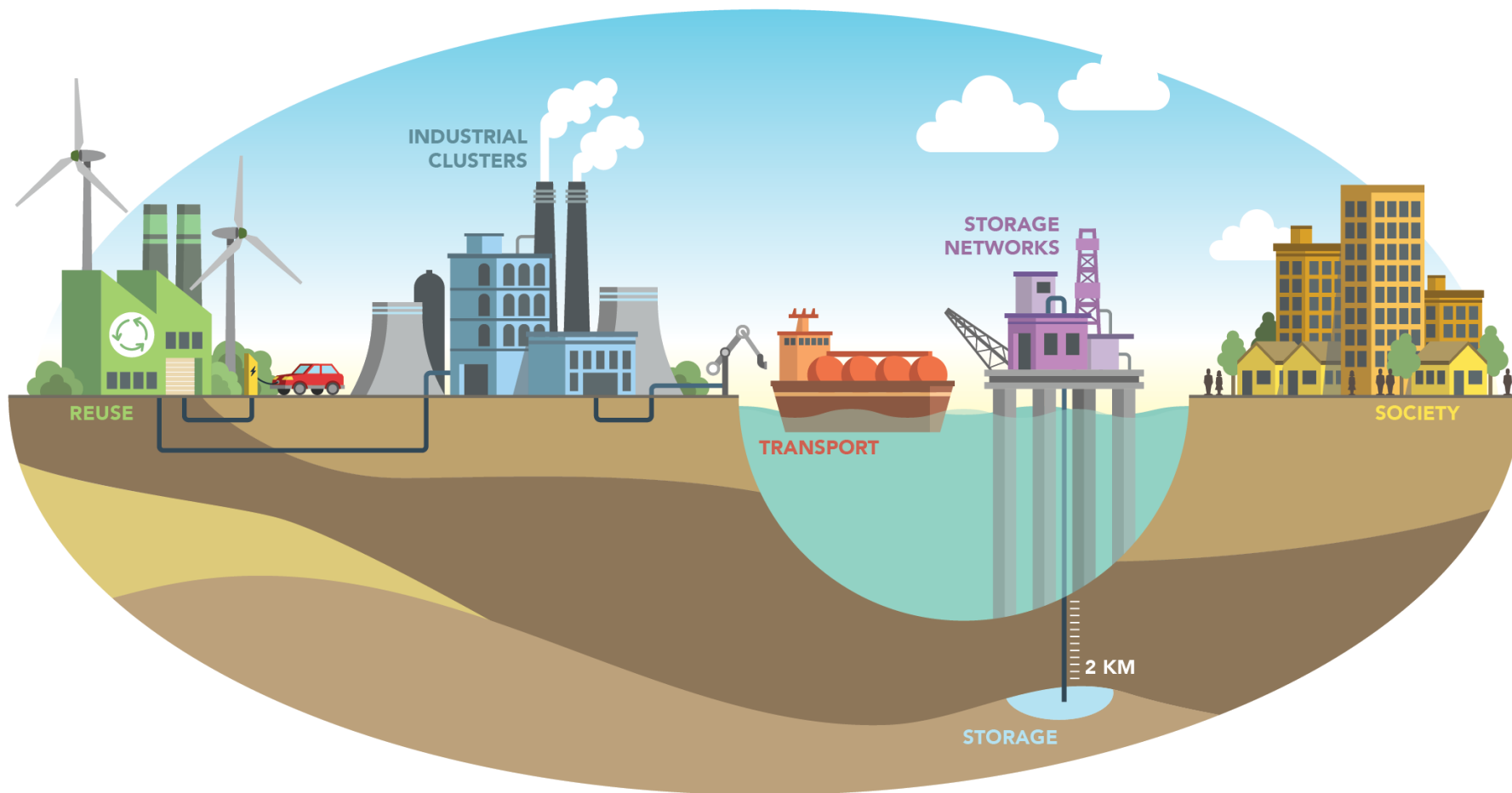


ALIGN | CCUS



Athens, Greece, November 6th – 7th 2019

4th ACT
Knowledge
Sharing
Workshop



 Peter van Os (TNO)

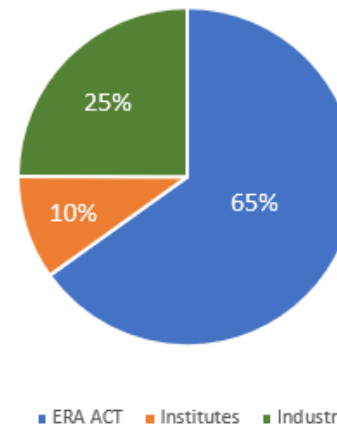
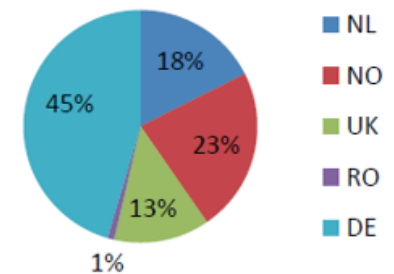
Coordinator of ALIGN-CCUS

Athens, Greece, November 6th – 7th 2019

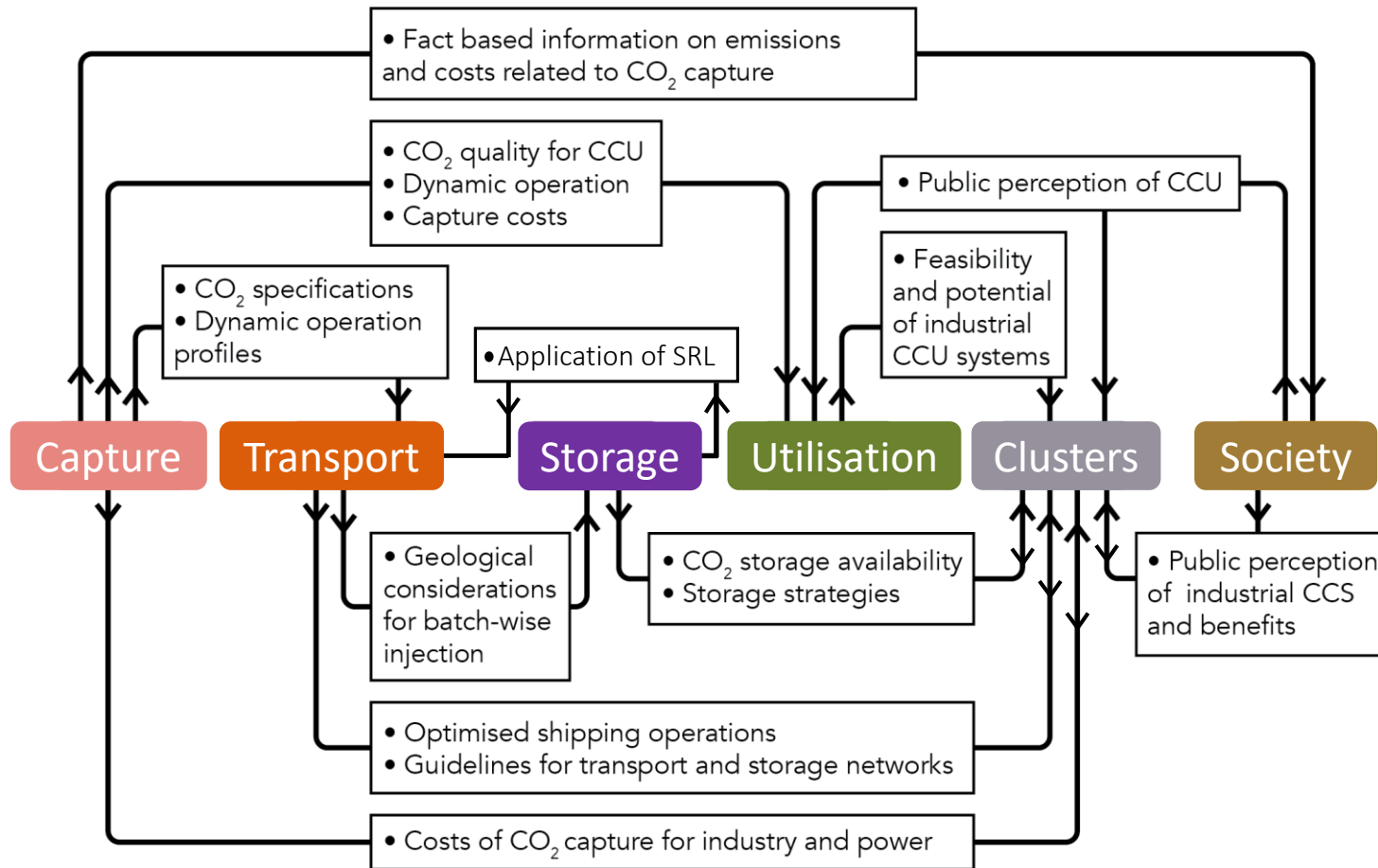
Project Characteristics

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

- 29 partners from NL, UK, DE, NO, RO
- 1 associated partner from DE
- Total budget: € 21.270.975
- Total funding: € 14.141.278



Full Chain, well integrated



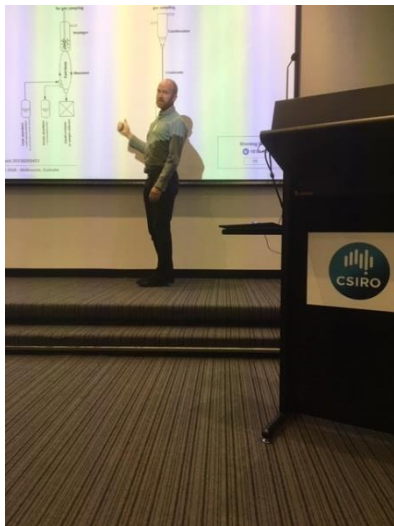
ALIGN-CCUS Overall Objectives

- 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.
- 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)
- These blueprints should be usable for other industrial clusters.



ALIGN-CCUS

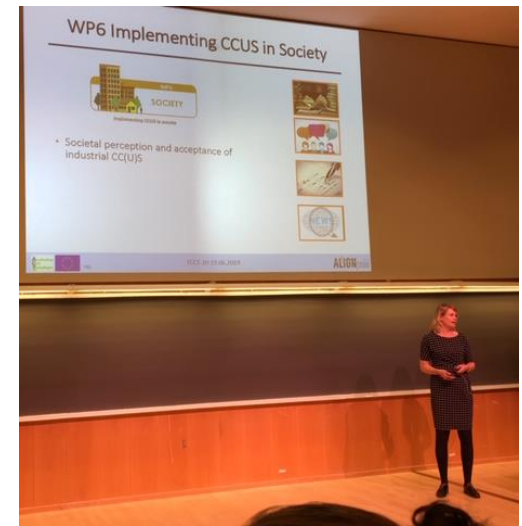
- Good cooperation with other ACT and H2020 projects ACORN, ELEGANCY, ECOBASE, PreACT and ENOS (especially on storage, clusters and society)
- Many dissemination activities, good branding.



