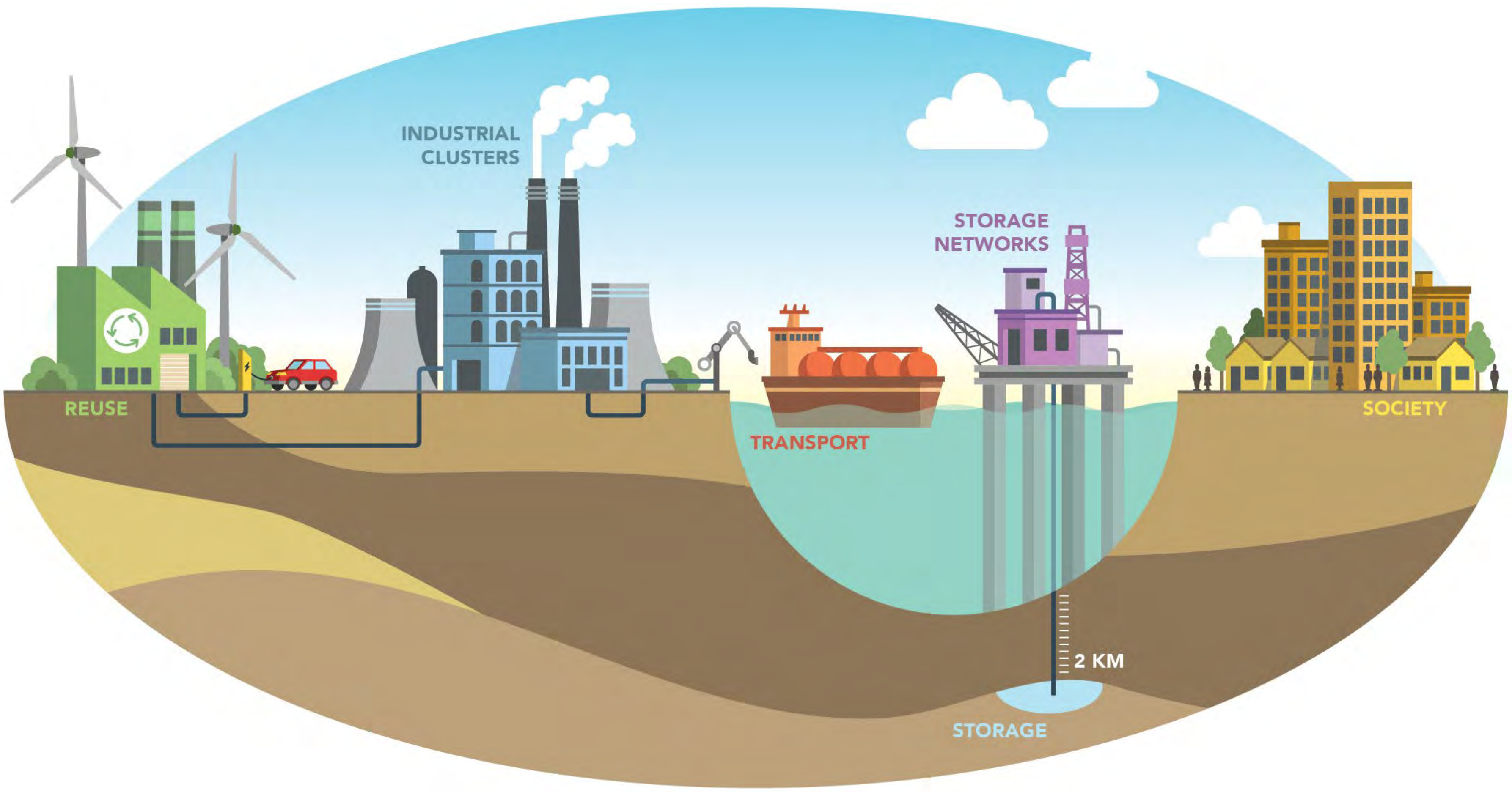
ALIGN CCUS

Accelerating CCS Technologies

European Commission



CSLF Technical Meeting

ALIGN CCUS

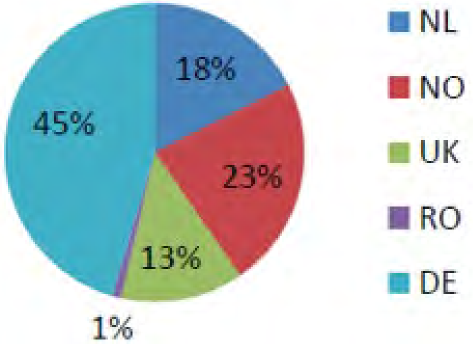
Project no 271501, ACT – Accelerating CCS technology

Tom Mikunda

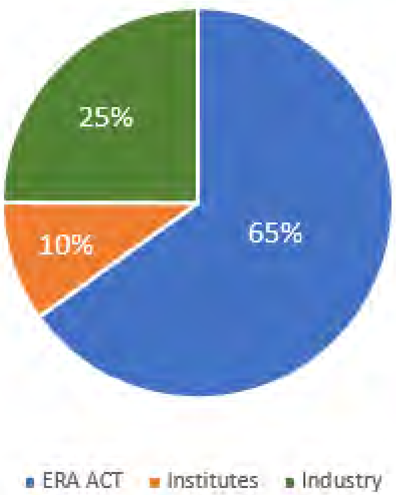
Energy policy consultant, TNO

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
- Active 2017-2020



Project partners

Asahi Kasei Europe GmbH

Bellona

British Geological Survey

CO2 Club Association

ECN

NUSPA

PicOil

FEV

Forschungszentrum Julich GmbH

GeoEcoMar

Heriot-Watt University

IFE

SINTEF Materials and Chemistry

Yara

Imperial College London

Leiden University

Mitsubishi Hitachi Power Systems Europe GmbH

Norcem

NTNU

Tel-Tek

TNO

RWE Power

RWTH Aachen University

Scottish Enterprise

UK Pilot-scale Advanced Capture Technology Facilities-PACT

University of Edinburgh

University of Groningen

TAQA Energy BV

Technology Centre Mongstad

Tees Valley Combined Authority

Supporting industrial clusters

- **Capture:** Enable near-term deployment of CO_2 capture by improving performance and reducing costs
- **Transport:** Optimising large-scale CO_2 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

