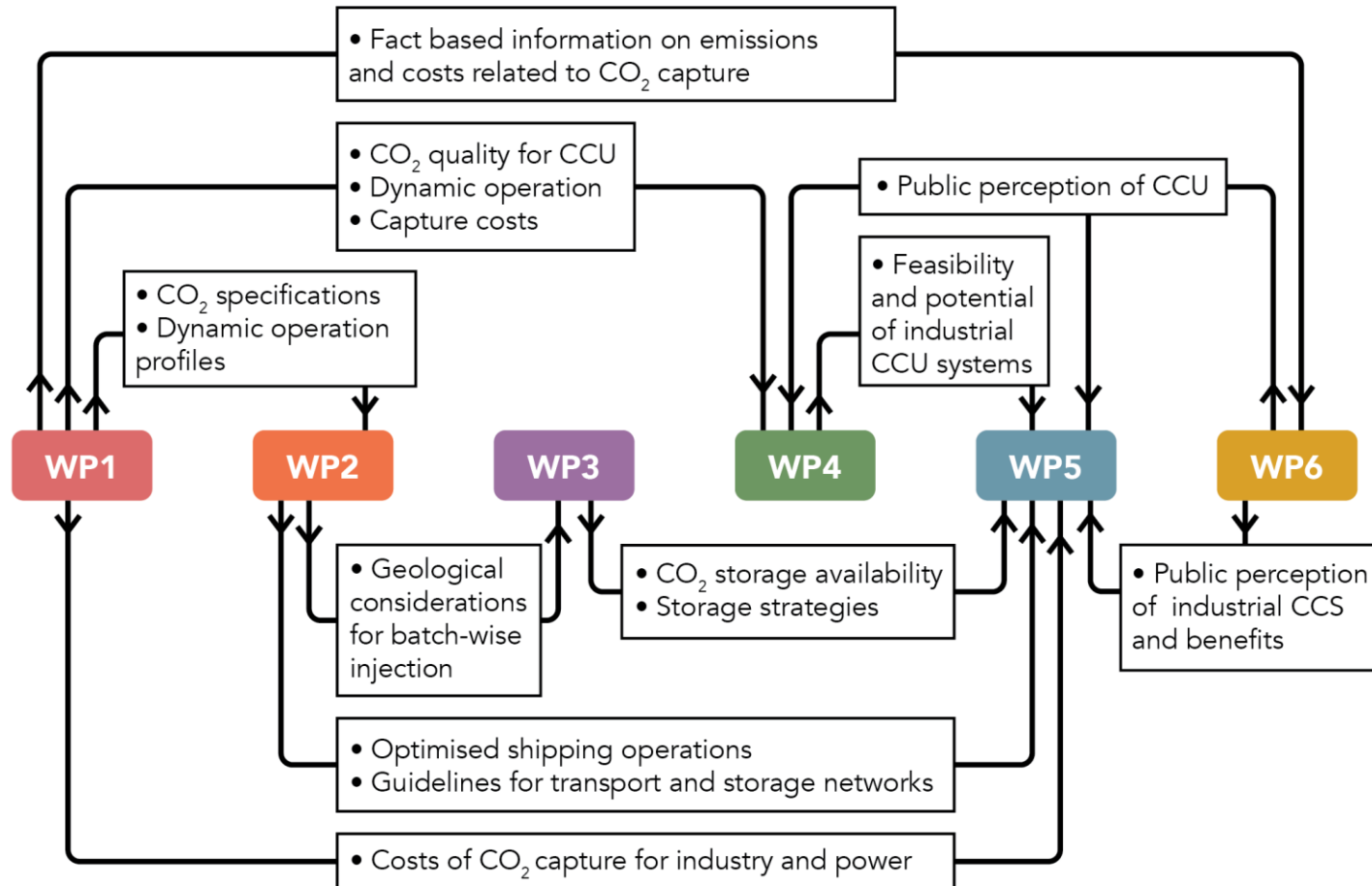
- Testing at world-class research facilities
- Multidisciplinary research teams
- Exceptional industrial commitment
- Demonstration of FOAK full-CCU chain
- Accessible and inclusive dissemination plan
- Links to Industry (IAG) and Australia (CSIRO)

