

Enabling a Low-Carbon Economy via Hydrogen and CCS

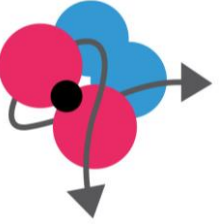
Svend Tollak Munkejord, SINTEF Energy Research, project coordinator

<http://www.elegancy.no/>

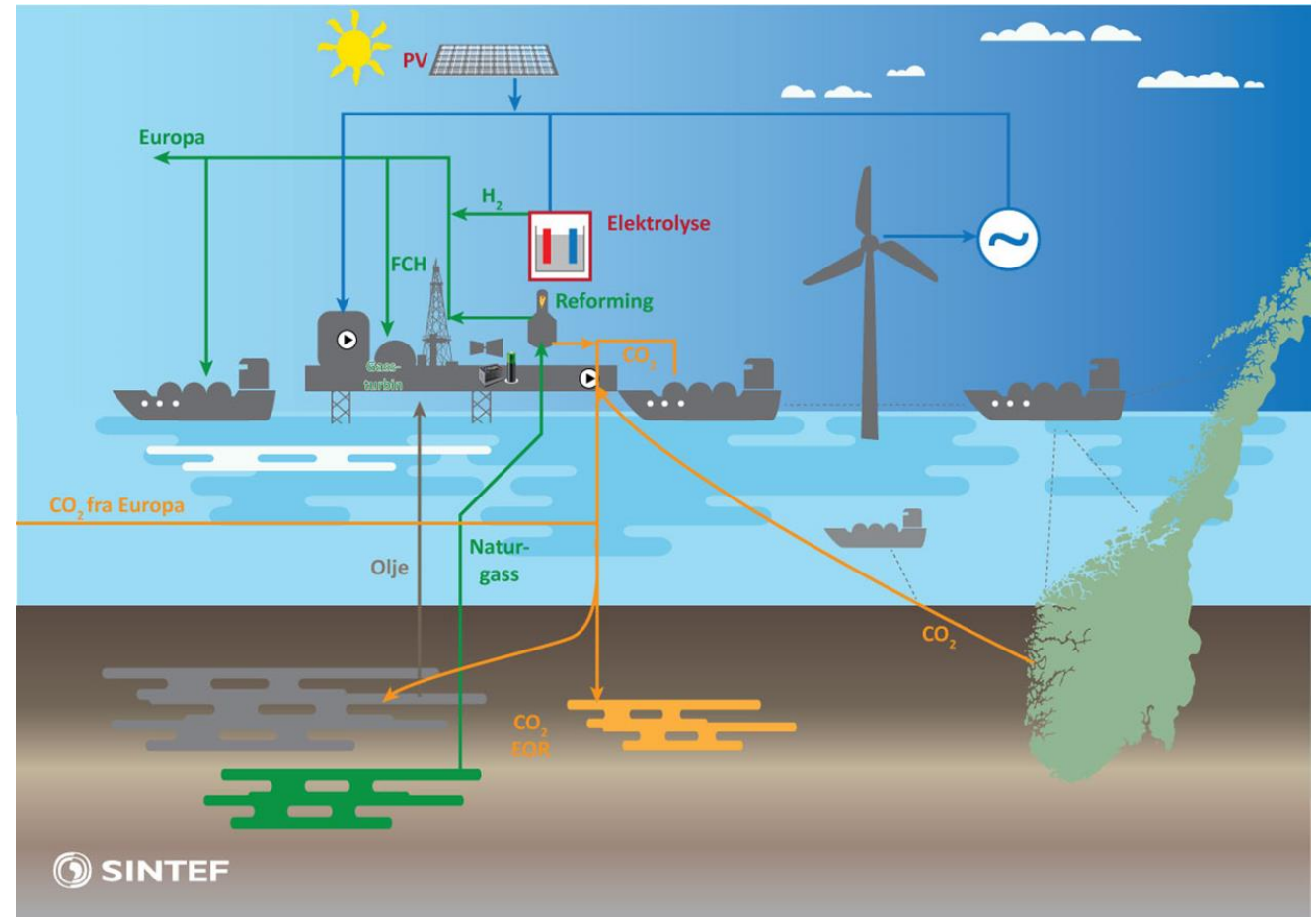
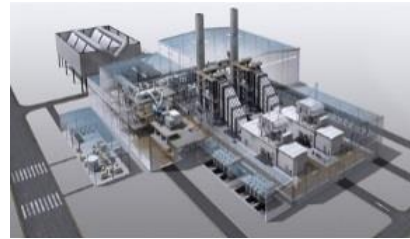
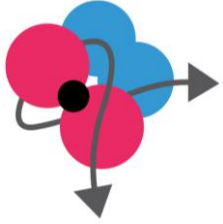
ACT knowledge-sharing workshop, Niederaußem, 2018-11-13