Workshop in Australia

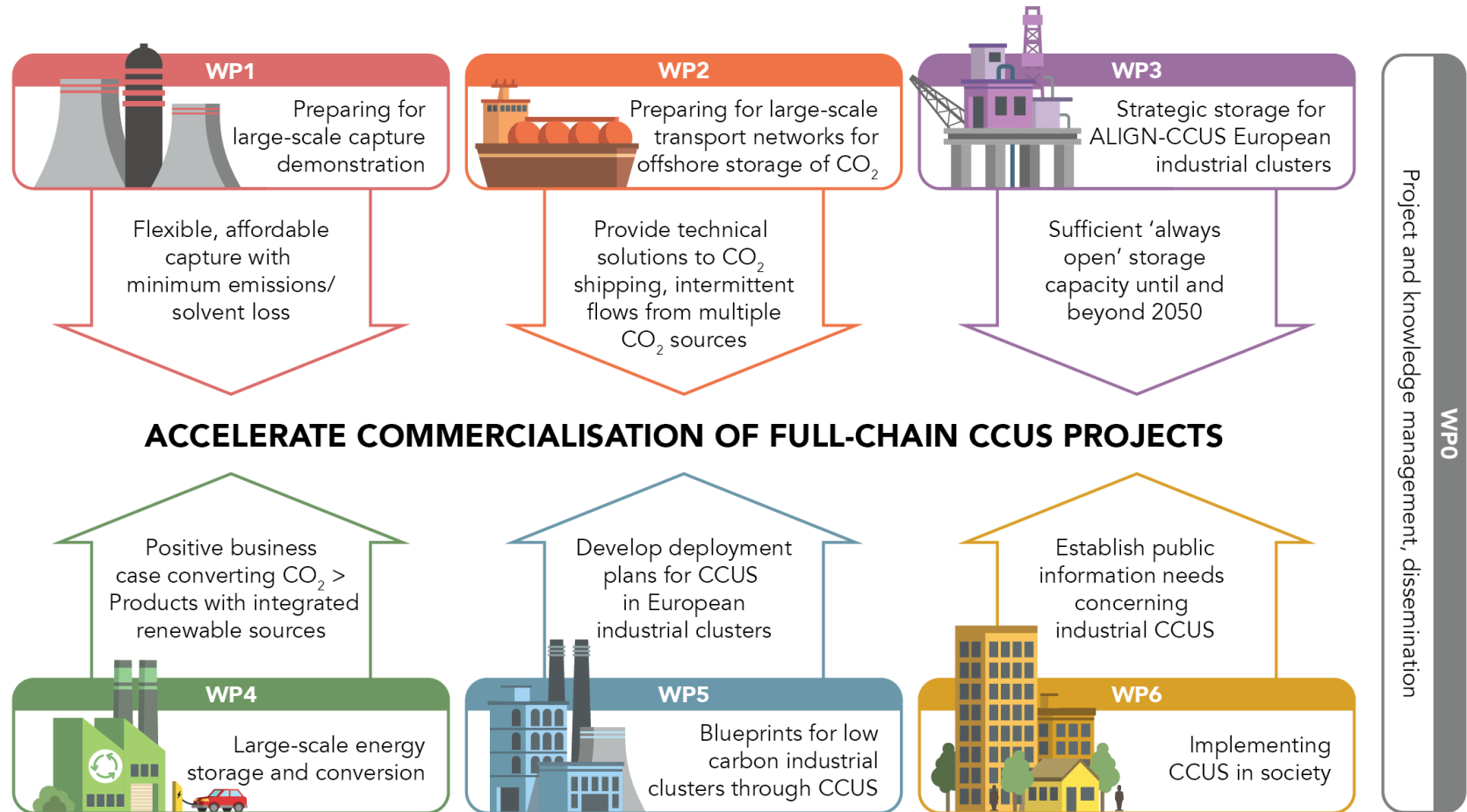


CO2 recycling conference in Japan

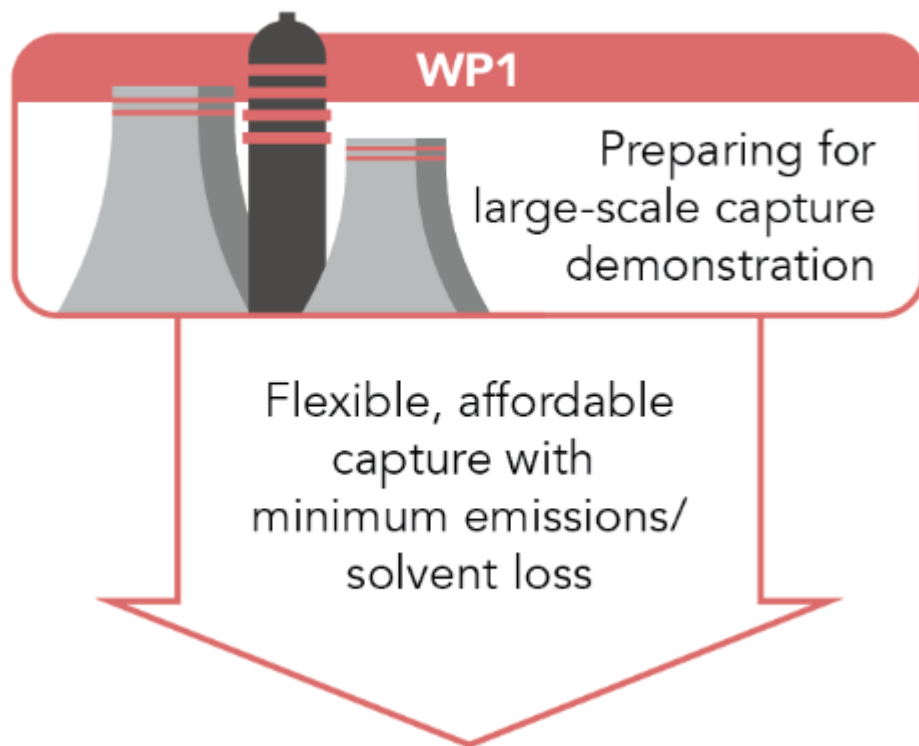


Trondheim TCCS conference

Work Packages in ALIGN-CCUS



Work Package 1: Capture

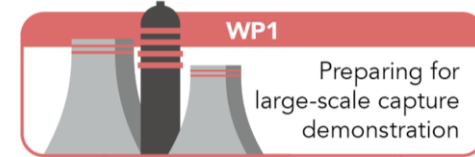


WP-leader: Hanne Kvamsdal (SINTEF)

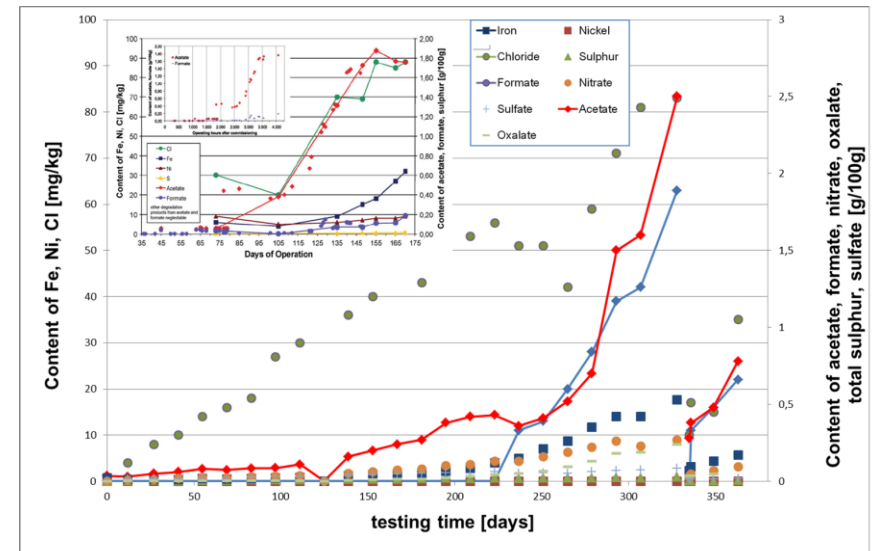
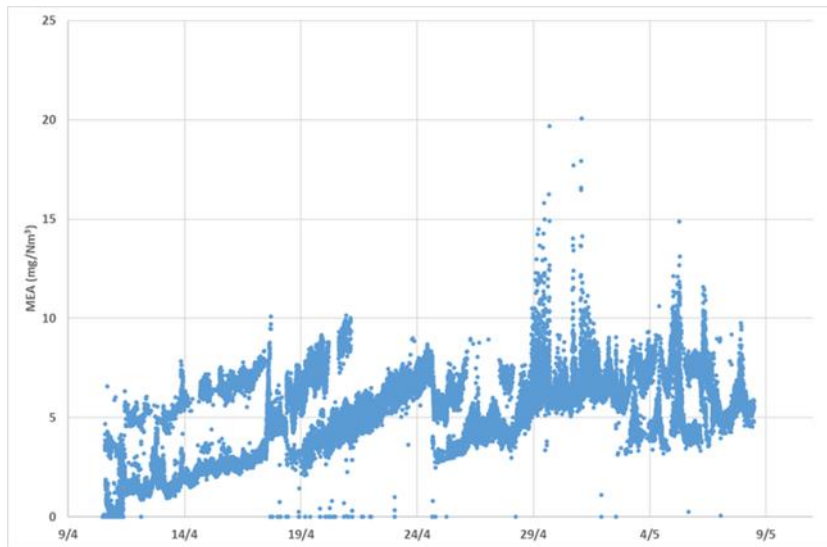
Partners:

- SINTEF
- TNO
- NTNU
- HWU
- RWE
- NORCEM
- UoSheffield
- UoSouthEastNorway
- TCM

WP1 Highlights



Long-term testing of MEA at RWE in Niederaussem > 13000 hours



Very low emissions of MEA: < 3-10 mg/Nm³

Particle measurements → aerosol-based emissions are negligible for the flue gas of a lignite-fired power plant with state-of-the-art gas treatment technologies

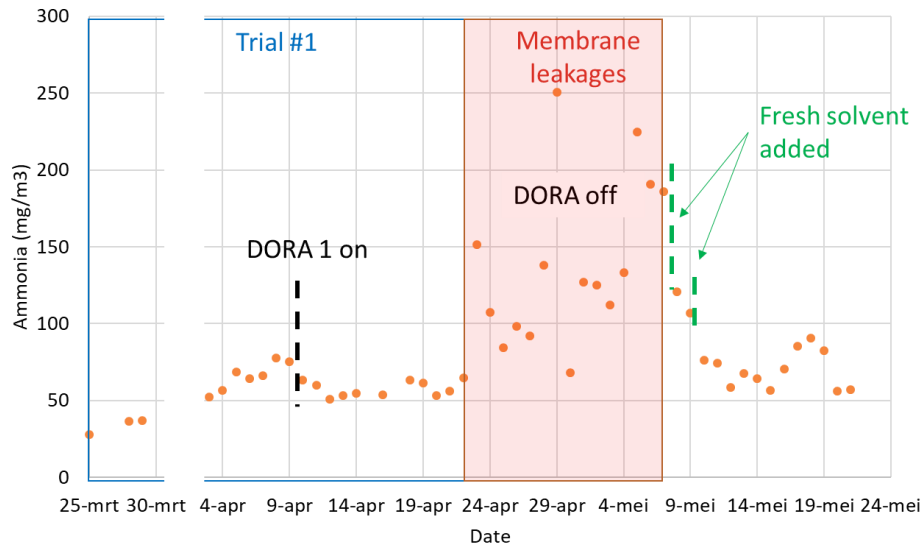
Most extensive solvent management dataset for MEA

- Confirmation of the non-linear degradation behavior
- Very low degradation rate for the first 6 months
- Opens-up for new modelling approaches

Athens, Greece, November 6th – 7th 2019

WP1 Highlights

Solvent management strategy – dissolved oxygen removal (DORA)



Initial tests with MEA degraded solvent from RWE positive.