We have a big project

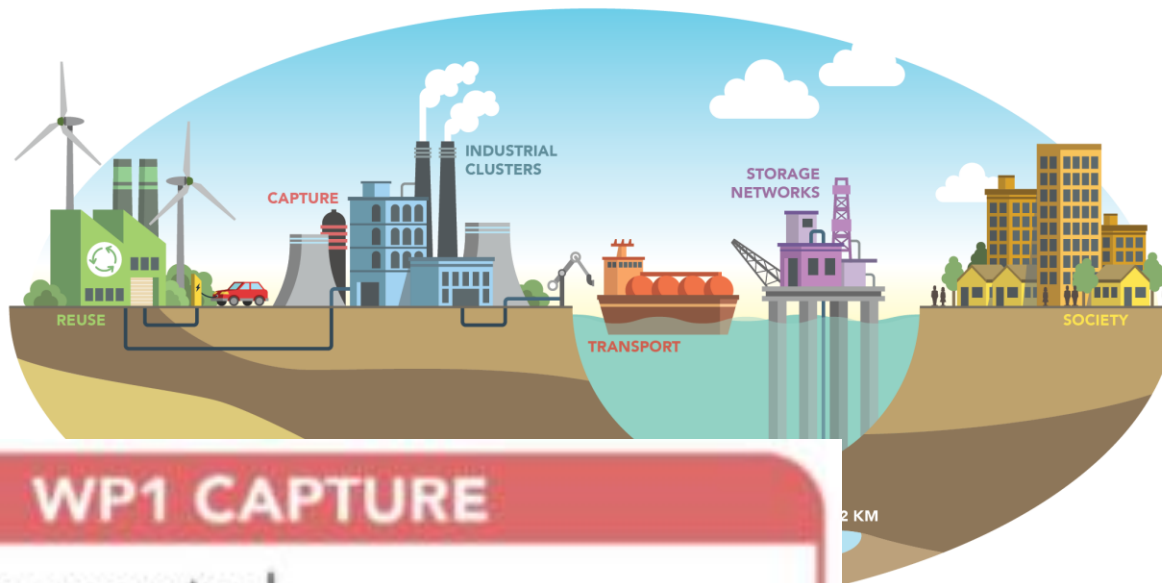
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WP	Task #	Description	Month
1	MS1.1	Aerosol behaviour understood and validated - D1.1 finished	M18 Jan-18
1	MS1.2	Understanding the effect of dynamics on solvent emissions - Pilot test of FIVE and TCM	M24 Jul-18
1	MS1.3	Qualification for test CESAR1 at TCM - Pilot test at Tiller finished	M24 Jul-18
1	MS1.4	Validated and demonstrated aerosol countermeasures - D1.1 finished	M24 Jul-18
1	MS1.21	Online solvent monitoring tool in operation at pilot plant (Tel-Tek)	M12 Jul-18
1	MS1.22	Degradation countermeasure implemented on pilot plant scale (TNO)	M18 Jan-19
1	MS1.23	Guidelines for effective solvent management compiled (FIVE)	M35 Jun-20
1	MS1.31	Identification of chain integration constraints (SINTEF MC)	M18 Mar-19
1	MS1.32	Designation of flexible operational scenarios (RHUJ)	M12 Jul-18
1	MS1.33	Optimised process control strategy taking into account flexibility, emissions and degradation (SINTEF MC)	M30 Jan-20
1	MS1.41	Non-power plants reference cases described and methodology for cost estimation defined (SINTEF MC)	M25 Aug-19
1	MS1.42	Techno-economic evaluations of the integration of MEA and CESAR1 (RHUJ)	M32 Mar-20
2	2.1	Pressure and temperature ranges and injection schedules which are technically and economically feasible for ship transport and offloading (Tel-Tek)	M12 Jul-18
2	MS2.31	Meeting agreeing on the CO ₂ specifications to be experimentally verified (IFE)	M9 Apr-18
3	3.1	Completion of national discussions with regulators and operators in Netherlands (TNO), UK (BGS) and Norway (SINTEF PR)	M12 Jul-18
3	MS3.12	Hold international benchmarking workshop (BGS)	M15 Oct-18
3	MS3.31	Workshop, legal issues (FUG)	M12 Jul-18
4	MS4.11	Engineering completed	M18 Jan-19
4	MS4.12	Erection completed	M24 Jul-19
4	MS4.13	Commissioning completed	M27 Oct-19
4	MS4.21	Definition and procurement of base injection systems (pump, injector, storage) for passenger car and peak power plant	M5 Dec-17
4	MS4.22	Procurement of optimized peak power injector and piston bowl	M19 Feb-19
4	MS4.23	Procurement of optimized peak power injector & piston bowl	M23 Jun-19
4	MS4.24	First operation of CCU-DIME-peak power engine Niederassum	M27 Oct-18
4	MS4.25	First operation of CCU-DIME-demonstrator vehicle	M30 Jan-20
4	MS4.31	Start operational parameter variation	M27 Oct-19
4	MS4.32	Start long-term testing with optimal parameter settings	M32 Mar-20
4	MS4.41	Survey of LCA studies of DIME production, data collection	M6 Jan-18
4	MS4.42	Benchmarking against existing CCU technologies and evaluation of competing pathways for CO ₂ and H ₂ provision	M32 Mar-20
5	MS5.11	Provision of relevant data from any CCUS pilot plants on Teesside	M28 Nov-19
5	MS5.12	Select agreed storage option	M12 Jul-18
5	MS5.13	Complete refinement of existing storage site model	M18 Jan-19
5	MS5.14	Complete simulation of storage scenarios	M24 Jul-19
5	MS5.15	Complete analysis of technology and operational impacts on storage cluster business	M30 Jan-20
5	MS5.31	Specifications on CO ₂ and H ₂ sources and DIME/DIME demand received from V/P4	M18 Jan-19
5	MS5.32	Matching of sources and sinks	M24 Jul-19
5	MS5.33	Description of possible CO ₂ pathways completed	M30 Jan-20
5	MS5.51	Matching of sources and sinks	M22 May-19
6	MS6.11	Preparation of informed polling questionnaire	M14 Sep-18
6	MS6.12	Completion of data collection	M19 Feb-18
6	MS6.13	Completion of data analysis	M23 Jun-18
6	MS6.14	Preliminary film shown at meeting plenary + debate	M28 Nov-18
6	MS6.21	Interview protocols finished	M10 May-18
6	MS6.22	Stakeholder interviews completed	M18 Jan-19
6	MS6.23	Workshop with key stakeholders	M22 May-19
6	MS6.24	Data collection completed	M28 Sep-19
6	MS6.31	Completion of desk research	M12 Jul-18
6	MS6.32	Completion of stakeholder interviews	M24 Jul-19
6	MS6.33	Completion of analysis	M27 Oct-19
6	MS6.34	Completion of focus group research	M32 Mar-20
0	0.1	Grant agreement in place	M3 Oct-17
0	0.2	Communication plan agreed with V/P and project lead	M1 Aug-17

Well integrated



Work Packages (WP1)



WP1 CAPTURE

- Emission control
- Solvent management
- Dynamics and control
- Cost reduction

WP3 STORAGE

Standardizing storage readiness
North sea storage appraisals
Re-use of existing assets