Outline of presentation

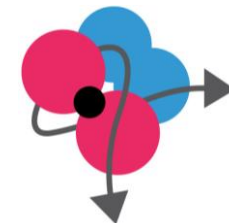
- ELEGANCY
 - Aim
 - Approach
 - Some highlights
 - Communication



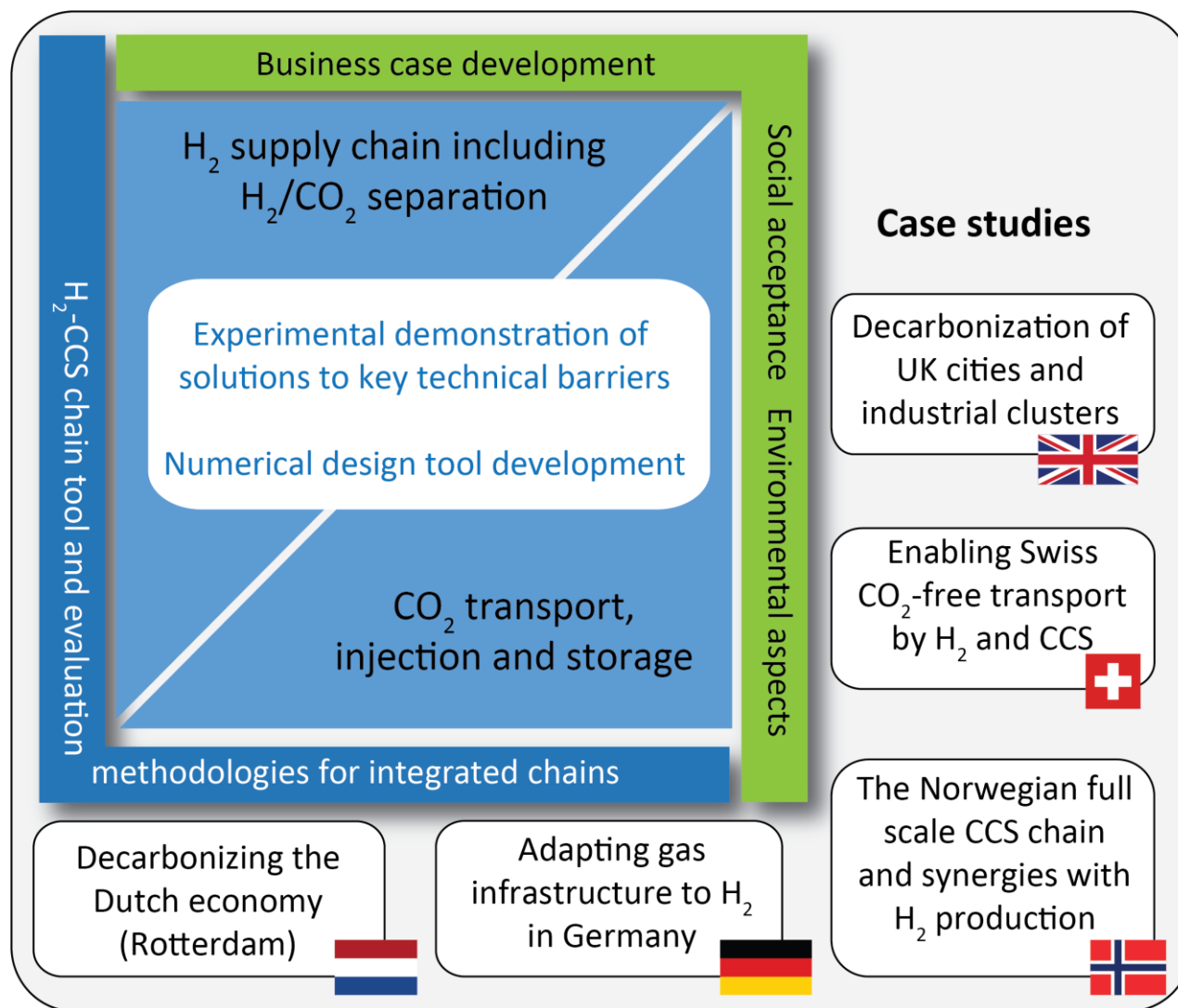
ELEGANCY – context



- The low-carbon economy needs H_2
- The low-carbon economy needs CCS
- Combining hydrogen with CCS offers an exciting opportunity for synergies and value creation
- ELEGANCY aims at contributing to fast-track the decarbonization of the European energy system