Tests at PACT are ongoing.

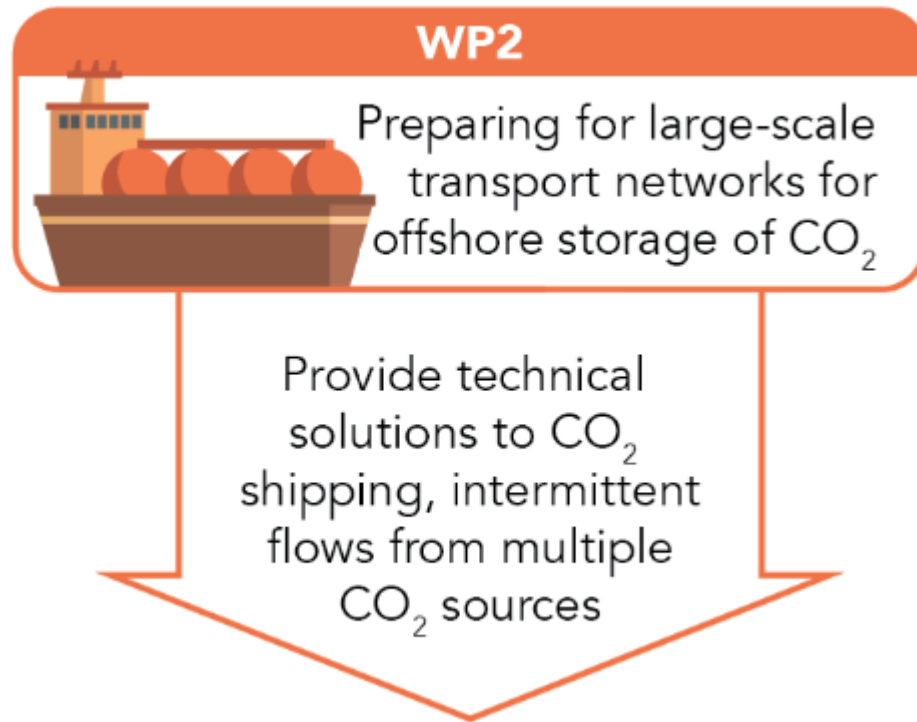
WP1 Impact - Status

- **Aerosol-based emission:**
 - Results from RWE campaign indicate that aerosol-based emissions are irrelevant for the flue gas of a lignite-fired power plant with state-of-the-art gas treatment technologies
 - **Solvent consumption:**
 - Results from RWE campaign indicate that solvent consumption of less than 0,3 kg per tonne of CO₂ captured is possible
 - Still three major campaigns to conduct before the solvent management strategy is set
 - **Guidelines for reliable and cost-efficient operation**
 - Campaign at Tiller pilot shows promising effect of advanced control (NMPC) during some flexible operation scenarios
- Solvent management and process control technologies are being utilized in new ACT and EU initiatives, including demonstration in commercial plants (refinery, waste incinerator)

WP1 Ongoing work

- Conduct 3 campaigns:
 - CESAR1 at RWE (long-term) and TCM (3 months)
 - MEA 40wt% at PACT (10 weeks)
- Further develop
 - models for emission and degradation (understanding)
 - technologies for the control of emission and degradation (mitigating)
- Cost estimation of efficient integration of capture plants into power and industrial plants (cement and waste incineration)
- Links with WP5 on cost drivers for integration of capture plants in CCS networks

Work Package 2: Transport



WP-leader: Hans Aksel Haugen (SINTEF)

Partners:

- SINTEF
- IFE
- Imperial College
- TNO
- TAQA

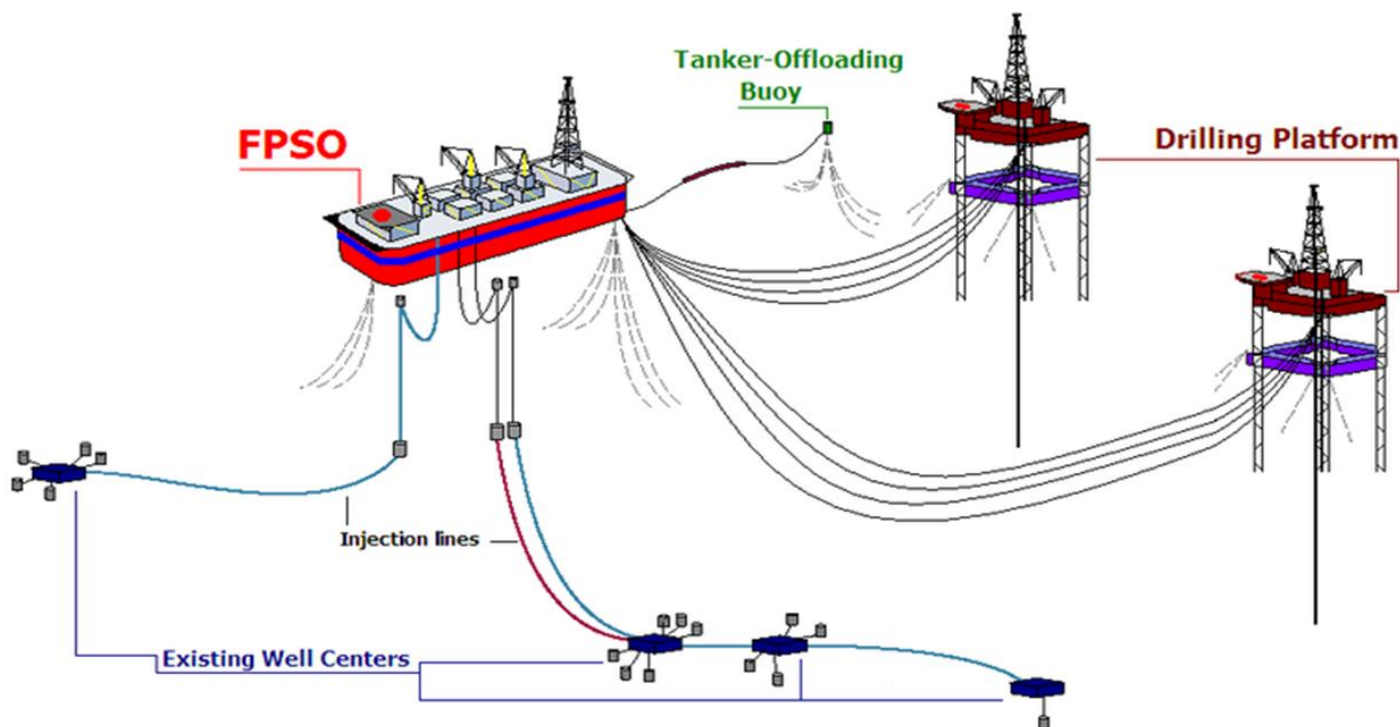
WP2 Highlights

- Focusing on ship transportation of CO₂, pressure and temperature ranges feasible for ships and CO₂-injection have been suggested



WP2 Highlights

- To avoid batchwise injection, CO₂ may be offloaded to a FPSO or other systems for intermediate offshore storage



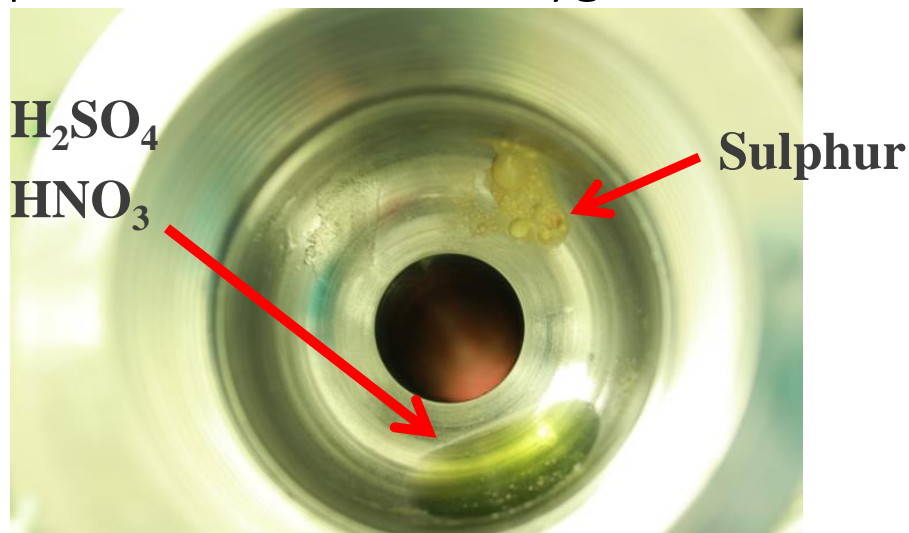


WP2 Highlights

- Injection of cold CO₂ may introduce risk of hydrate formation in the reservoir and stress on well cement due to thermal contraction of steel casing
 - Suggested solutions:
 - Avoid injection of CO₂ colder than 10 – 15 °C at the bottom hole
 - Include contraction loads due to cooling in the design of new injection wells and in assessments of well integrity risks in existing wells to be re-used for CO₂-injection

WP2 Highlights

- There is a need to define a safe operation window with regard to varying compositions of CO₂. WP2 looks at finding such window before process plants are designed and built.
 - Experiments performed
 - Focus on impurities like water, oxygen, NO_x, SO_x etc.



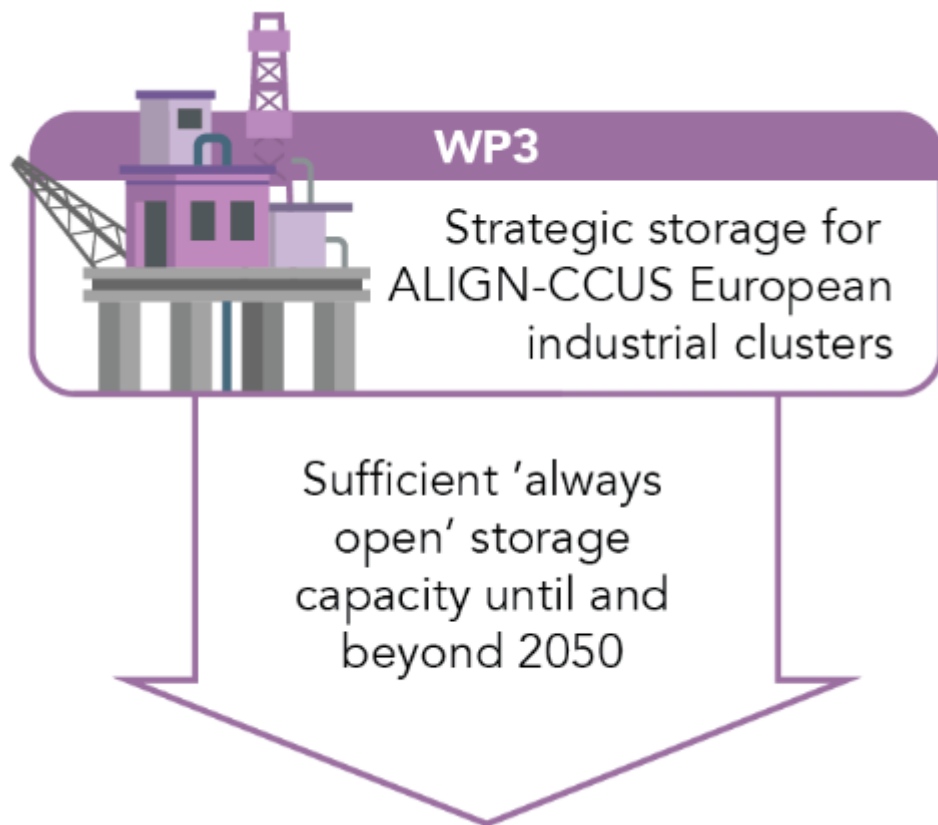
WP-2 Impact - Status

- ALIGN-CCUS is connecting to the ongoing Norwegian full scale CCS infrastructure initiative by comparing the pressure/temperature conditions recommended in this project with other possible p/t combinations
- Also, the ALIGN-CCUS work on CO₂-specification is strongly connected to the Norwegian full-scale initiative.
- Parallel project established between SINTEF and an industry consortium including a Norwegian ship building company from May 2019 to look into implications of ALIGN-CCUS recommended p/t conditions for design of ships for CO₂ transport.