Preparing for large-scale capture demonstration

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

Preparing for large-scale transport networks for offshore storage of CO2

- CO_2 shipping
- Batch-wise injection
- CO_2 specifications
- Planning for flexible networks

Strategic storage for ALIGN-CCUS European industrial clusters

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

Large-scale energy storage and conversion

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

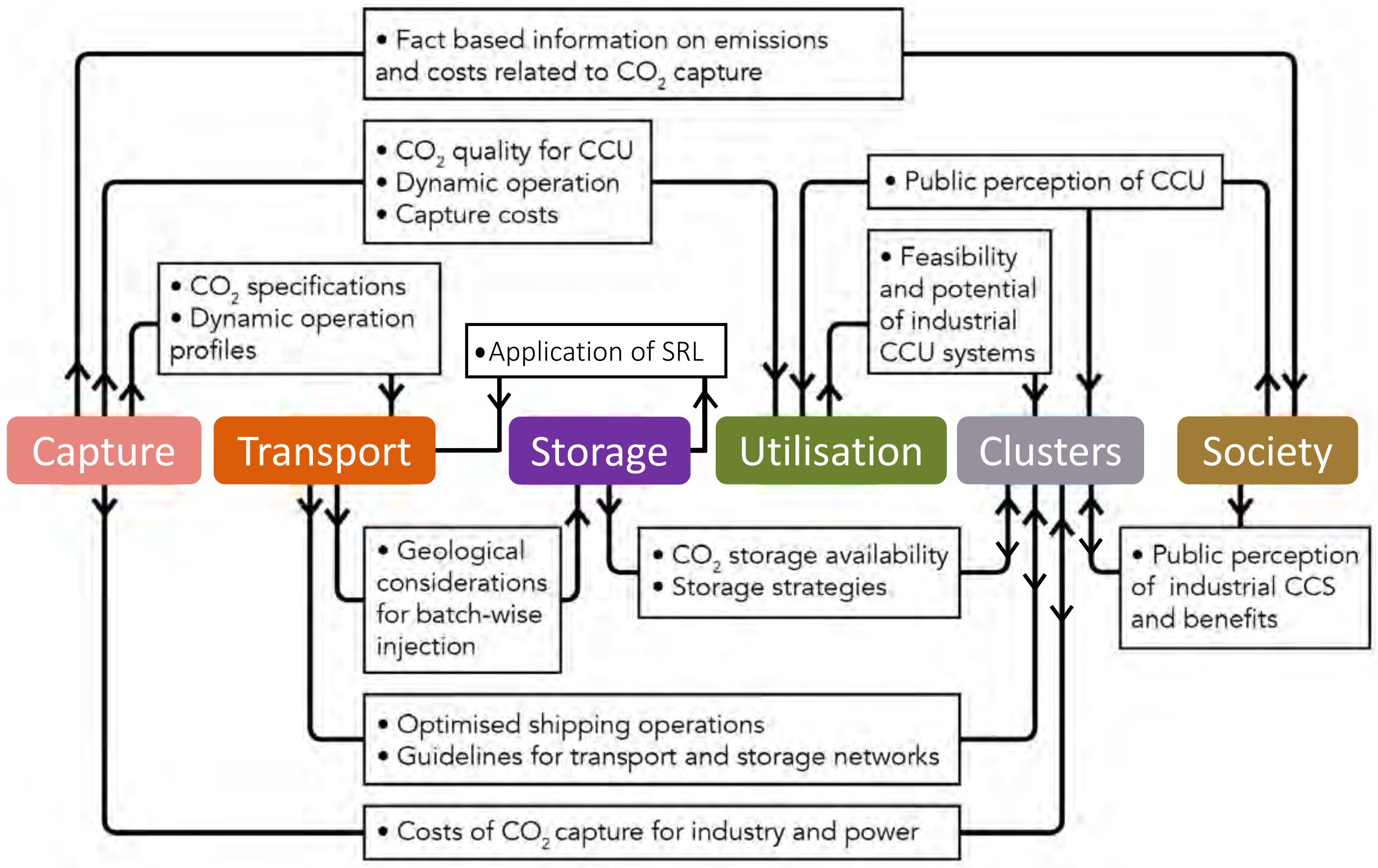
Blueprints for low carbon industrial clusters through CCUS