ELEGANCY – key information



Case studies

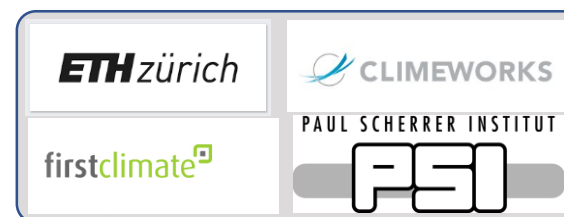
Decarbonization of UK cities and industrial clusters



Enabling Swiss CO₂-free transport by H₂ and CCS

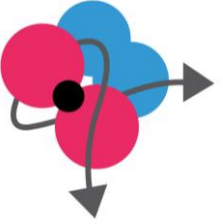


The Norwegian full scale CCS chain and synergies with H₂ production



- Duration: 2017-08-31 to 2020-08-31.
- Budget: 15 599 kEUR

ELEGANCY – project-management team



Svend T. Munkejord
SINTEF



Hans L. Skarsvåg
SINTEF



Marco Mazzotti
ETH Zürich



Catherine Banet
University of Oslo



Nilay Shah
Imperial College London



Gunhild A. Reigstad
SINTEF



An Hilmo
SINTEF

ELEGANCY – work packages

Case studies incl. social acceptance, environmental aspects and CCS-H₂ market considerations:
UK (large-scale decarbonization), Netherlands (Rotterdam decarbonization), Norway (full scale CCS chain and H₂ production), Switzerland (decarbonization of transport sector), Germany (adapting gas infrastructure and processes to H₂)

WP5

H₂-CCS chain tool and evaluation methodologies for integrated chains: (ICL, SINTEF, PSI, RUB, TNO)

WP4

Business case development: (UiO, FirstClimate, SDL)

WP3

H₂ supply chain including H₂/CO₂ separation

WP1

- H₂ from natural gas (ETH, PSI)
- H₂ from other sources (ECN)
- Characterization of CO₂-CO-H₂ mixtures (RUB)

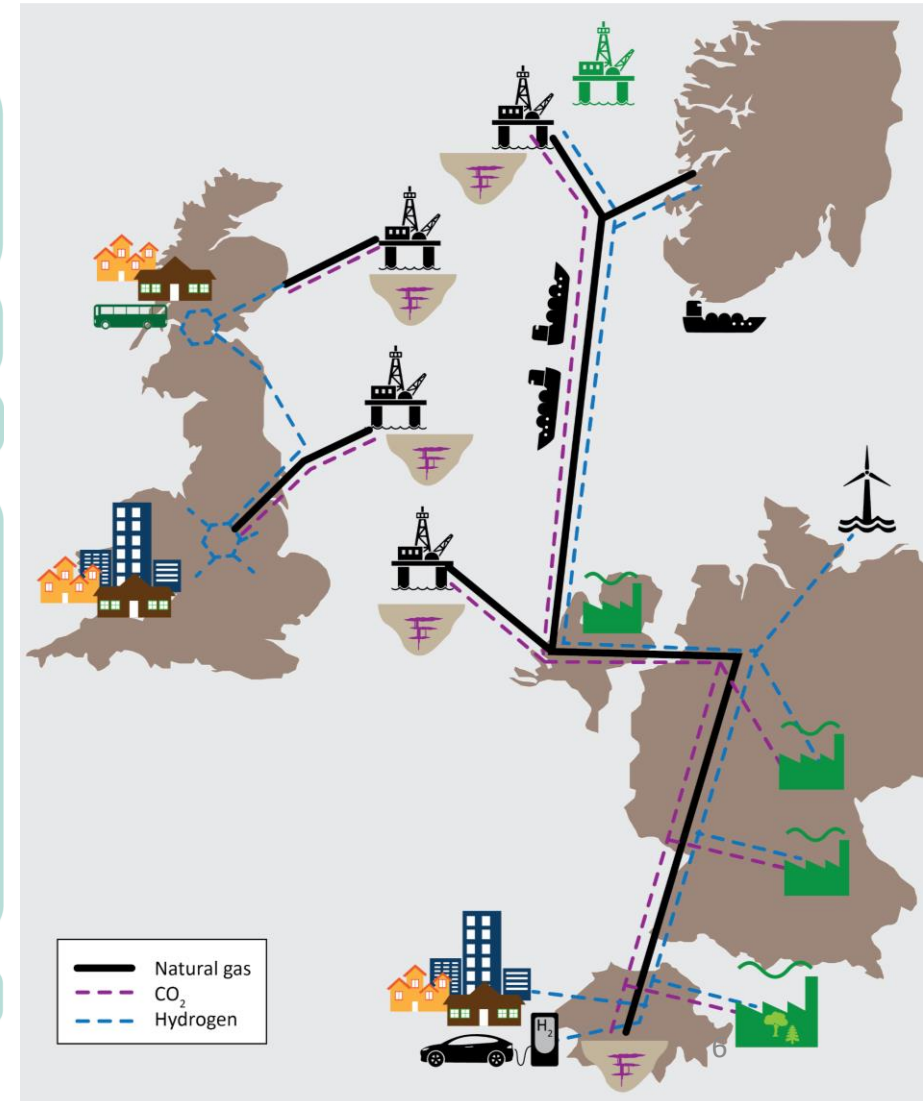
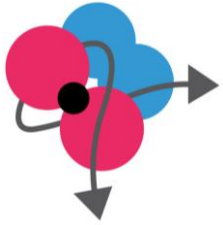
CO₂ transport, injection and storage