WP6 SOCIETY

Assessing public opinion
Compensation strategies
Improving EU dialogue on CCUS

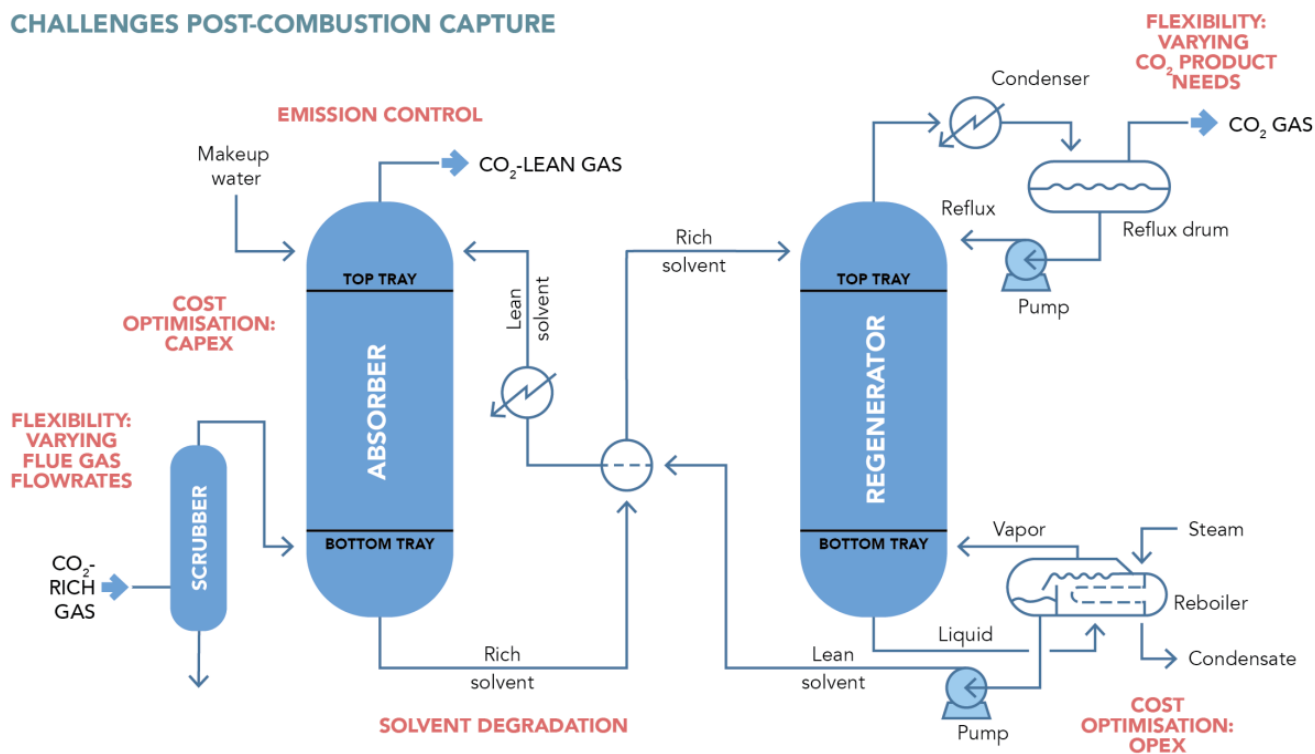
WP0 MANAGEMENT

Commercial models for CCUS clusters

WP1 Capture (SINTEF, NTNU, TNO, HWU, RWE, UoS, TCM, Tel-Tek)

Enable near-term deployment of integrated capture facilities and cluster development.

CHALLENGES POST-COMBUSTION CAPTURE



WP1 Pilot plants in the project

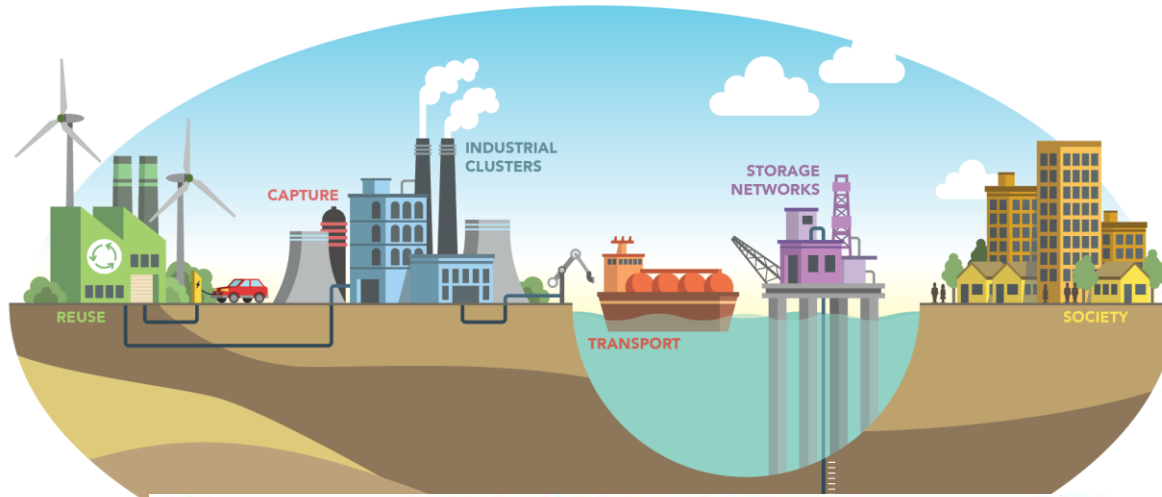
- Using pilot plants for testing and validate models

Pilot plant	Scale & flue gas source	ALIGN Focus
Mongstad, Norway (TCM) ~2000 hrs CESAR1	12.5 tCO ₂ captured/h Flue gas from a natural-gas-fired Combined Heat and Power (CHP) plant and from a Residue Fluid Catalytic Cracker (RFCC)	<ul style="list-style-type: none"> - Long-term test of CESAR1 solvent system - Test Brownian Demister - Varying process conditions and dynamic tests - Reclaiming - Degradation and corrosion testing - Deliver data for modeling
Niederaussem, Germany (RWE) ~12.000 hrs MEA ~12.000 hrs CESAR1	0.3 tCO ₂ captured/h Flue gas from raw lignite-fired power plant	<ul style="list-style-type: none"> - Very long term testing - Emission control - Solvent management - Study dynamic effects - CCUS re-use - Testing On line solvent monitoring tools - Deliver data for modeling
Tiller, Trondheim, Norway (SINTEF) ~700 hrs CESAR1	0.03-0.04 tCO ₂ captured/h Flue gas from propane, coal or biomass burner with CO ₂ up to 30 vol.%	<ul style="list-style-type: none"> - Solvent management CESAR1 solvent system - Test and evaluate online liquid and emission measurement equipment - Evaluate NMPC (Nonlinear Model Predictive Control) strategies - Deliver data for modeling
PACT facilities, UK (UoS) ~600 hrs MEA ~600 hrs CESAR1	0.04 tCO ₂ captured/h Flue gas from either air combustion plant or gas turbine	<ul style="list-style-type: none"> - Solvent management for natural gas derived flue gases - Test degradation counter measures - Test flexibility options - Effect of inhibitors - Deliver data for modeling

WP1 Key expected results

WP	Key expected results	Impacts
WP1. Capture	Complete characterisation of aerosol-based emission and demonstration of countermeasures at TRL 6/7	Validation of the performance of proposed countermeasures for aerosols at industrial scale
	Ensuring solvent consumption below 0.3kg amine/ton capture at TRL 6	Significant OPEX reduction compared with published solvent consumption and reduction of waste streams
	Guidelines for reliable and cost-efficient operation at varying feed conditions and CO ₂ product requirements	Improved CO ₂ capture plant design for flexible operation and niche applications.