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

Implementing CCUS in society

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

Full-chain, well integrated



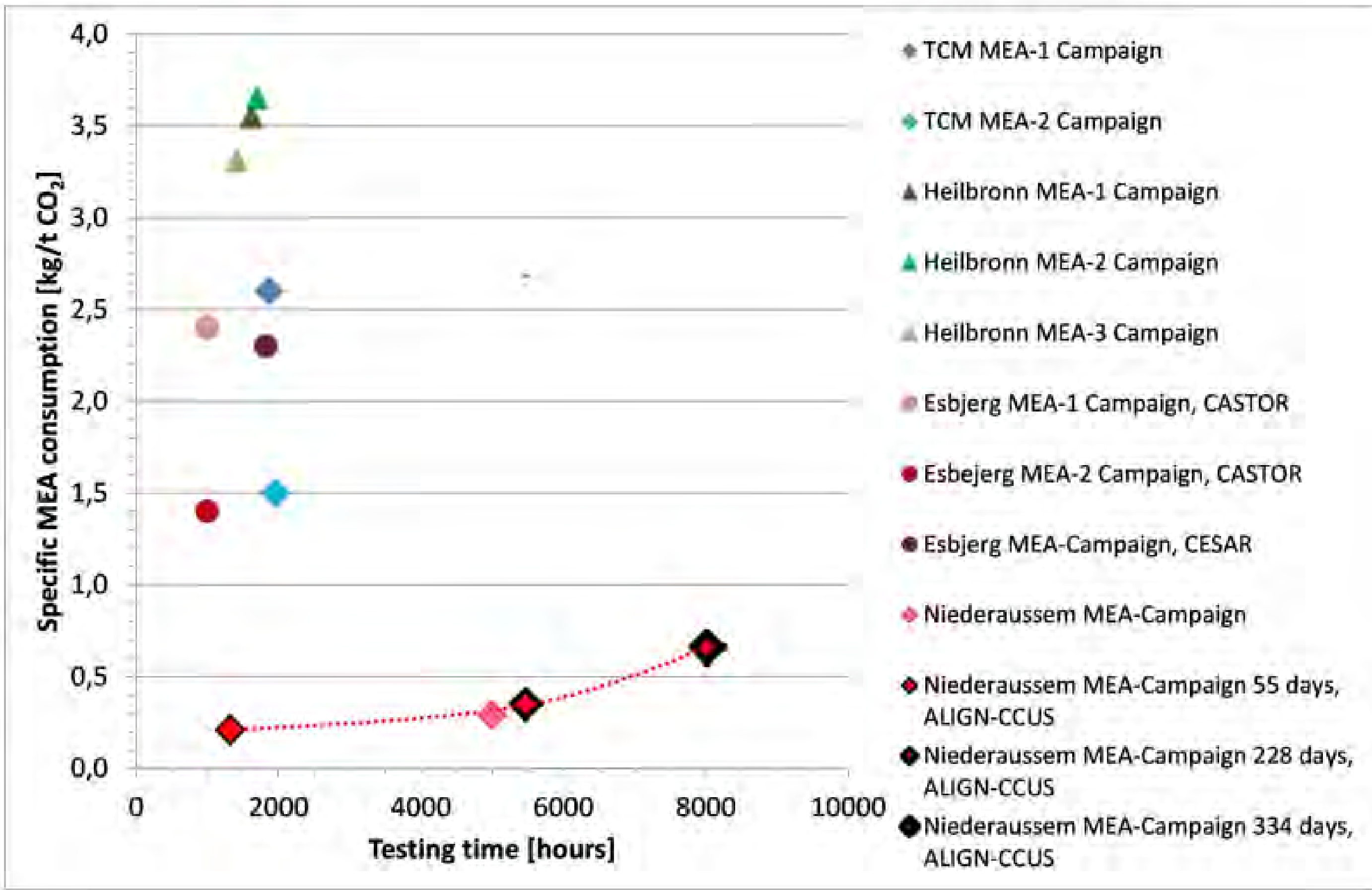
WP1 Capture

- Control of solvent emissions, development of aerosol counter-measures
- Control of solvent degradation, solvent testing
- Understand impacts of dynamic operations
- Cost optimisation based on pilot results

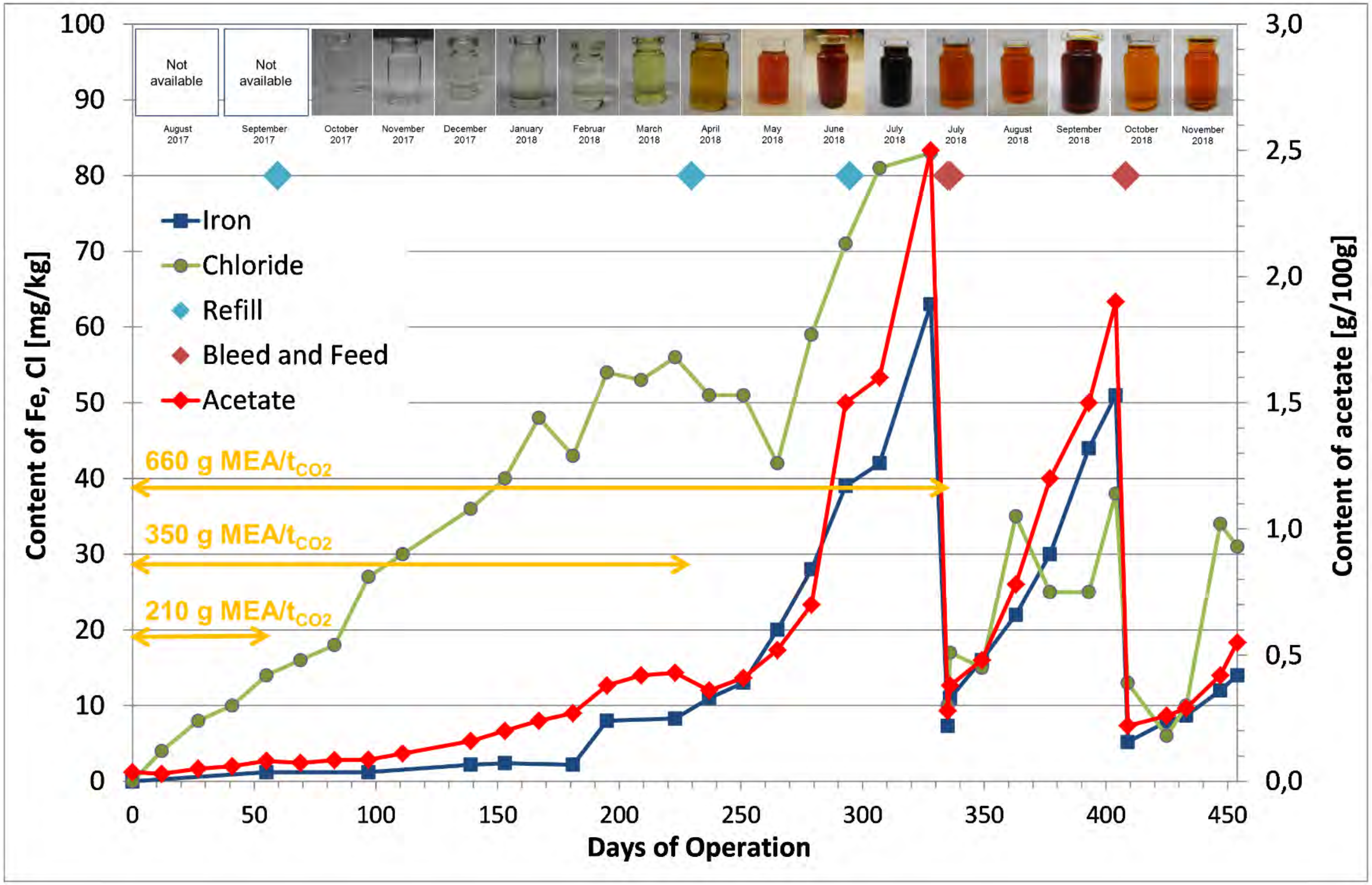
Pilot site	Operator	Location	Scale	Focus for ALIGN
Wilhelmshaven	UNIPER	Germany	Pilot-scale	Solvent management MEA
RWE Niederaussem	RWE	Germany	Pilot-scale	Emission control, solvent management, study dynamic effect / CCUS re-use
Tiller	SINTEF/NTNU	Norway	Pilot-scale	Solvent management 2^{nd} generation CESAR1 solvent system, NMPC control
TCM	TCM	Norway	Industrial-scale	Long-term test of CESAR1 solvent system