WP-2 Ongoing work

- Final recommendation on strategies for resolving identified technical challenges within shipping and offshore unloading of CO₂, and for monitoring of storage integrity and performance
- CO₂ specification, recommended for ALIGN-CCUS partners
- Development of techno-economic assessment tool for transport and storage, followed by guidelines for the development of flexible transport and storage networks

Work Package 3: Storage



WP-leader: Maxine Akhurst (BGS)

Partners:

- BGS
- SINTEF
- TNO
- TVCA
- Groningen University

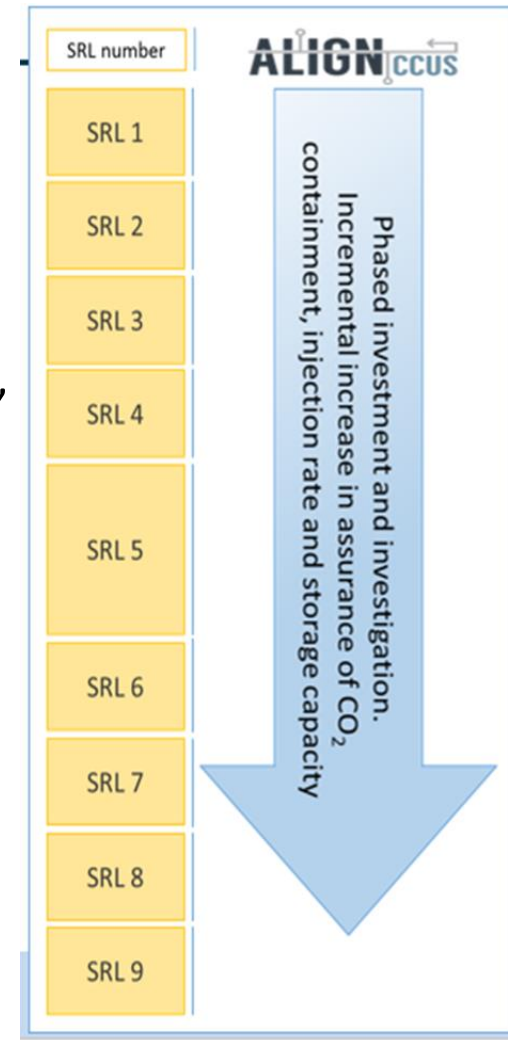
WP3 - Objectives

Reduce uncertainty in the provision of large-scale storage networks by:

- Establishing a unique CO₂ storage readiness assessment protocol to accelerate the definition of CO₂ storage capacity
- Better characterized potential storage locations in the North Sea to support decision-making for near- and mid-term infrastructure planning for CO₂ clusters
- Assess existing offshore oil and gas assets for suitability of re-use for CO₂ transport and storage

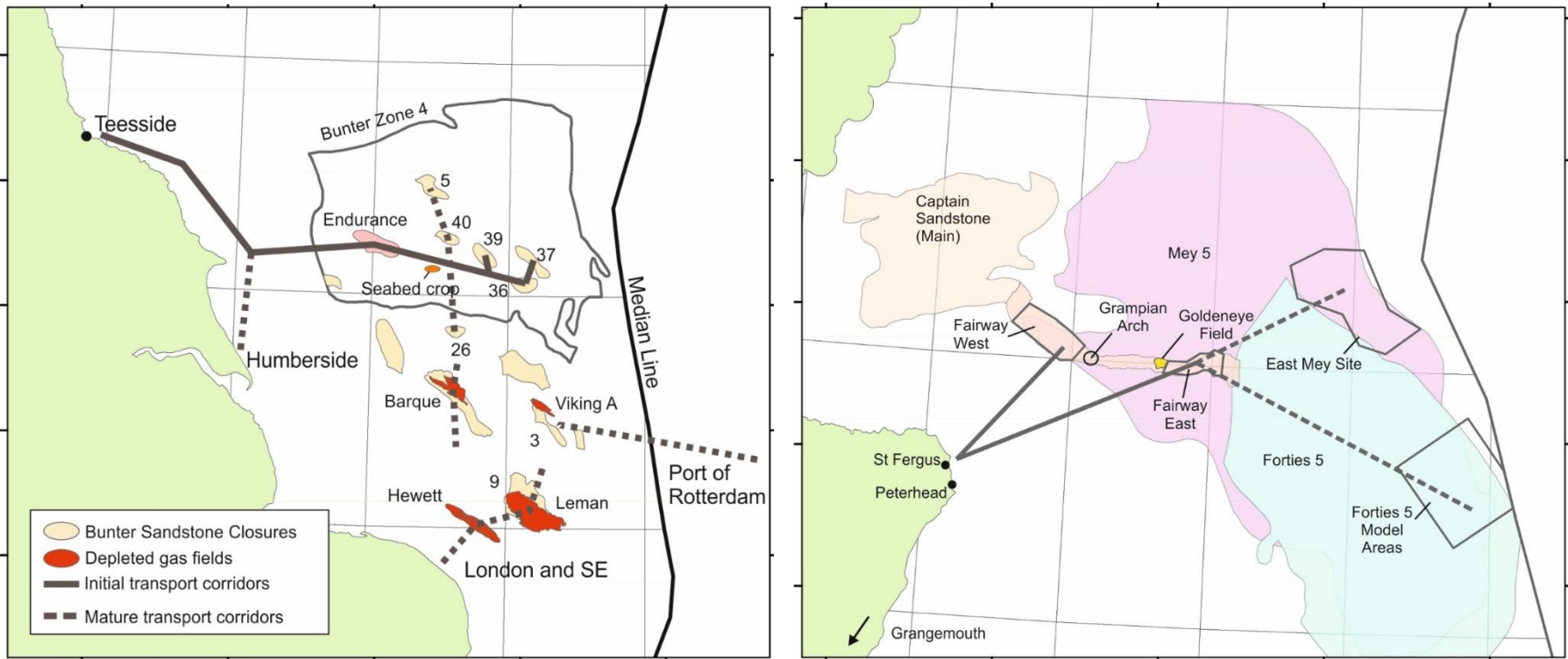
WP3 Highlight

- Nine levels from first recognition to operation, with increased assurance
- Based on experience and practise, and expert, industry and regulator input
- Each level has detail on characterisation, permitting & project planning
- Consistent with published industry work
- Mapped onto UK, NO & NL storage sites
- Communicates 'readiness' & informs of the technical appraisal, permitting and planning achieved
- Highlights what remains for operation



WP3 Highlight

Better characterized stores, conceptual storage networks for ALIGN-CCUS clusters Teesside & Grangemouth, UK



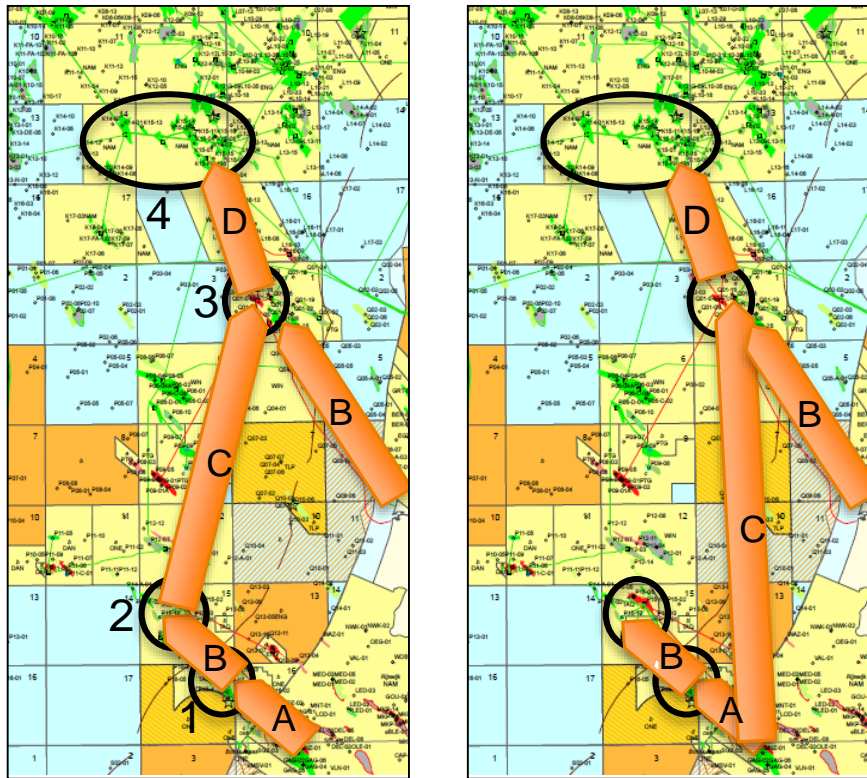
Multi-store sites with proposed storage networks for scenarios of initial, growth & mature CCS projects deployment. Network modelling, including economic factors, in progress within ALIGN WP5. Stores with higher SRLs assessed. Input from NL appraisal of batch-wise injection for Teesside selection.