Work Packages (WP2)



WP2 TRANSPORT

- CO₂ shipping
- Batch-wise injection
- CO₂ specifications
- Planning for flexible networks

- Emiss
- Solve
- Dyna
- Cost

- CCU
- Engin
- Operation and testing
- CCU integration and scale-up

- North Rhine-Westphalia (DE)
- Grenland (NO)
- Oltenia region (RO)
- Commercial models for CCUS clusters

- Improving EU dialogue on CCUS

WP0 MANAGEMENT

WP2 Removing technical barriers to large-scale CO₂ transport.

(Tel-Tek, ICL, TNO, IFE, TAQA)

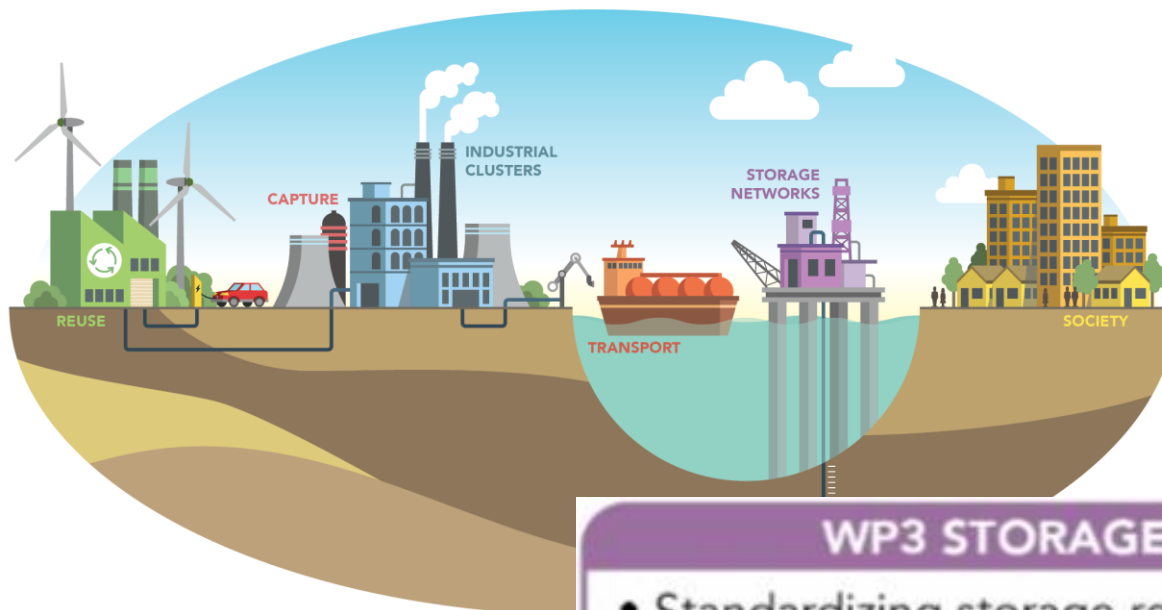
- Not just straight forward
 - Pipeline and/or ship?
 - Shipping temperature and pressure conditions: different combinations have different advantages and disadvantages
 - Ships introduce batch-wise delivery
 - Handling of impurities
 - Design of transport (and storage) networks
 - Cost



WP2 Key expected results

WP	Key expected results	Impacts
WP2. Transport	Derive cost estimates and benchmarks for CO ₂ shipping and offshore unloading with reduced uncertainty	Improved understanding of the business case for shipping and direct injection
	Quantification of the impacts of batch-wise injection on the integrity of the storage system	Allow operational guidelines to be developed for batch-wise injection
	CO ₂ specifications expected from pilot-scale post-combustion capture systems are evaluated in dense-phase CO ₂ corrosion lab	Allow the identification of an optimum balance between stream composition and transport infrastructure needs
	A real-options multi-period CCS network optimisation model including capture from power and industry, energy storage and conversion is developed	Improved cost-benefit analysis capabilities for planning full-chain CCUS projects and CCUS clusters

Work Packages (WP3)



WP3 STORAGE

- Standardizing storage readiness
- North sea storage appraisals
- Re-use of existing assets

WP1 CAPTURE

- Emission control
- Solvent management
- Dynamics and control
- Cost reduction

WP2 T

- CO₂ shipping
- Batch-wise injection
- CO₂ specifications
- Planning for future

WP4 RE-USE

- CCU demonstrator construction
- Engine adaptation
- Operation and testing
- CCU integration and scale-up

WP5 INDU

- Teesside and C
- Rotterdam (NL)
- North Rhine-Westphalia (DE)
- Grenland (NO)
- Oltenia region (RO)
- Commercial models for CCUS clusters

- Compensation strategies
- Improving EU dialogue on CCUS

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WP3 Large-scale storage networks

(BGS, TNO, SINTEF PR, TAQA, TVCA, Scottish Enterprise, RUG, SDL)



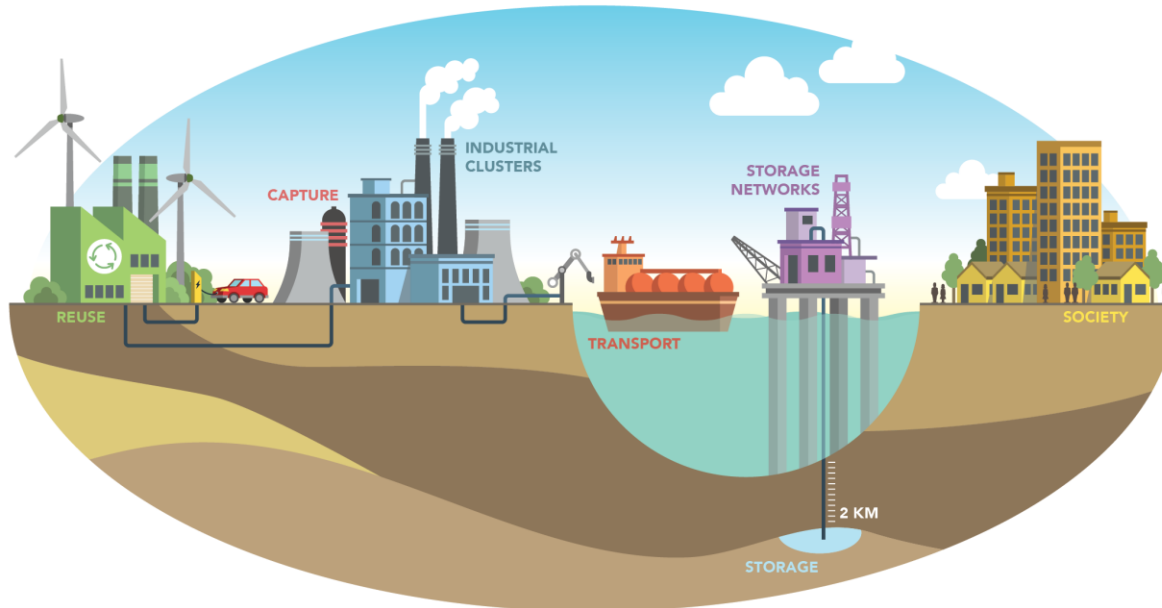
- Vast potential storage capacity beneath the North Sea (fields and formations)
- Prospective industry CCS operators require:
 - increased confidence in availability
 - sufficient capacity
 - realistic costs and timing of storage provision.