Solvent consumption

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



Degradation products

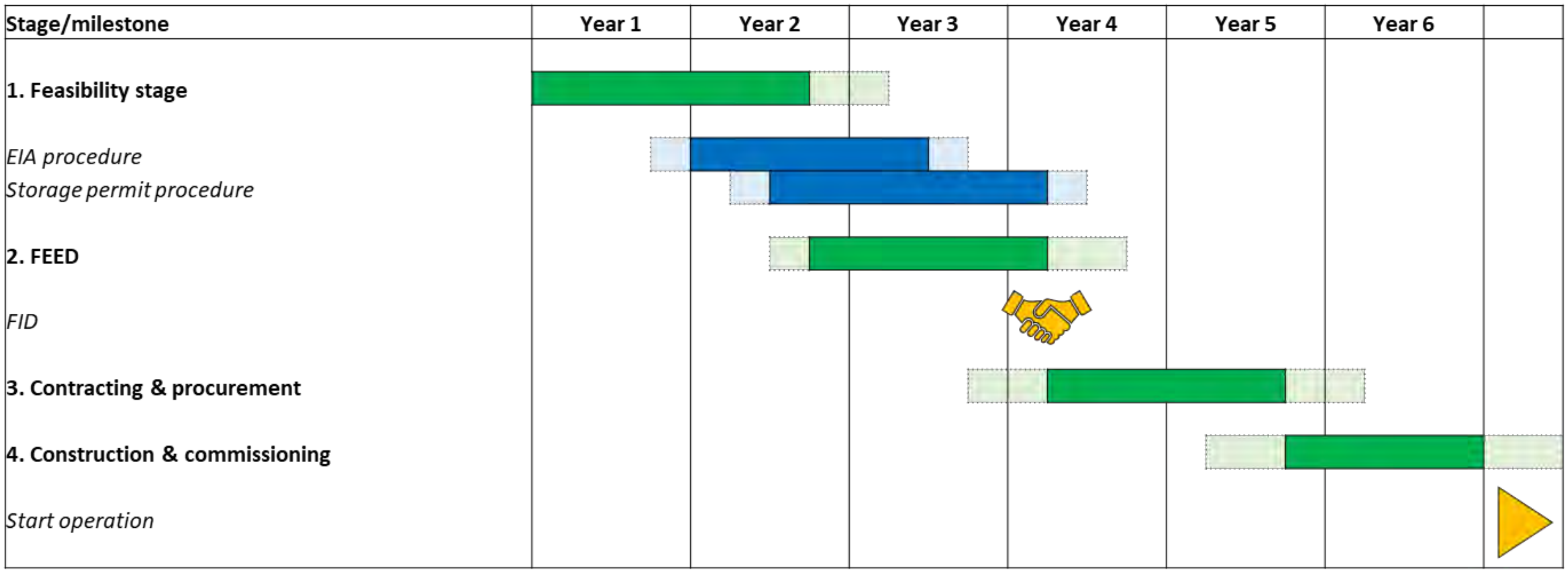


WP3 – Large scale storage networks

WP3 aims to achieve three outcomes to support CO_2 storage deployment in the North Sea:

- Develop a methodology to produce standardised definitions of the levels of storage readiness for putative storage sites across the North Sea
- Create a portfolio of selected storage sites that have been characterised sufficiently to provide strategic storage for the leading ALIGN industrial clusters
- Create inventories of existing North Sea oil and gas infrastructure for possible reuse for CO_2 T&S.

Timeline for storage site development



Typical duration of development depleted field for CO_2 storage: ~ 6 years

WP3 -Storage readiness levels

SRL number	Description/title of SRL
SRL 1	First-pass assessment of storage capacity at country-wide or basin scales
SRL 2	Site identified as theoretical capacity in a storage atlas
SRL 3	Screening study to identify an individual storage site & an initial storage project concept
SRL 4	Storage site validated by desktop studies & storage project concept updated
SRL 5	Storage site validated by detailed analyses, then in a relevant 'real world' setting
SRL 6	Storage site integrated into a feasible CCS project concept or in a portfolio of sites (contingent storage resource)
SRL 7	Storage site is permit ready or permitted
SRL 8	Commissioning of the storage site and test injection in an operational environment
SRL 9	Storage site on injection

Project 'milestones'

- Feasibility study, Norway. Pre-feasibility study, UK & Netherlands. (SRL 3–4)
- Feasibility study, UK & Netherlands (SRL 5)
- *FEED study UK, Pre-FEED, Netherlands (SRL 6)
- †Contingent storage resource (→ SRL 7)
- Major investment decision (MID) (→ SRL 8)

Stages and thresholds in the storage site permitting process

- Gathering information for an exploration permit (SRL 1–4)
- Exploration permit required
- Planning & plan iterations for a storage permit♦ (SRL 5–6)
- Storage permit♦ application & iteration (SRL 7)
- Storage permit♦ required
- Injection permit application (SRL 8)
- Injection permit required

Stages and thresholds in technical appraisal & project planning

- Technical appraisal (SRL 1–5)
- Confirmation well drilled
- Outline planning for development
- Technical risk reduction completed
- Project planning & permitting iterations
- All planning work completed
- Construction & testing
- Site construction completed
- Operation & monitoring