WP3 Highlights

Better characterised stores NL & NO

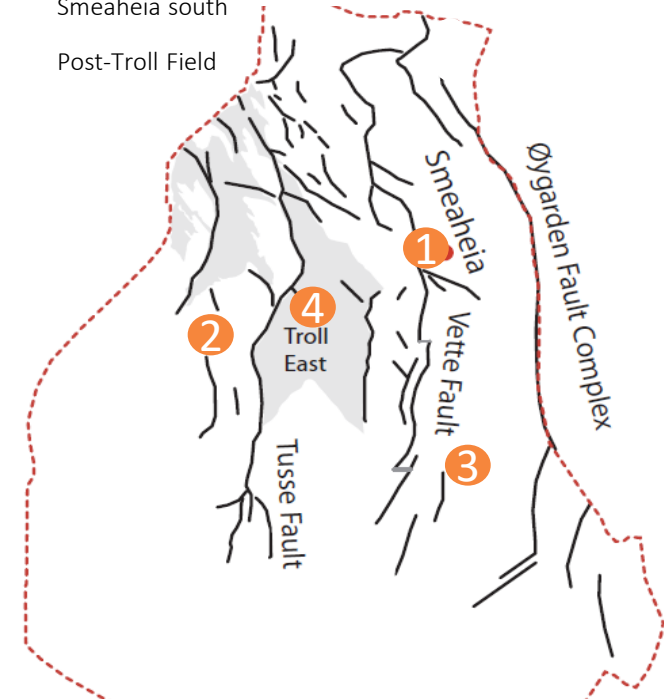
Potential network development scenarios

Support Porthos preliminary design selection



Roadmap for CO₂ Storage Smeaheia Hub

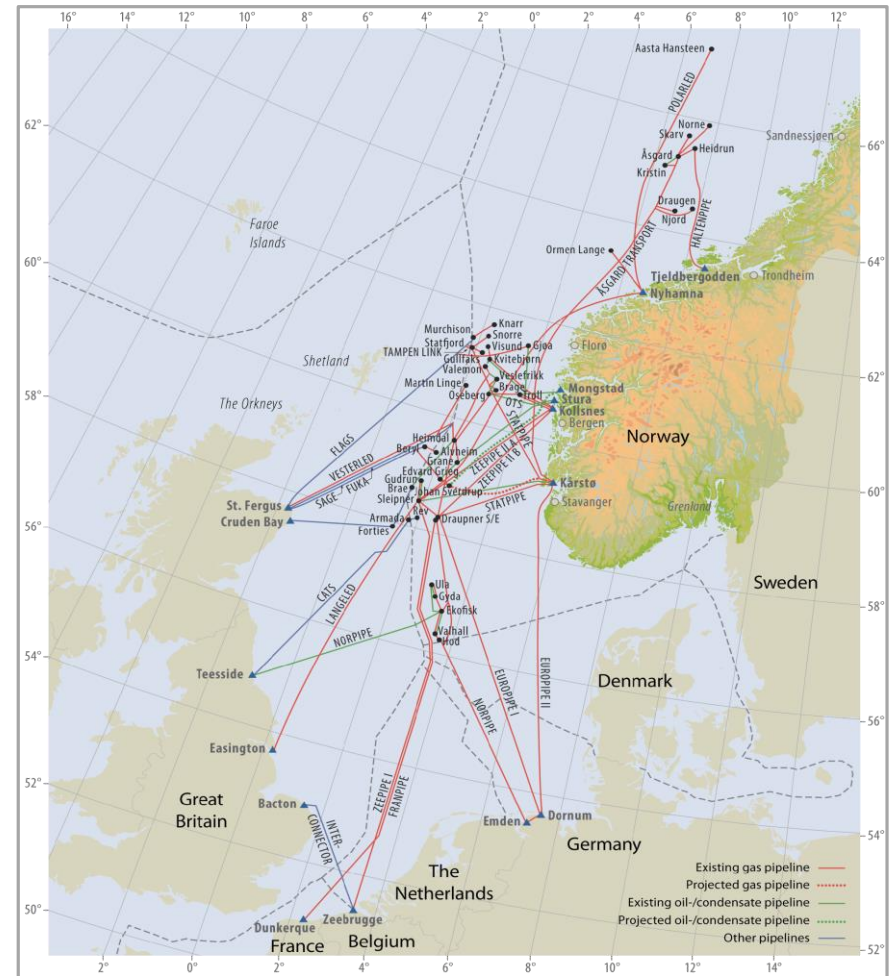
- 1) Smeaheia
- 2) Aurora structure
- 3) Smeaheia south
- 4) Post-Troll Field



WP3 Highlight

Re-use of oil and gas assets for CO₂ transport and storage Methodology to assess infrastructure re-use based on published criteria.

- Application for ALIGN stores in national case studies tested
- Criteria are ranked for each country based on data availability and effectiveness of screening.
- Legal issues on infrastructure re-use, three national workshops, differing audiences and key points
- Temporal gap between hydrocarbon operations and CCS implementation
- Intermediary 'operator of last resort' to span temporal gap



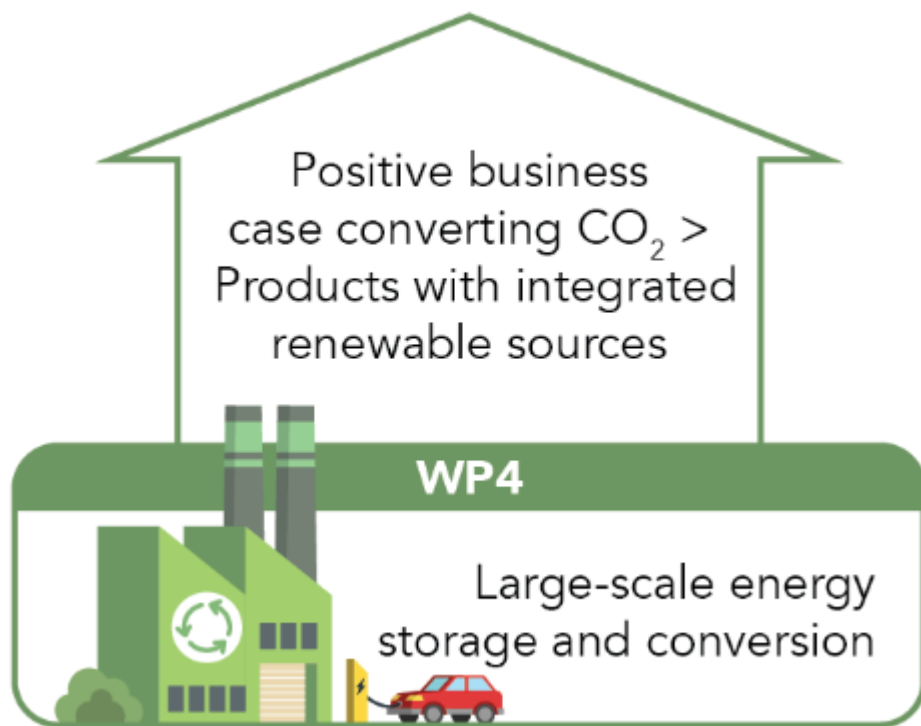
WP3 – Impact - Status

- Lot of attention for SRL. Paper in preparation.
- Connection made with national projects:
 - Porthos
 - Northern Light
 - Activities at Teesside & Grangemouth

WP3 - Ongoing work

- Completion of deliverables (all under review)
- Dissemination & learning: ALIGN-CCUS WP3 webinar was on 30 October, papers for external publication
- Accelerate impact by presentation to industry bodies and national authorities of research findings to support implementation of national emissions reduction strategies
 - Infrastructure re-use assessment
 - Strategic site appraisal activities
 - Planning long-term storage site development

Work Package 4: CO₂ re-use.



WP-leader: Peter Moser (RWE)

Partners:

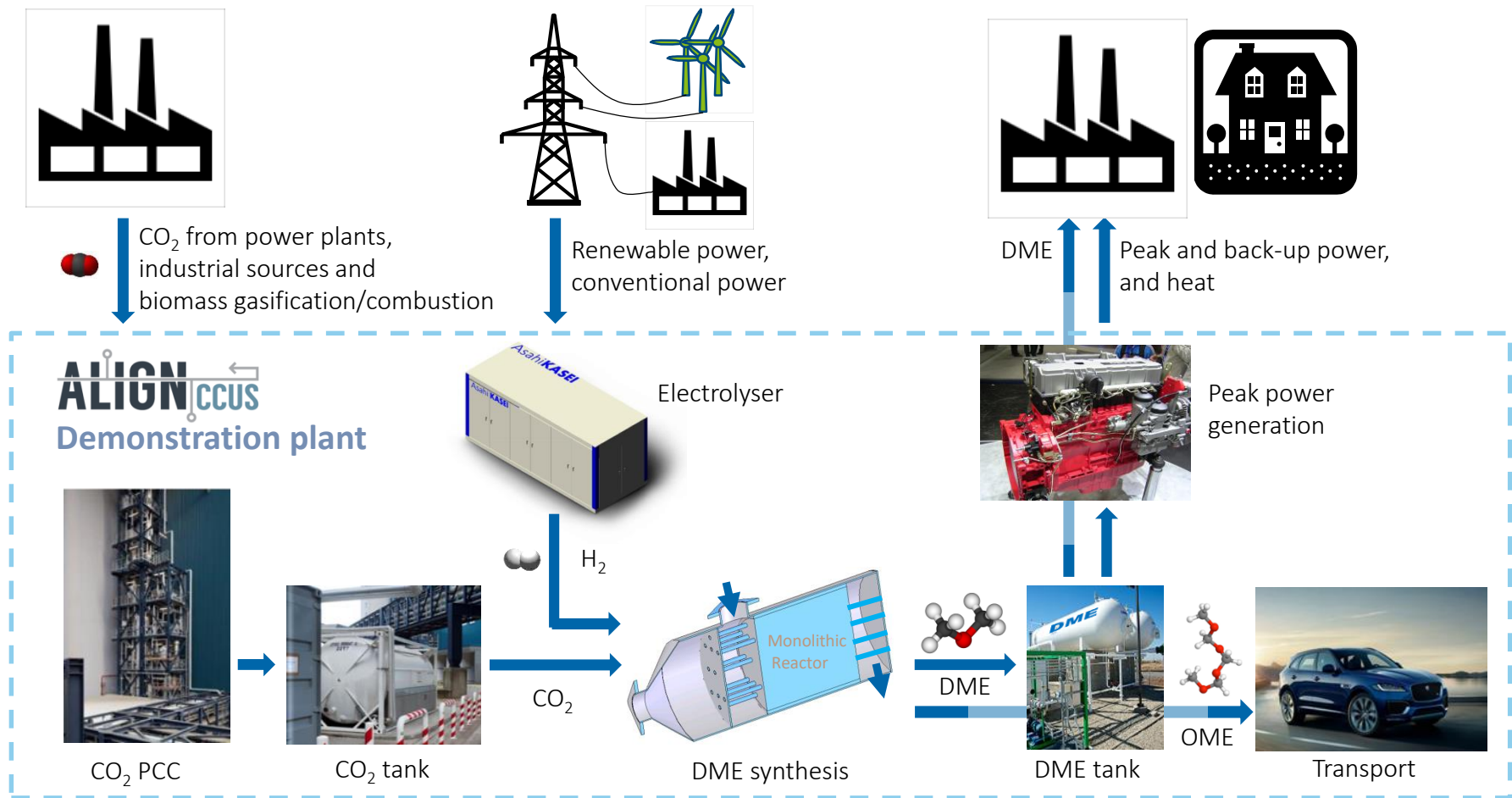
- RWE
- MHPSE
- RWTH
- FEV
- Asahi Kasai
- FZ Jülich
- TNO

Associated Partner:

- Bosch

WP4 Objectives

Demonstration, evaluation, optimisation and scale-up of a full CCU chain - a blue print for sector coupling



WP4 Highlight



CO₂ capture plant

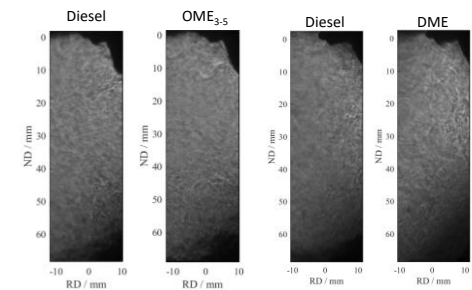


- Equipment being installed!