- European resource of learning from operating projects, planned and permitted storage capacity
- Increase operator certainty in future storage provision

WP3 Key expected results

WP	Key expected results	Impacts
WP3. Storage	Provide a classification framework for storage readiness levels benchmarked against existing storage sites	Increased investor confidence in timeframe and resource needs for follow-on storage development.
	A portfolio of selected storage sites in the UK, Netherlands and Norway to provide certainty on storage for ALIGN clusters	Enables FIDs on transport and storage infrastructure and supporting development plans for storage roll-out.
	An asset register of existing North Sea oil and gas infrastructure and assessments of their suitability for re-use for CCUS projects	Supports decommissioning policy and regulation for transport and injection infrastructure.

Work Packages (WP4)



WP1 CAPTURE

WP2 TRANSPORT

WP3 STORAGE

WP0 MANAGEMENT

WP4 RE-USE

- CCU demonstrator construction
- Engine adaption
- Operation and testing
- CCU integration and scale-up

- Standardizing storage readiness
- North sea storage appraisals
- Re-use of existing assets

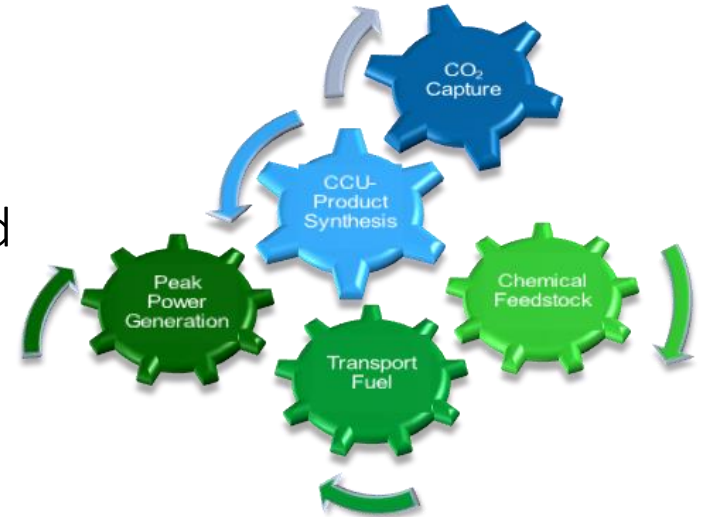
WP6 SOCIETY

- Assessing public opinion
- Compensation strategies
- Improving EU dialogue on CCUS

WP4 CCUS as an element for large-scale energy storage and conversion

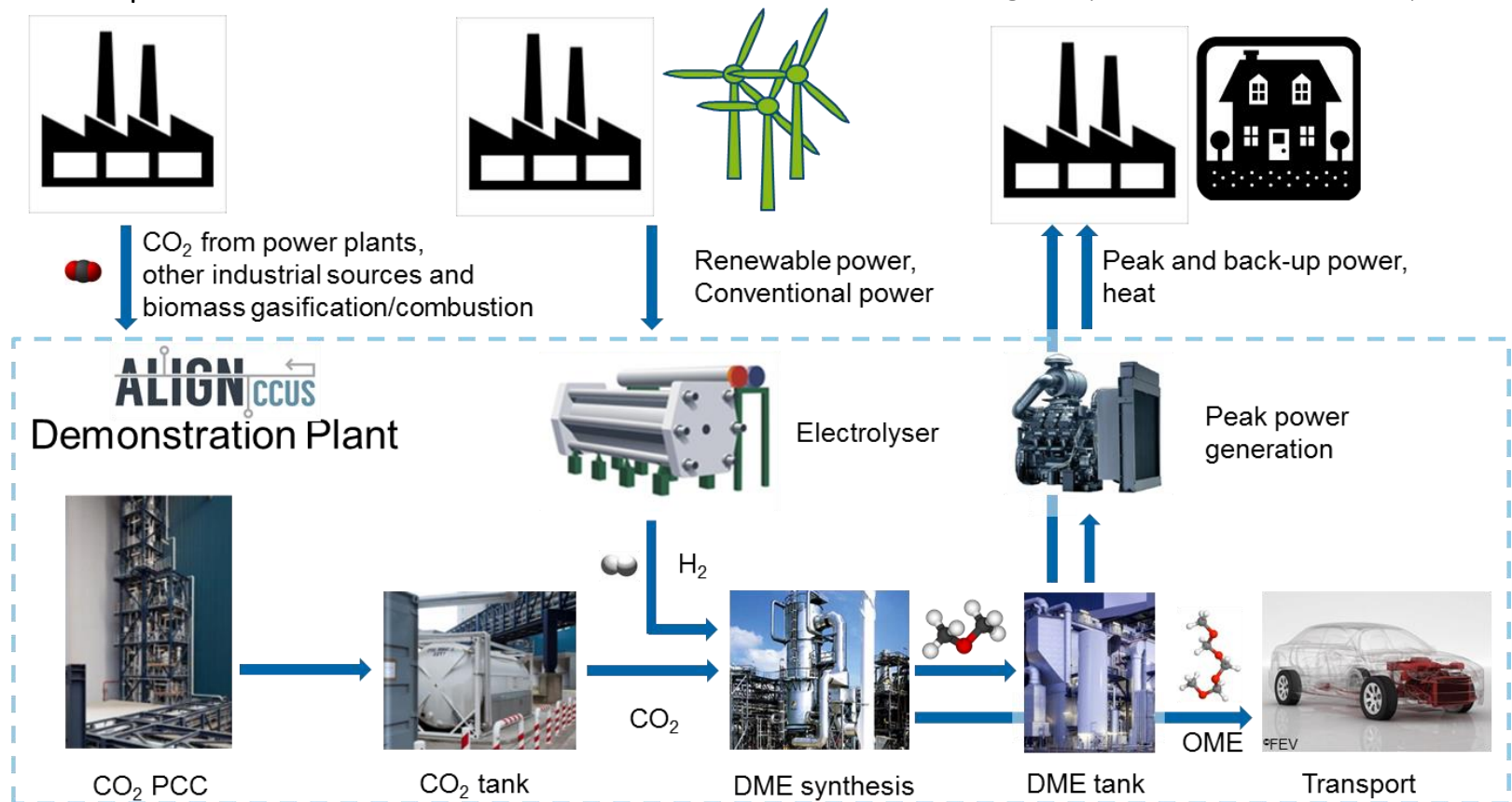
(RWE, MHPSE, AKEU, FEV, FZ Julich, TNO, RWTH, ECN, Bosch, Deutz)