Application of SRL to storage sites

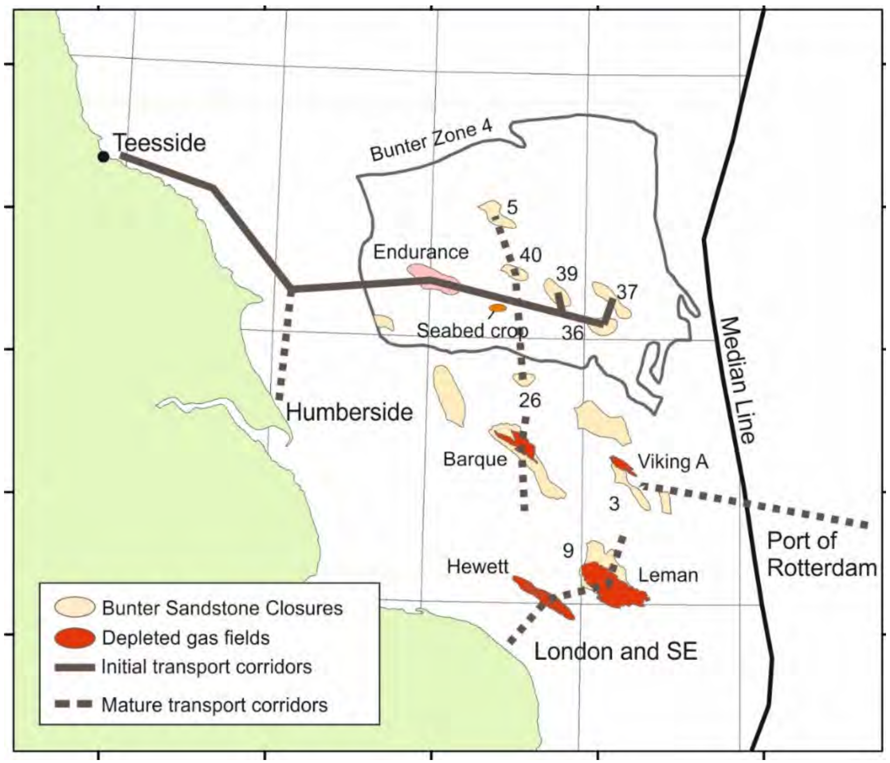
- Measure time taken and SRL achieved

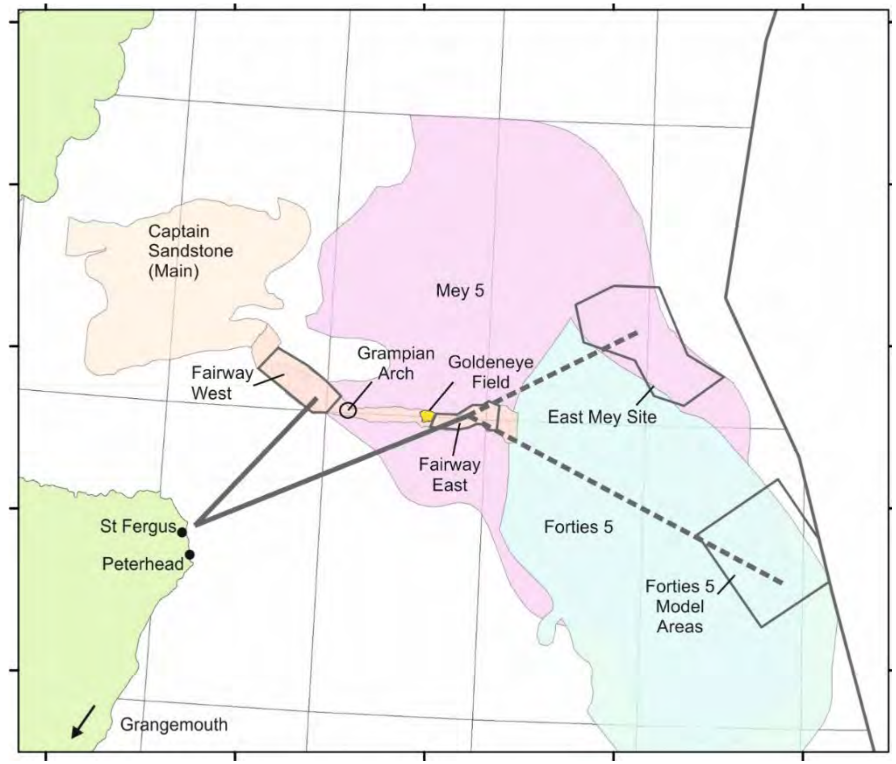
Site FEED study or theoretical assessment		Duration of appraisal	Total time to Storage Permit (including appraisal)	SRL at start	SRL at end
Duration	White Rose FEED (National Grid, 2016a)	30 months	33 months	2	7
	Peterhead FEED (Shell, 2016)	16 months	20 months	2/3	7
	P18-4 pre-FEED (ROAD, 2018)	24 months	48 months	2/3	8

- Tabulated spend to achieve SRL 1-3 & SRL 4-8 for 16 EU sites
- Time and effort to advance the SRL is site specific:
  - whether within a hydrocarbon exploration region
  - has existing available data
  - previously performed appraisals
- Cost and time differs whether assessing a hydrocarbon field or a saline aquifer site

WP3 Highlights – better characterised stores UK

Conceptual storage networks for ALIGN-CCUS clusters Teesside & Grangemouth, UK





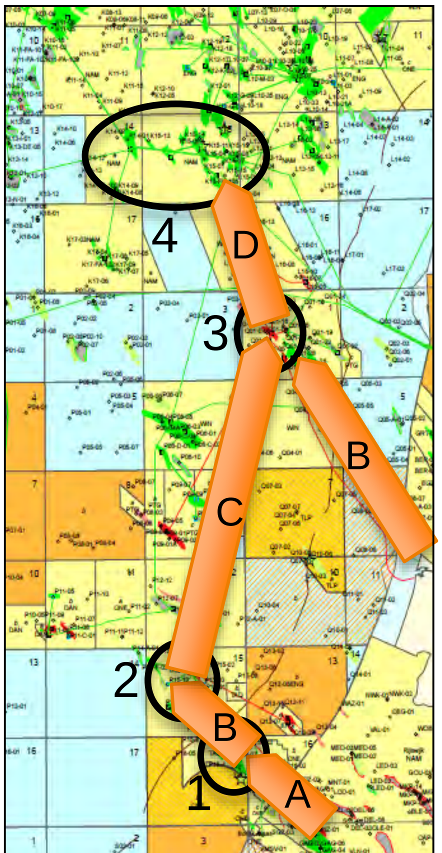
Multi-store sites with storage networks for scenarios of initial, growth and mature CCS projects deployment, shown as solid and dashed CO_2 transport corridors