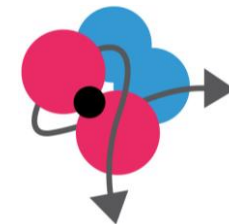
WP2

- CO₂-brine model (RUB, ICL)
- CO₂ transport-injection interface (SINTEF)
- Storage-site characterization and selection (ICL)
- Mt. Terri decametre scale experiment (ETH)
- Impact of H₂ in the CO₂ stream on storage (BGS)
- De-risking storage

ELEGANCY project management, network building and dissemination (SINTEF)

WP6

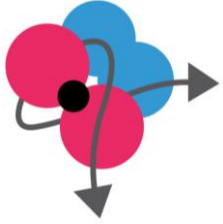




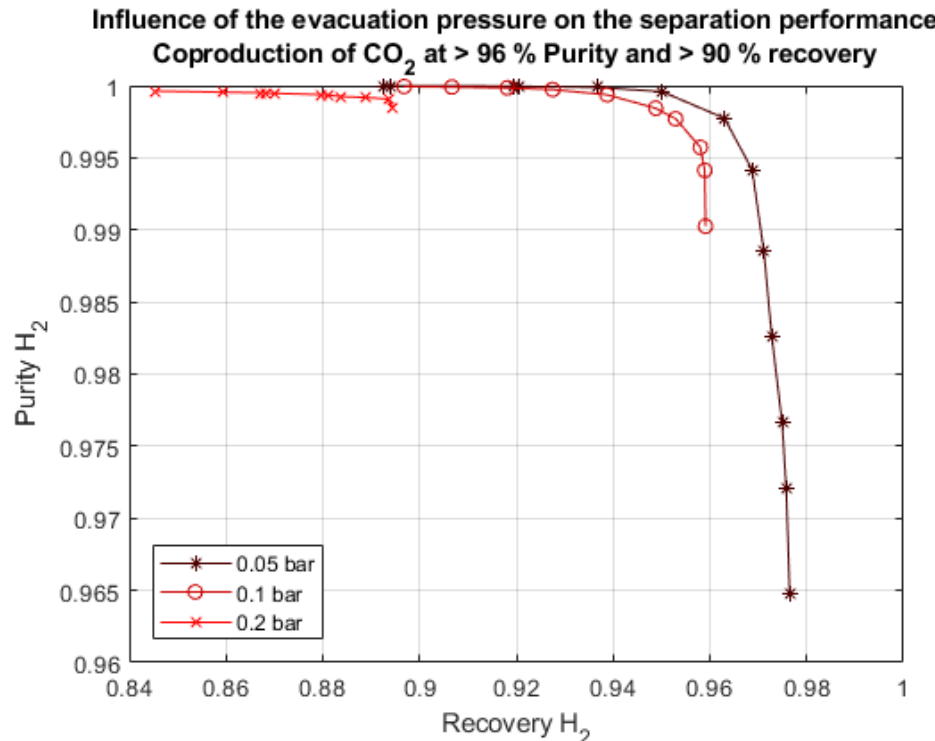
World-class research infrastructure

Description	Scale	Partner
Adsorption infrastructure (ECCSEL)	Lab-scale	ETH
Cycling adsorbent analyser	Lab-scale	ECN
Single- and multi-column reactive PSA/TSA equipment	Pre-pilot, TRL 5	ECN
Equipment for measurements of density, speed of sound and dielectric permittivity	Lab-scale	RUB
Vertical flow facility	Pilot-scale	SINTEF
Pipe and vessel depressurization (ECCSEL)	Lab-scale	SINTEF
Core-flooding laboratory	Lab-scale	ICL
Batch-reactor for mineral-dissolution kinetics	Lab-scale	ICL
Equipment for measurements of CO ₂ -brine-mineral contact angle, interfacial tension and phase behaviour	Lab-scale	ICL
Hydrothermal laboratory (ECCSEL)	Lab-scale	BGS