- WP4 aims at accelerating the integration of CCU applications into the energy system by:
 - Demonstrating the full CCU-chain and utilisation of CCU-products in the power and transport sectors
 - Obtaining acceptance for CCU by additional benefits: security of supply and low-emission fuels
 - Generating added value by CCUS and gain cost reduction potential by innovative technology
 - Assessing socio-economic value and benefits of CCUS



WP4 Demonstration setup

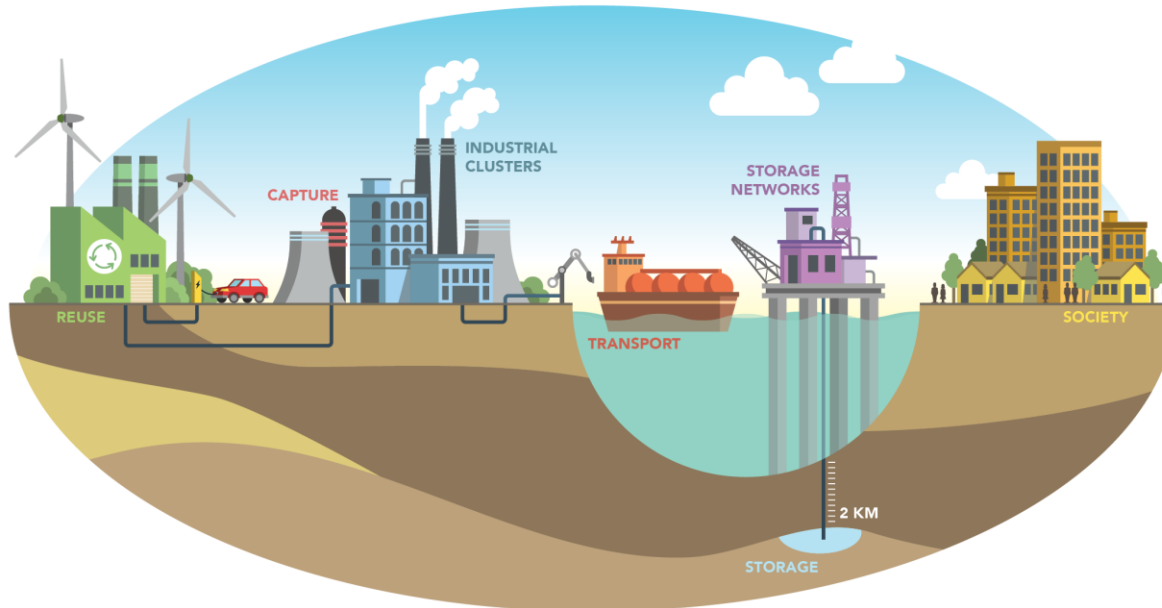
- Demonstration of CCU and Sector Coupling
CCU, chemical long-term energy storage, fuel for peak power generation and transport sector Co-benefit: DME lowers emissions of Diesel engines (NO_x, Particulates, CO₂)



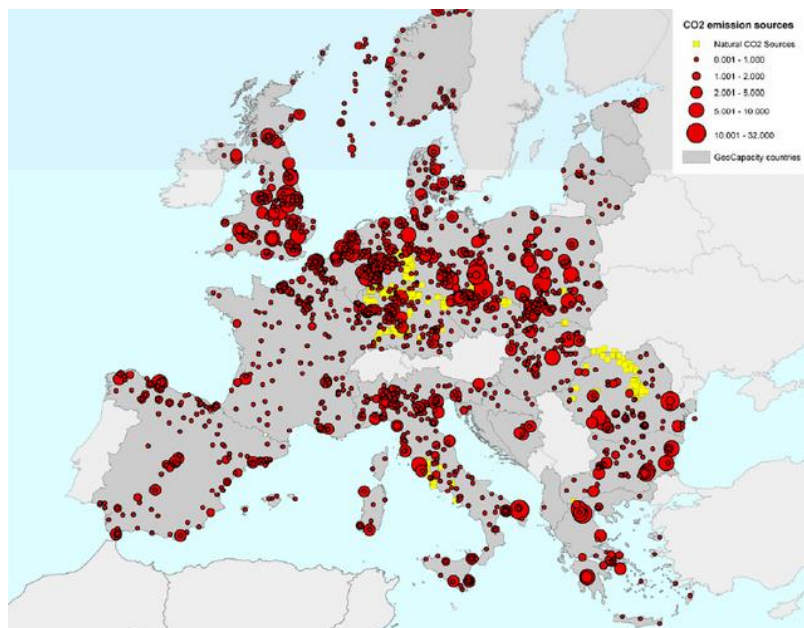
WP4 Key expected results

WP	Key expected results	Impacts
WP4. Re-use	Demonstration of the full CCS/CCU chain	Proven feasibility and viability of a utilisation chain, increases public awareness and acceptance of CCS/CCU as a climate protection technology
	Understand the additional multi-sector benefits of establishing a CCUS chain producing low-emission transportation fuels	Quantifies the potential socio-economic effects of CCS/CCU beyond climate protection by intelligent coupling of the sectors energy, industry and transport.
	Techno-economic optimisation of the CCU demonstrator technology	Enhances the chance for accelerated implementation of CCU due to better economic performance.
	Quantify the environmental performance of a full CCUS chain using data derived from actual operation	Makes the advantages of CCUS transparent in comparison with other competing climate protection technologies.