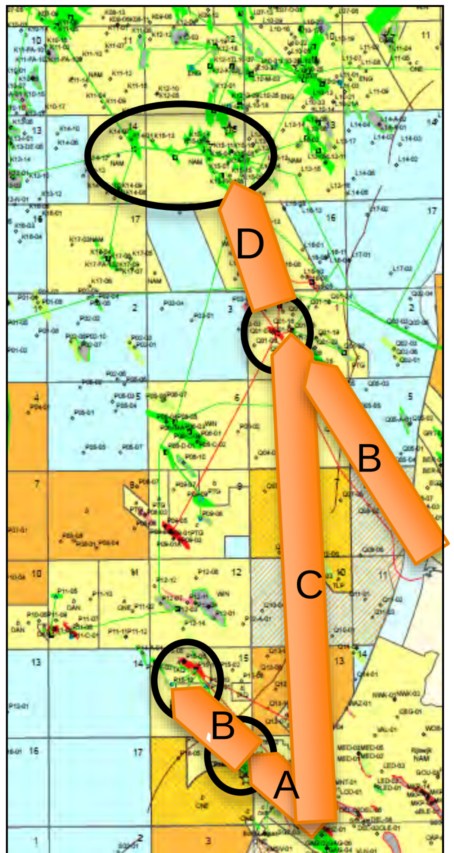
Stores with higher SRLs assessed. Input from NL appraisal of batch-wise injection for Teesside selection.

WP3 Highlights – better characterised stores NL & NO

Potential network development scenarios

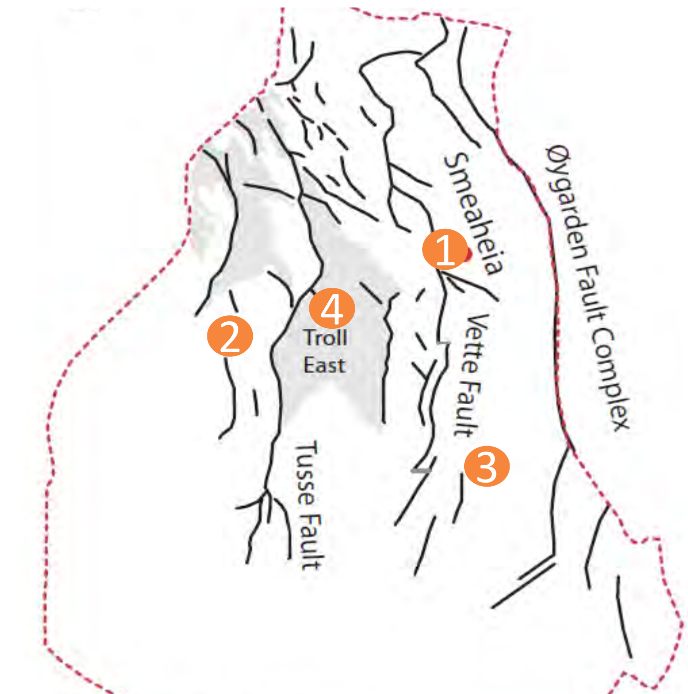
Support Porthos preliminary design selection





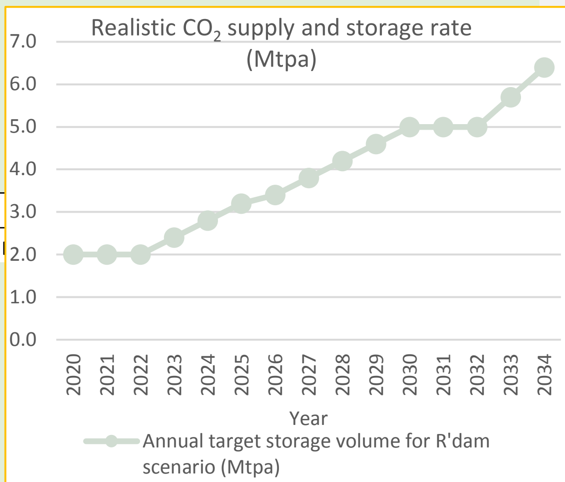
Roadmap for CO_2 Storage Smeaheia Hub

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



Matching CO_2 supply with storage capacity

Year	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Available annual storage capacity (Mtpa)																
P18-a	2	2	2	2	2	2	2	2	2	2						
P18-b	1.1	1.1	1.1	1.1	1.1	1.1	1.1									
P15-a						1	1	1	1	1	1	1				
P15-b						1	1	1	1	1	1	1				
P15-c						0.7	0.7	0.7	0.7	0.7						
K15-a											3	3	3	3	3	3
K15-b															2	2
K15-c																3
K15-d																
K14-e																
K14-f																
Annual																
P18-a	2	2	2	2	2	2	2	2	2	2						
P18-b				0.4	0.8	1.1	1.1	1.1	1.1	1.1	1					
P15-a						0.1	0.3	0.7	0.6	1	1	1	1	1	0.3	
P15-b									0.5	0.5	1	1	1	1	1	1
P15-c											0.7	0.7	0.7	0.7	0.7	
K15-a											2	3	3	3	3	3
K15-b															2	2
K15-c																1
K15-d																
K14-e																
K14-f																
Annual matched storage capacity (Mtpa)	**2**	**2**	**2**	**2.4**	**2.8**	**3.2**	**3.4**	**3.8**	**4.2**	**4.6**	**5.7**	**5.7**	**5.7**	**5.7**	**7**	**7**
Cumulative matched storage volume (Mt)	**2**	**4**	**6**	**8.4**	**11.2**	**14.4**	**17.8**	**21.6**	**25.8**	**30.4**	**36.1**	**41.8**	**47.5**	**53.2**	**60.2**	**67.2**