Geo-microbiology laboratory (ECCSEL)	Lab-scale	BGS
Rock deformation laboratory (ECCSEL)	Lab-scale	SCCER
Micro-seismic monitoring arrays	Lab-scale	SCCER
Mt. Terri research rock laboratory (EPOS)	Pilot-scale	SCCER

H₂ supply chain and H₂-CO₂ separation

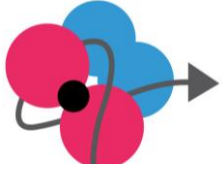


- Optimized VPSA cycles developed for SMR syngas (ETH – presented at GHGT-14)



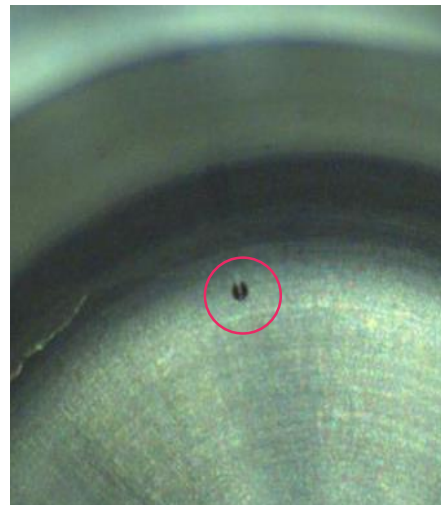
- Coproduction of high purity H₂ and CO₂ within a single VPSA cycle is possible
- Hydrogen purities > 99.97 % can be reached → PEM fuel cell purity
- Decreasing the evacuation pressure increases the separation performance
- Best energy consumption falls within range of MDEA energy consumption

CO₂ transport, injection and storage

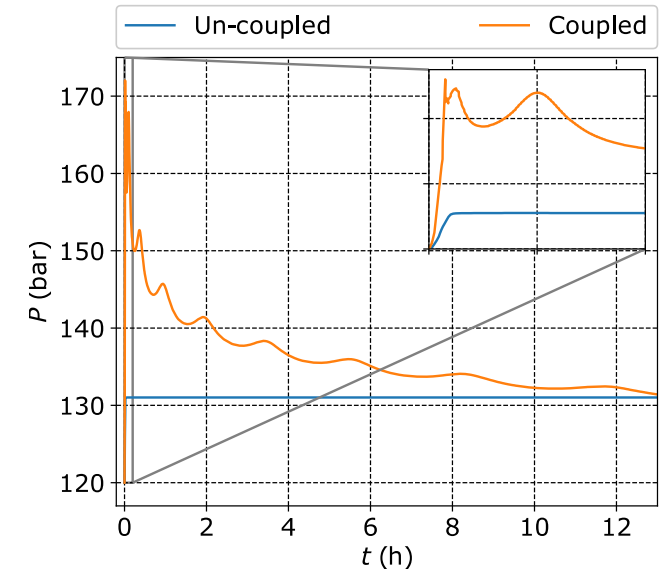


- Construction and assembly completed for the apparatus to be used in the study of gas solubility in brines at high pressures – initial testing started (ICL – below)
- Combination of seawater EOS (Feistel) with Helmholtz EOS (EOS-CG) in progress (RUB – bottom right)
- First version of coupled well-reservoir (near-well) model is running – presented at GHGT-14 (SINTEF – far right)