Work Packages (WP5)

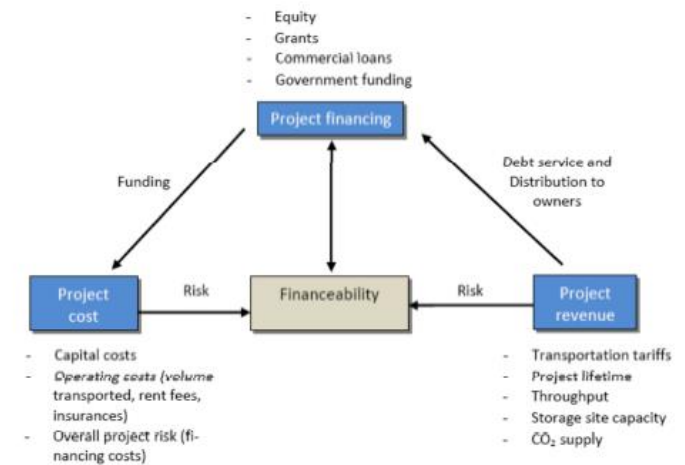
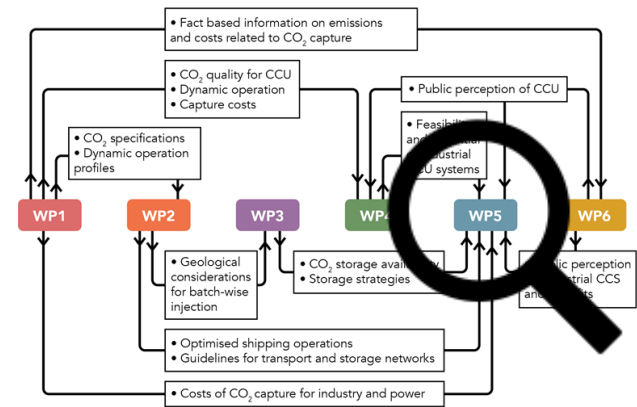


WP5 Targeted CCUS activities in industrial clusters (TNO, BGS, TCVA, SDL, ICL, Scottish Enterprise, Bellona, FZ Julich, Tel-Tek, Yara, Norcem, GeoEcomar, PicOil, CO2Club)



WP5 Industrial clusters

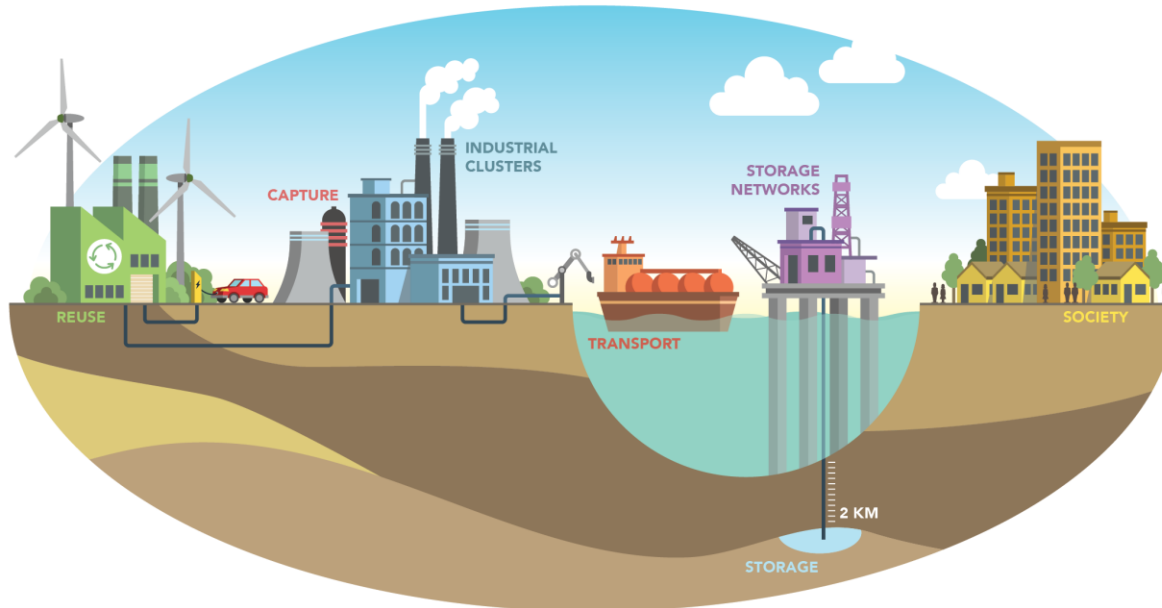
Industrial cluster/ region	Development priority in ALIGN	Existing appraised storage			Extended storage capacity to be identified in ALIGN
		Storage site	Capacity	Status	Target stores
Rotterdam (NL)	Develop plans for centralised CO ₂ removal from natural gas, and increased H ₂ use in power generation and industry	P18-4 Gas Field	8 Mt	Permit awarded	P18, P15 and Ijmuiden fields and sandstone formations
Teesside (UK)	Identify cost reduction opportunities through shared infrastructure / optimise transport and storage plans	Endurance structure	200 Mt	Permit ready	Depleted fields, closures in the Bunter and other sandstone formations
Grangemouth (UK)	Identify cost reduction opportunities through shared infrastructure / optimise transport and storage plans	Goldeneye Field	10-15 Mt	Permit ready	Depleted fields, closures in the Captain and other sandstone formations
North Rhine-Westphalia (GER)	Evaluate CCU as a multi-sector CO ₂ mitigation option in the region	n/a	n/a	n/a	n/a
Grenland (NOR)	Advance engineering plans for an intermediate CO ₂ surface storage facility capable of handling CO ₂ from multiple sources	Smeaheia area	100 Mt	Feasibility study	Closures in the Sognefjord Sandstone and in deeper formations.
Oltenia Region (ROM)	Evaluate multi-modal CO ₂ transportation routes and use in enhanced oil recovery with permanent storage	Deep saline aquifers within a 50km radius of Turceni	1.5 Mt/yr	Feasibility study	Potential storage sites in the Moesian Platform