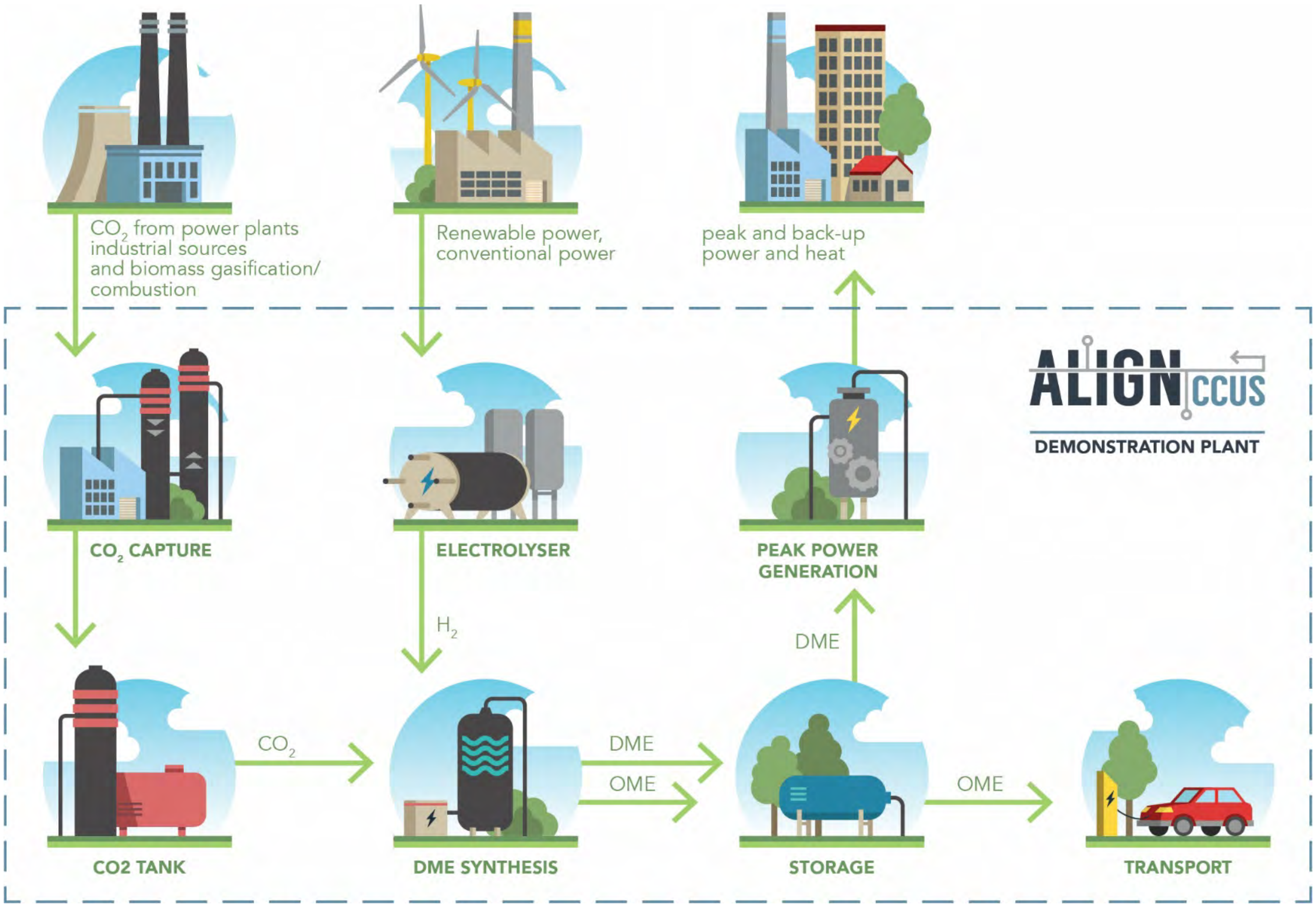


WP4 - CCUS as an element for large-scale energy storage and conversion

WP4 of ALIGN-CCUS aims to accelerate 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
- Testing synthetic transportation fuel in internal combustion engine
- Obtaining acceptance for CCU by additional benefits: security of supply and low-emission fuels
- Providing clarity on the environmental impacts of a CCU process

WP4 – The ALIGN CCU Concept

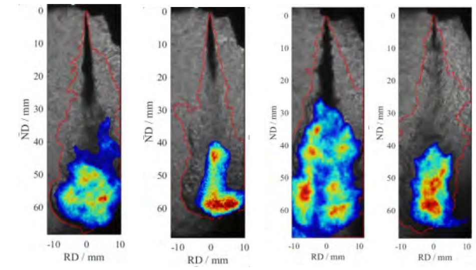


CCU advantages

- National interests - lack of CO_2 storage space
- DME/OME - Alternative transport fuels
  - Cleaner burning that diesel (lower NOx, no soot)
  - Only require minor adjustments to ICE, no major infrastructural changes