Athens, Greece, November 6th – 7th 2019

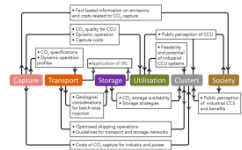
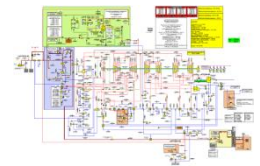
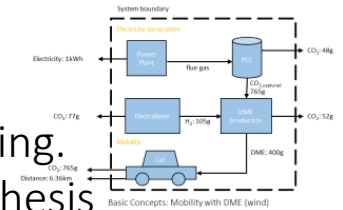
WP4 Highlights

- Treatment of purge gas by innovative catalytic burner system to meet German regulation for air protection and to avoid a flare at the power plant site.
- Online and offline analysis concept for DME synthesis finalised (sampling points and intervals, methods, investigated compounds).
- Optical Investigations in High-Pressure Chamber are nearly finished for the first set of injectors. Reference measurements with diesel fuel and also measurements with OME₃₋₅ and DME have been carried out.



WP4 Highlight

- Life Cycle Assessment (Cradle-to-Grave approach, special attention on reduction of SO_x , NO_x , CO, particulates/soot emissions) for the full CCU chain is ongoing. First results for the Global Warming Potential of the DME and OME synthesis and the impact of the electricity source of the electrolyser have been calculated and indicate a superiority of DME over OME.
- Patent application - options for waste heat utilisation and flue gas/carbon recycling from peak-power engines in the power plant with PCC.
- A continuous exchange between WP4 and WP5 “Industrial Cluster” and WP6 “Society” has been established. Important aspects have been jointly identified which have impact on the design of a future CCU system (e.g. avoidance of CO_2 -pipelines).

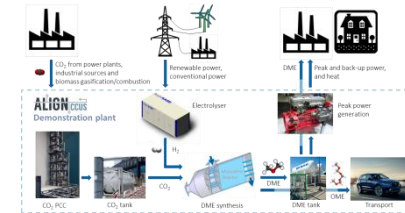


WP4 Impact

- High interest exists – especially at German stakeholders and politics – regarding the status of the ALIGN-CCUS project and sector coupling on basis of energy carriers produced by CCU.
- In Germany the next step in the development of CCU is under preparation: a large-scale CCU demonstration-scale plant to produce e-fuels using “green” hydrogen based on renewable sources in the Rhenish mining area.

RWE Power has joined forces with project partners to participate in the national call “Real laboratories for the energy transition”. A pre-proposal has been submitted: “Sustainable PowerFuel” .

Up to now three of the partners from ALIGN-CCUS are participating. The project idea has been considered as a key project in the final report of the German commission “Growth, structural change and employment”.



Reallabor „Sustainable PowerFuel“

Gemeinsame Vorhabenbeschreibung
für den Ideenwettbewerb „Reallabore der Energiewende“

Antragsteller
RWE Power AG, Essen (Koordinator)

Georg Fischer
[https://www.georgfischer.com](#)
 Georg Fischer AG, 41074 Essen, Germany

Technische Universität Braunschweig
[https://www.tu-braunschweig.de](#)
 Technische Universität Braunschweig, 38106 Braunschweig, Germany

Datum: 05.04.2019

WP Ongoing work

- Erection and commissioning of the demonstrator at Niederaussem; inauguration ceremony at second half of November 2019



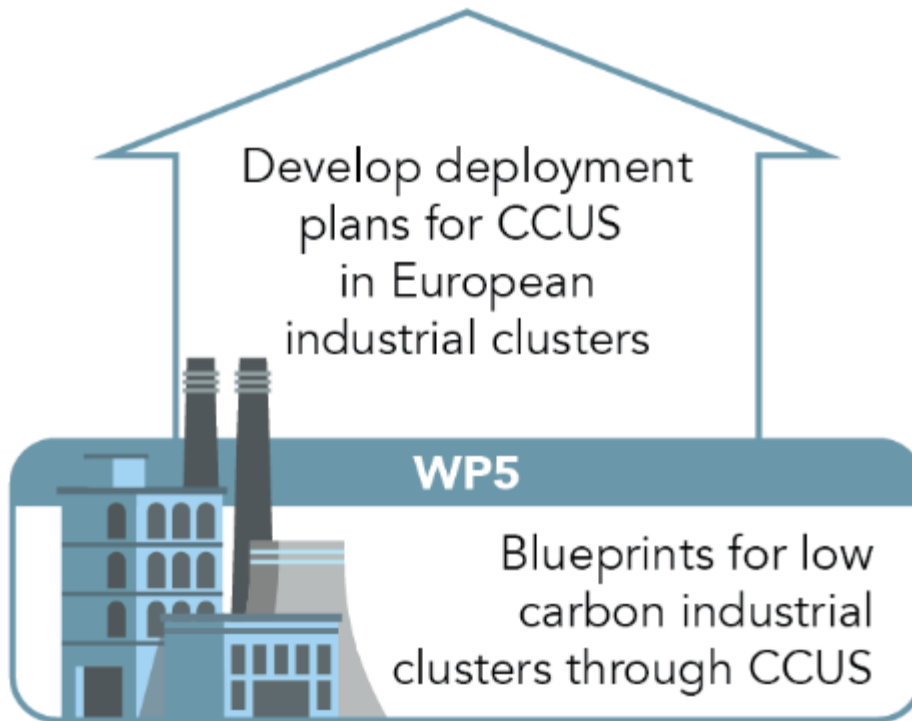
- Finalisation of the engine adaption to DME and start of testing of the peak power generator beginning of 2020 at Niederaussem
- Finalisation of the engine adaption to OME and start of testing of the personal car late 2019/start 2020.
- Techno-economic-environmental evaluation based on operating data, CCU chain optimisation and scale-up using the joint work of WP1/2/4/5/6

Work Package 5: Clusters

WP-leader: Tom Mikunda (TNO)

Partners:

- TNO
- BGS
- TVCA
- Imperial College
- Scottisch Enterprise
- Bellona
- FZ Jülich
- Yara
- NORCEM
- GeoEcoMar
- PicOil
- CO2Club

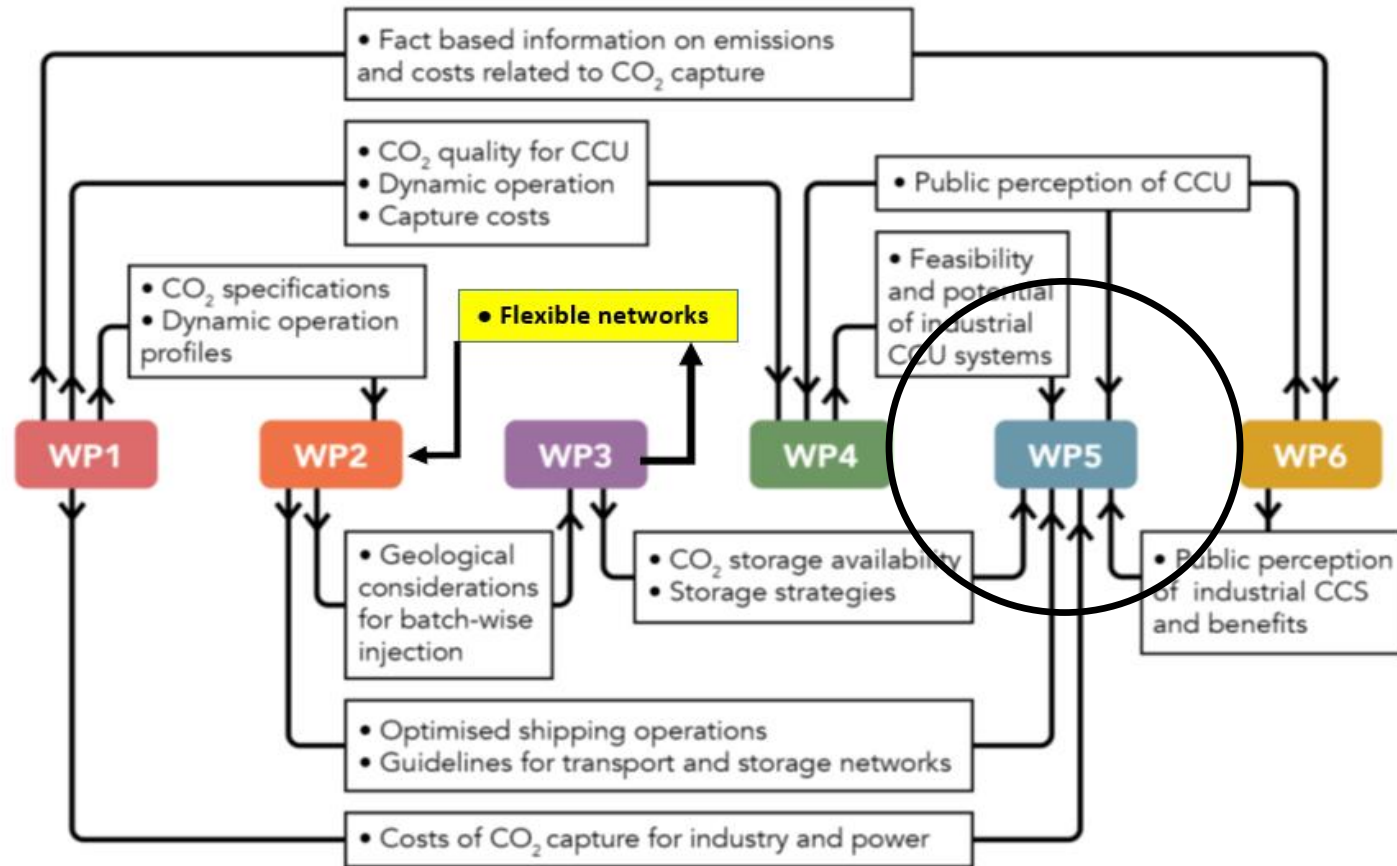


Targeted CCUS activities in industrial clusters

- Kick-starting, or advancing the development of CCUS in six industrial regions
- Identified specific development and research needs per cluster
- Use modelling tool developed in WP2 for consistent assessment



WP5 – integration is key



Recent events in industrial clusters

- March 2019 - 4th Projects of Common Interest list CO₂ transport infrastructure:
 - ERVIA Cork - Ireland (relevant for T5.4)
 - CO₂ Sapling - UK (relevant to T5.1)
 - Northern lights - Norway (relevant for T5.4)
 - ATHOS – The Netherlands (relevant for T5.2)
 - CO₂TransPorts – The Netherlands (relevant for T5.2)
- Shipping, buffering, CO₂ quality standards and storage portfolios remain key issues