WP5 Key expected results

WP	Key expected results	Impacts
WP5. Industrial clusters	Provide a set of actionable development plans for targeted CCUS activities in 6 key industrial clusters across the EU	Supports national and regional governments in decision-making for industrial decarbonisation strategies
	Develop commercial models for embryonic CO ₂ cluster infrastructure using results from pilot-testing and optimisation modelling completed in ALIGN	Greater clarity on the expected investment requirements and benefits for public and private actors

Work Packages (WP6)



WP1 CAPTURE

- Emission control
- Solvent management
- Dynamics and control
- Cost reduction

WP2 TRANSPORT

- CO₂ shipping
- Batch-wise injection
- CO₂ specifications
- Planning for flexible

WP3 STORAGE

WP4 RE-USE

- CCU demonstrator construction
- Engine adaption
- Operation and testing
- CCU integration and scale-up

WP5 INDUSTRIAL

- Teesside and Grang
- Rotterdam (NL)
- North Rhine-Westp
- Grenland (NO)
- Oltenia region (RO)
- Commercial model

WP6 SOCIETY

- Assessing public opinion
- Compensation strategies
- Improving EU dialogue on CCUS

WP6 Implementing CCUS in Society

(LU, UEDIN, ECN, FZ Julich, Bellona, NUPSPA)

- Reduction of non-technical risk for CCUS implementation by
 - Assessing public and stakeholder perception about CCUS, specifically towards industrial CCUS and CO₂ utilisation projects
 - Developing theory-based, evidence-based communication and compensation strategies that instigate trust and have a positive effect on societal acceptance of CCUS



BURIED TROUBLE

Investors saying "no to CO₂" are just one roadblock facing carbon sequestration — a strategy it could help prevent dangerous climate change. **Richard Van Noorden** investigates.

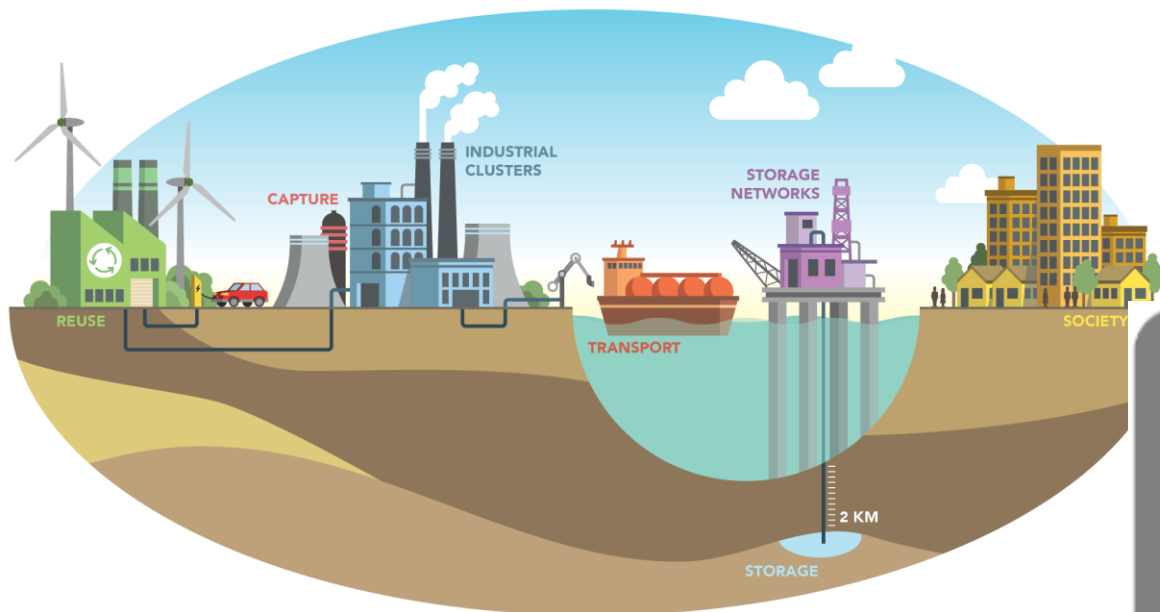
When it comes to carbon dioxide, investors are saying "no to CO₂". But that's just one roadblock facing carbon sequestration — a strategy it could help prevent dangerous climate change. **Richard Van Noorden** investigates.

Investors are worried about the stability of carbon sequestration — but that's not the only roadblock. There are also concerns about the safety of the technology. **Richard Van Noorden** investigates.

WP6 Key expected results

WP	Key expected results	Impacts
WP6. Society	Understanding of public and stakeholder perception concerning CCUS projects in industrial applications, including CO ₂ utilisation	Provides tools for making site selection decisions and developing effective consultation and communication strategies
	Evidence-based insight in best practices regarding the use of compensation schemes for CCUS projects	The identified success factors and pitfalls support project developers and national governments in designing effective compensation strategies
	Development and testing of new communication materials for CCUS	Provides strategic elements for a dialogue with society about the need and necessity of CCUS

Work Packages (WP0)



WP1 CAPTURE

- Emission control
- Solvent management
- Dynamics and control
- Cost reduction

WP2 TRANSPORT

- CO₂ shipping
- Batch-wise injection
- CO₂ specifications
- Planning for flexible networks

WP3 STORAGE

- Standardizing storage readiness
- North sea storage appraisals
- Re-use of existing assets

WP4 RE-USE

- CCU demonstrator construction
- Engine adaption
- Operation and testing
- CCU integration and scale-up

WP5 INDUSTRIAL CLUSTERS

- Teesside and Grangemouth (UK)
- Rotterdam (NL)
- North Rhine-Westphalia (DE)
- Grenland (NO)
- Oltenia region (RO)
- Commercial models for CCUS clusters

WP6 SOCIETY

- Assessing public opinion
- Compensation strategies
- Improving EU dialogue on CCUS

WP0 MANAGEMENT

Bucharest, Romania, October 24th 2017

WPO Management and Dissemination (TNO, Tel-Tek, SINTEF, BGS, LU, NUPSPA, UEDIN)

- Project management
 - Coordinator, Project Management Team
- Industrial Advisory Group
 - Leading industry companies on CCUS
- Professional dissemination partner (SCCS-UEDIN)

ALIGN CCUS Outreach



www.alignccus.eu



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ALIGN-CCUS

ALIGN CCUS connection with other ACT projects

- On cluster activities
- On social acceptance
- Combining dissemination activities
- We will learn more during this workshop

Acknowledgements

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