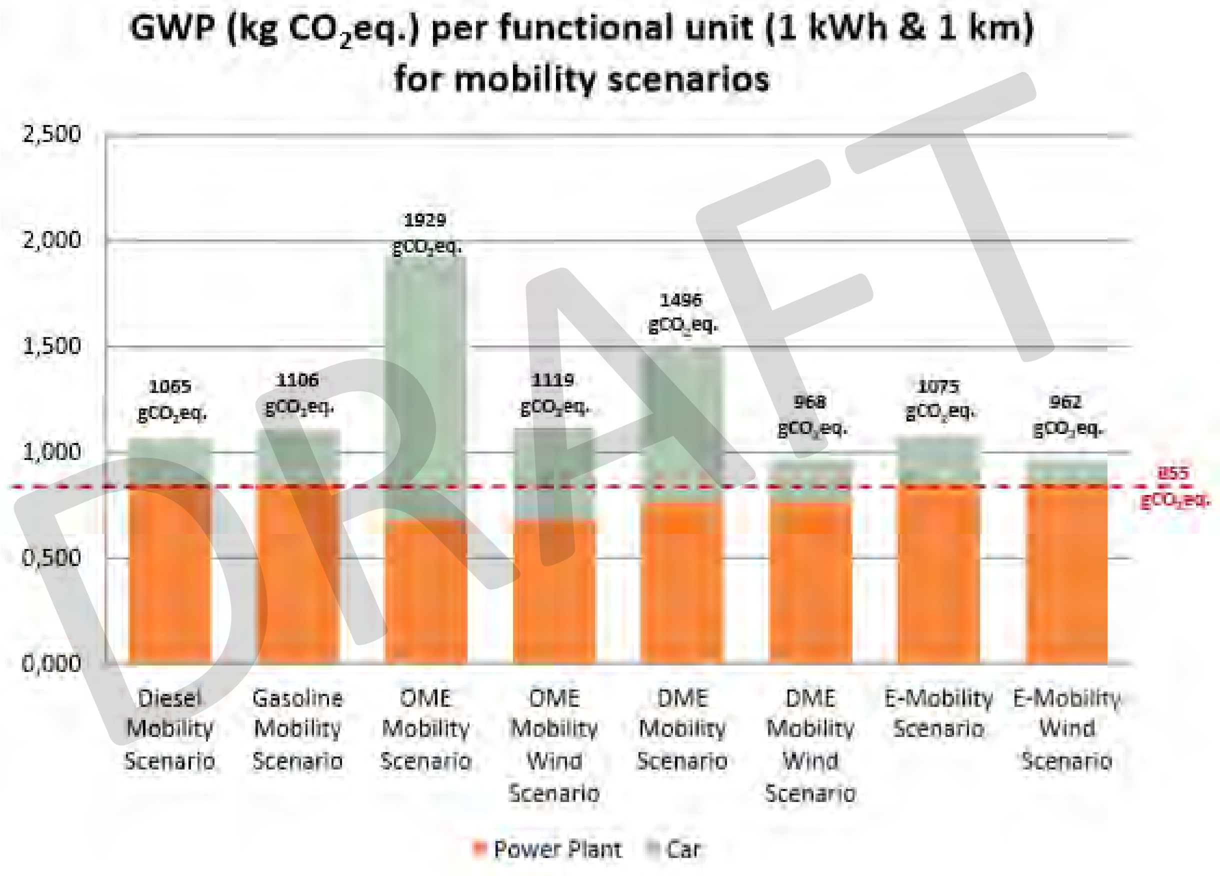
CCU demonstrator – status Q4 2019

- Final engineering and procurement of components for DME synthesis, electrolyser and completed, manufacturing ongoing.
- Injection system adaption: Optical Investigations in High-Pressure Chamber
- The stationary power generator has arrived
- Demonstration elements are arriving in Niederaussem (DE) and the site construction is ongoing.
- Inauguration event on the 19th of November at the RWE power station in Niederaussem.



Assessment of climate benefit

- Preliminary mobility benchmarking scenarios



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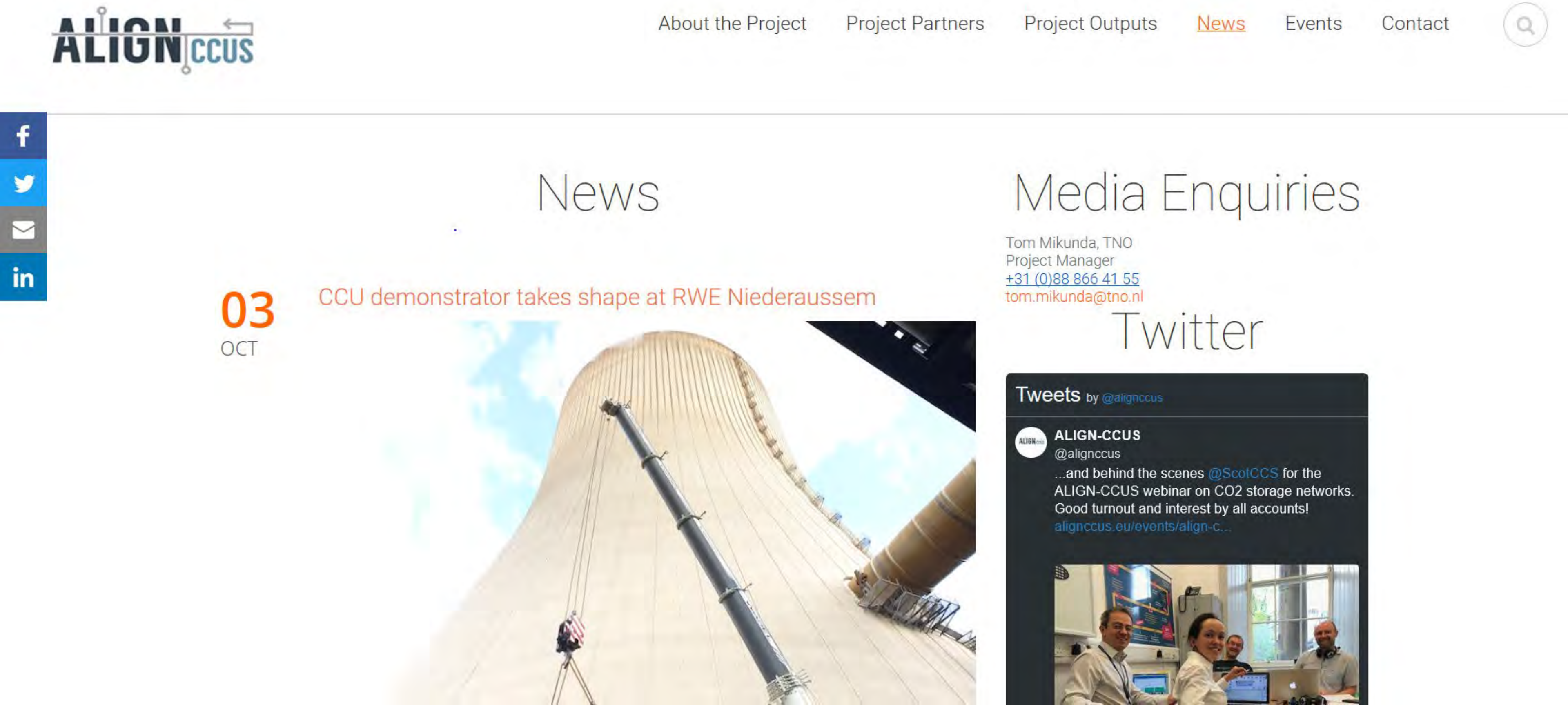

Acknowledgements

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