Teesside

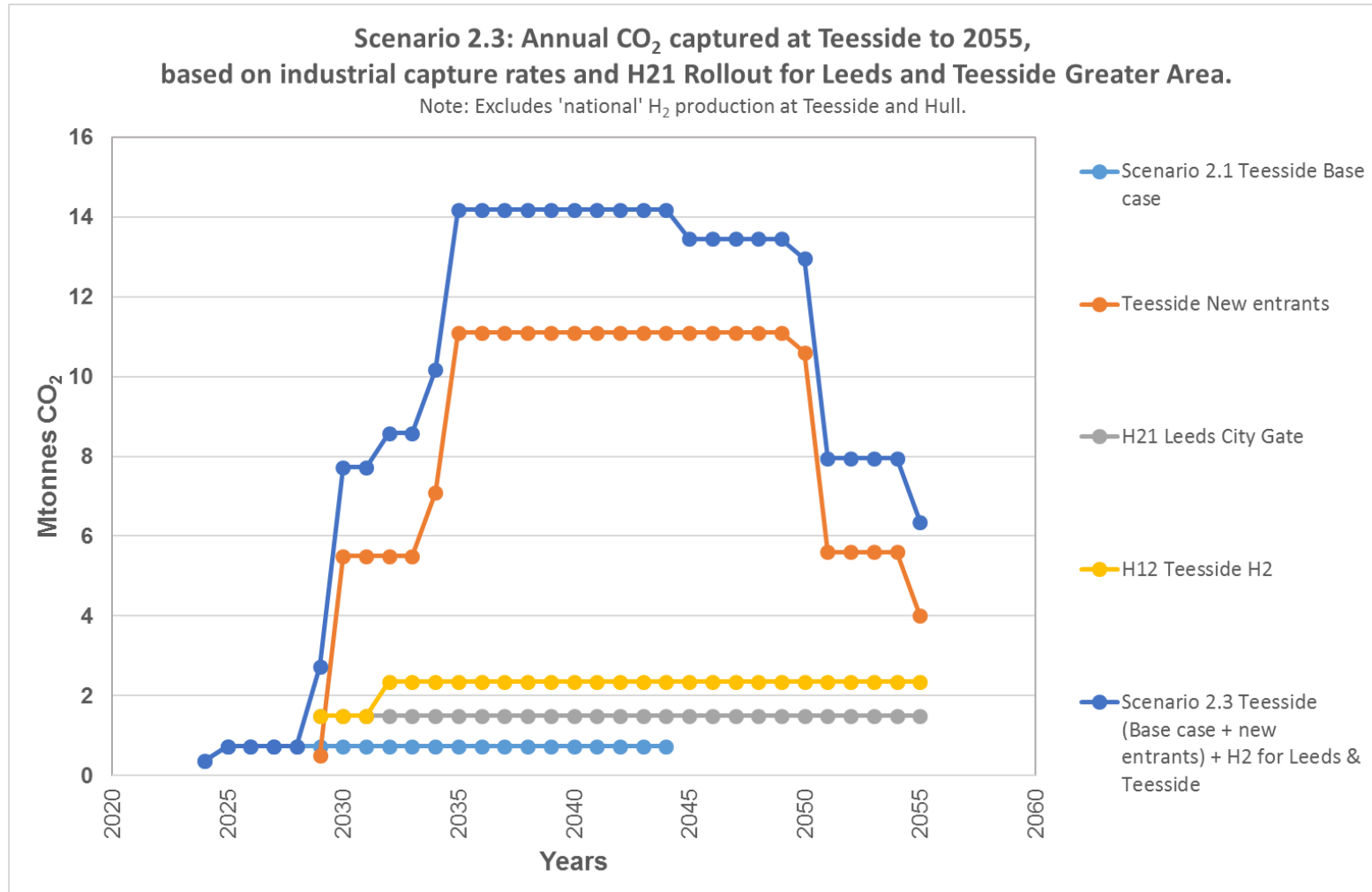
- 3 interconnecting sites covering chemicals, H₂ production, steel, gas processing, energy from waste, biomass power, and biofuels
- ~6 MtCO₂/yr, 6% UK industrial emissions
- €12 billion/yr / 25,000 jobs.

Objectives

- Cost reduction in capture and transport
- Optimise storage options under different CO₂ supply scenarios
- Business case development

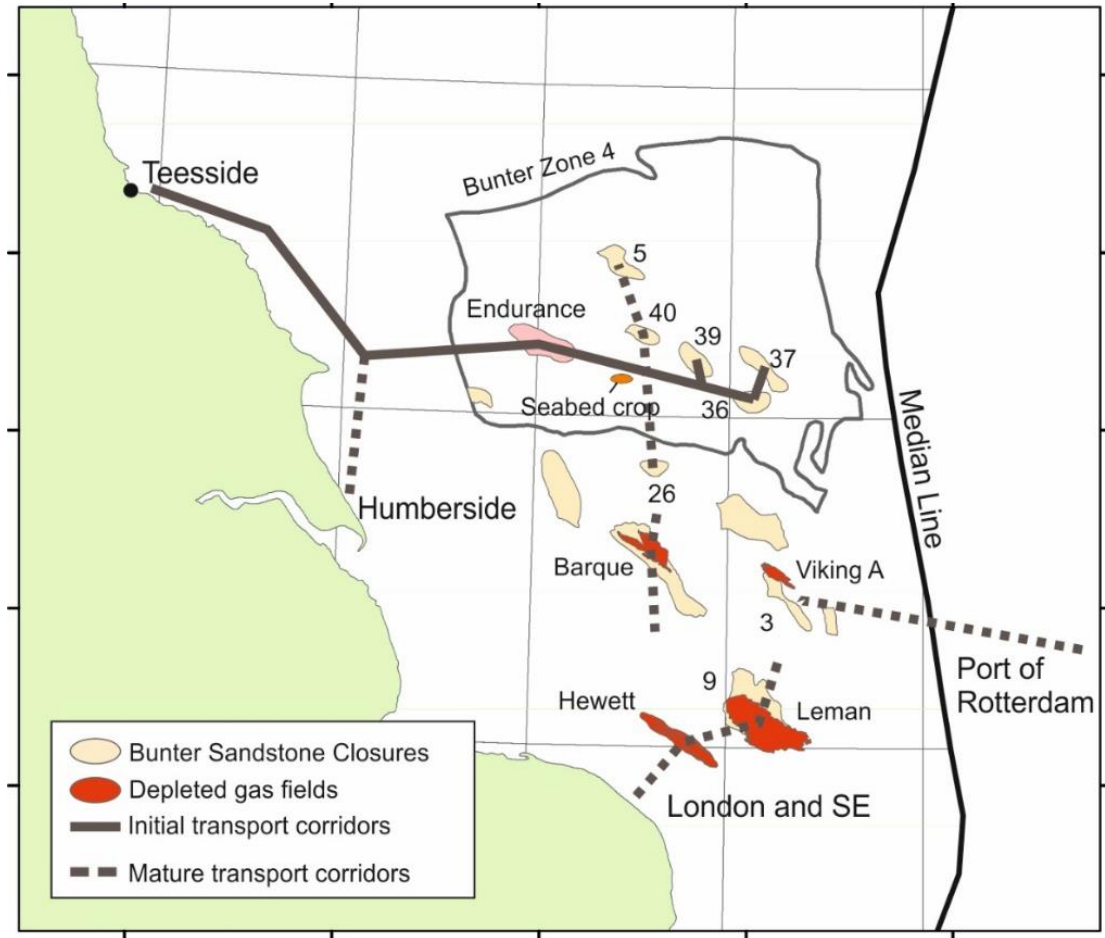


CO₂ profiling to match storage



Teesside storage options

- UK CO₂ supply scenario used in WP3 to select potential storage options for Teesside cluster
- Initial modelling of selected stores in progress to establish boundary conditions and pressure response for growth & mature scenarios
- Conceptual storage network to be tested for least-cost options



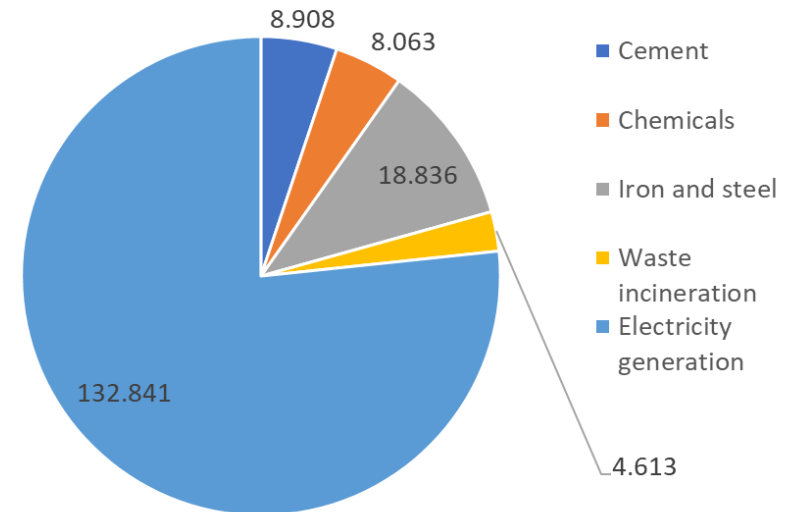
North Rhine Westphalia

- Heavily industrialised state, one-third of total German CO₂ emissions (~300 Mt/yr)
- No CO₂ storage permitted in many states
- CCU for low-carbon transport fuels

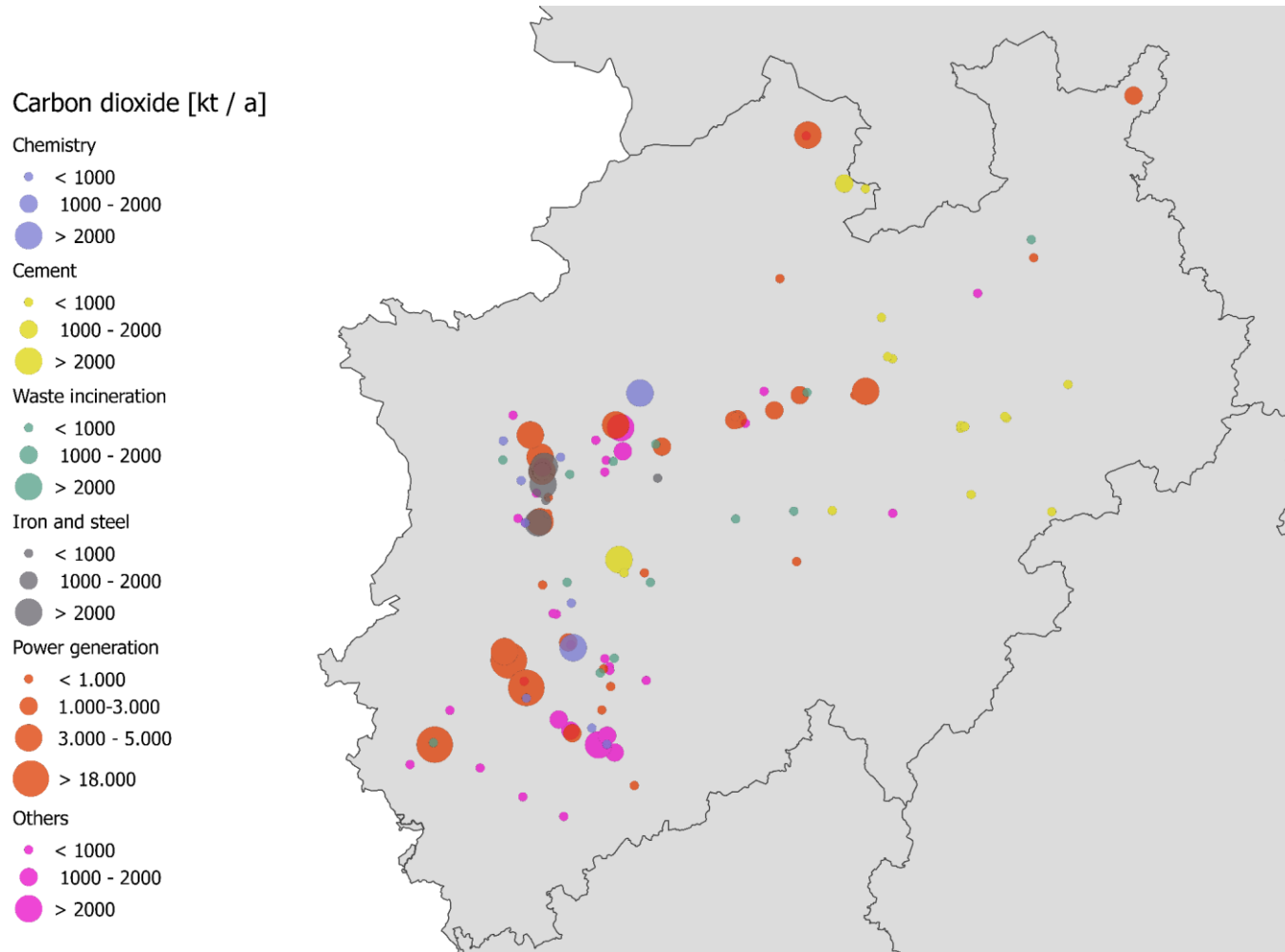
Objectives

- Identification of CCU pathways
 - CO₂ and H₂ availability
 - Methanol-based fuel demand (Transport sector / stationary power)
 - Sub-cluster identification
 - Source-sink matching

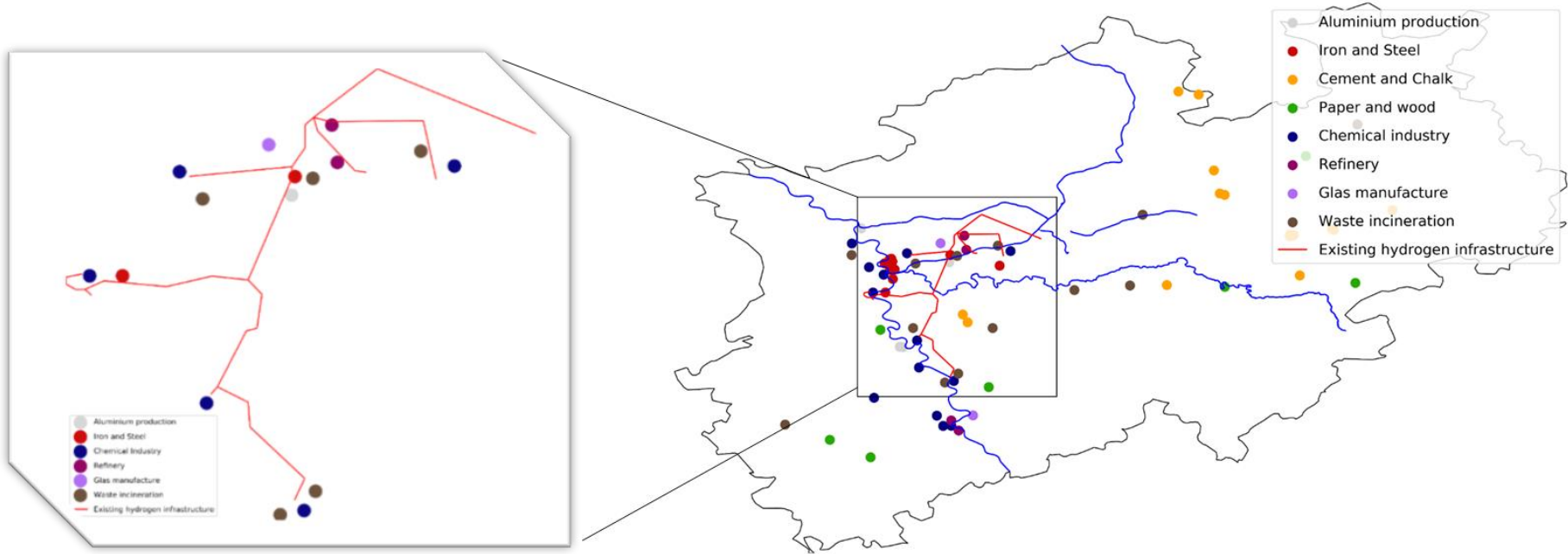
CO₂ emission from energy and industry 2015 (MtCO₂)



Identification of clusters

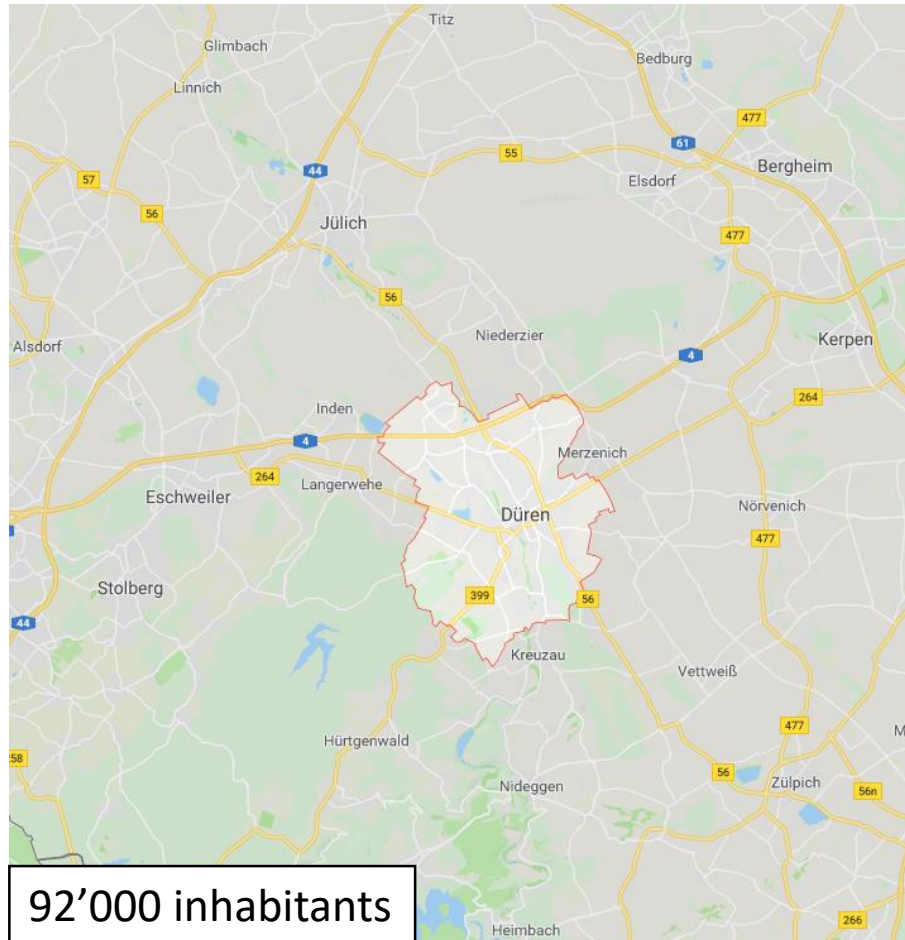


Sub-cluster identification



- 16 out 118 sources, 13.5 MtCO₂/yr
- Existing hydrogen grid, waterway infrastructure

Dürener Bus Fleet Diesel Consumption



11x



42x

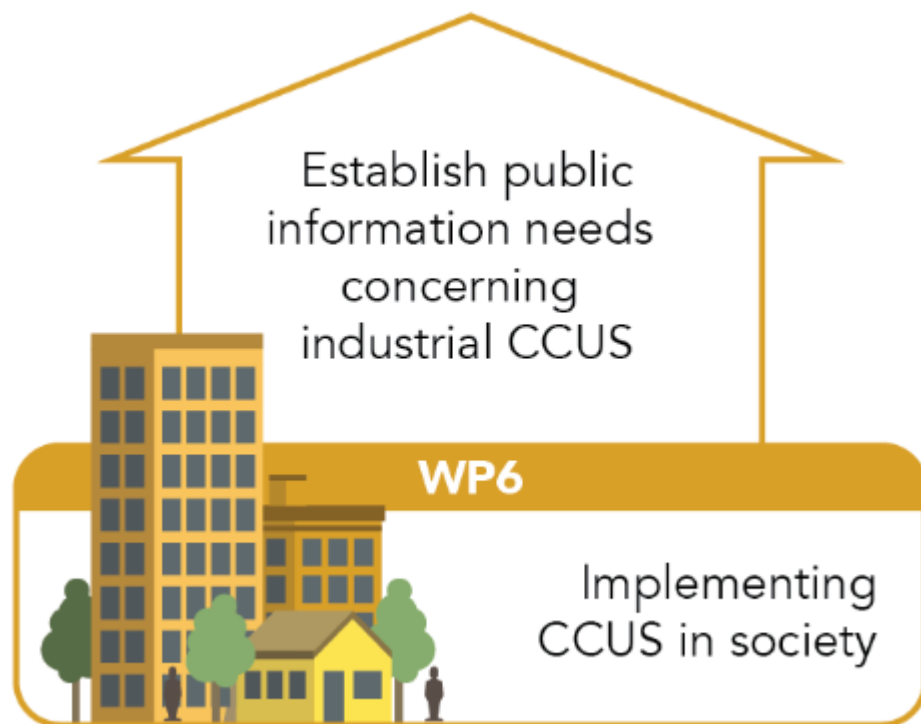


Different Operating Cycles
Consumption Depending on Age
Rough Estimation results in
~ **800 t Diesel / year**
→ **1.72 kt OME**

Impact

- Provide a set of actionable development plans for targeted CCUS activities in 6 key industrial clusters across the EU
- Supports industry, national and regional governments in decision-making for industrial decarbonisation strategies
- Work continues to be executed alongside current cluster initiatives and Projects of Common Interest

Work Package 6: Society



WP-leader: Emma ter Mors (LU)

Partners:

- Leiden University
- UEDIN
- TNO
- Bellona
- FZ Jülich
- SNSPA

WP6 Objectives

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.

WP6 Highlights

*Insights in narratives, arguments and visuals used in the **media**, relevant **stakeholders** and their perceptions, and determinants of **public** opinion – this will help in making site selection decisions and developing effective public engagement strategies*



WP6 Highlights

*Mixed method approach to understand do's and don'ts in **community compensation and engagement** both from theory and practice and close knowledge gaps – this work is focused on learning from, and sharing knowledge and findings with, stakeholders in the field*



WP6 Highlights: Social Science Network



ALIGN ← **CCUS**



WP-6 Impact - Status

- Collaboration and knowledge sharing with other ALIGN work packages.
- WP6 is connecting with CCUS initiatives (Porthos, Athos, waste incinerators) and CCUS stakeholders through bilateral meetings, WP6 interviews, the July 2019 WP6 workshop, and by participating in (inter)national CCUS networks/events (e.g. CATO meetings).
- ALIGN-CCUS, ACORN, ELEGANCY, ECO-BASE, ENOS social science network.
- Broad range of dissemination activities: e.g. scientific conference presentations, journal articles in preparation, blogs, interviews, workshop, seminars, bilateral meetings, a film.

WP-6 Ongoing work

- ✓ Finalizing data collection, data analysis, dissemination & integration of results.
- ✓ Providing concrete, evidence-based recommendations for designing effective compensation, engagement and communication strategies.

Acknowledgements

ACT ALIGN CCUS Project No 271501

This project has received funding from RVO (NL), FZJ/PtJ (DE), Gassnova (NO), UEFISCDI (RO), BEIS (UK) and is cofunded by the European Commission under the Horizon 2020 programme ACT, Grant Agreement No 691712

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