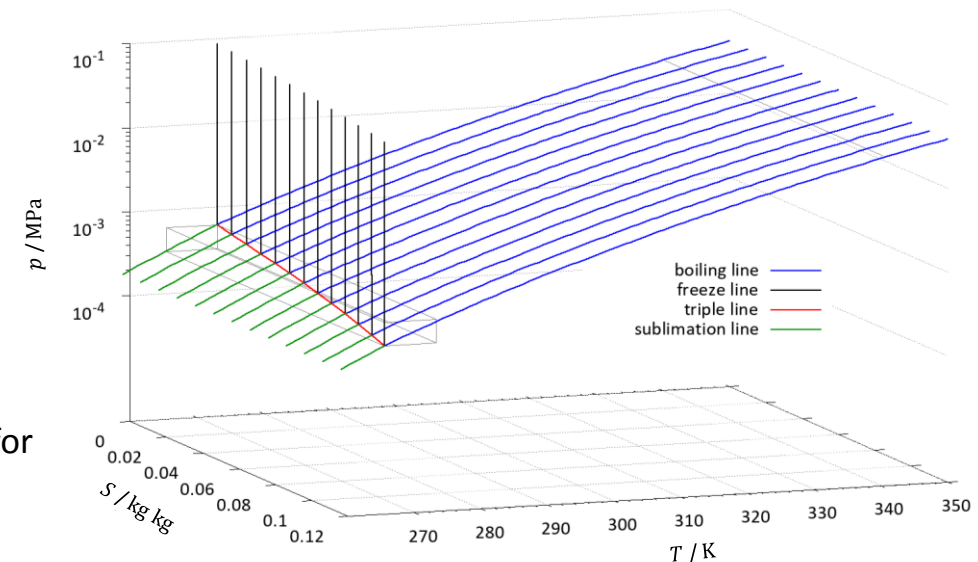
Small gas bubble on the point of dissolution.



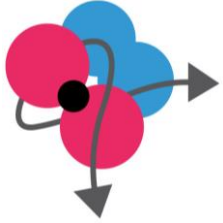
Bottom-hole pressure in CO₂ injection well: The inclusion of a near-well model significantly impacts pressure dynamics.



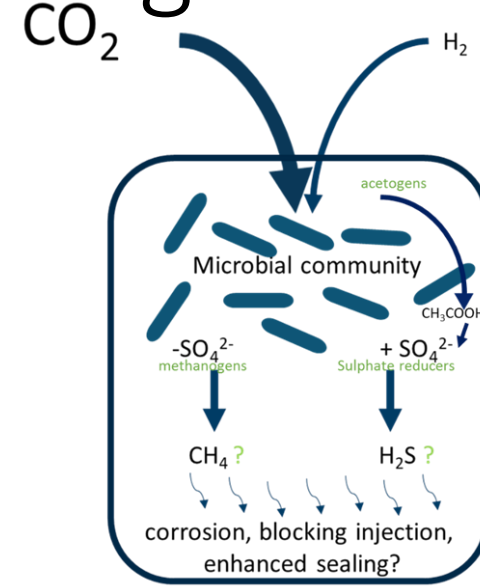
PT diagram for different salinities.



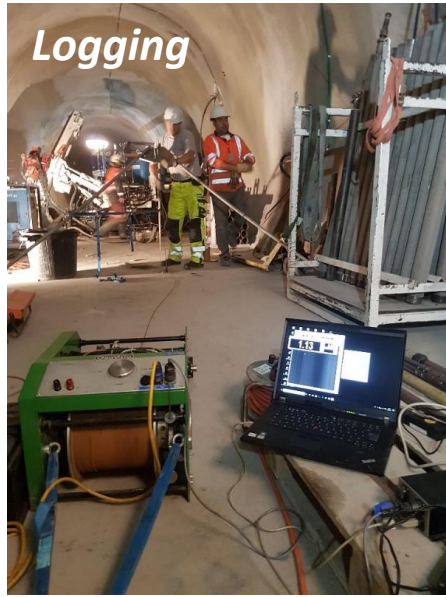
CO₂ transport, injection and storage



- Literature reviews completed and construction and operation of experimental geomicrobiological apparatus in progress (BGS, right)
- Petrophysical characterisation of rock samples from three boreholes of the Mont Terri field site (D2.3.2), focusing on sorption properties (ICL, below right)
- Five of seven boreholes completed at Mt Terri. CO₂ injection expected to start in November (SCCER, below)



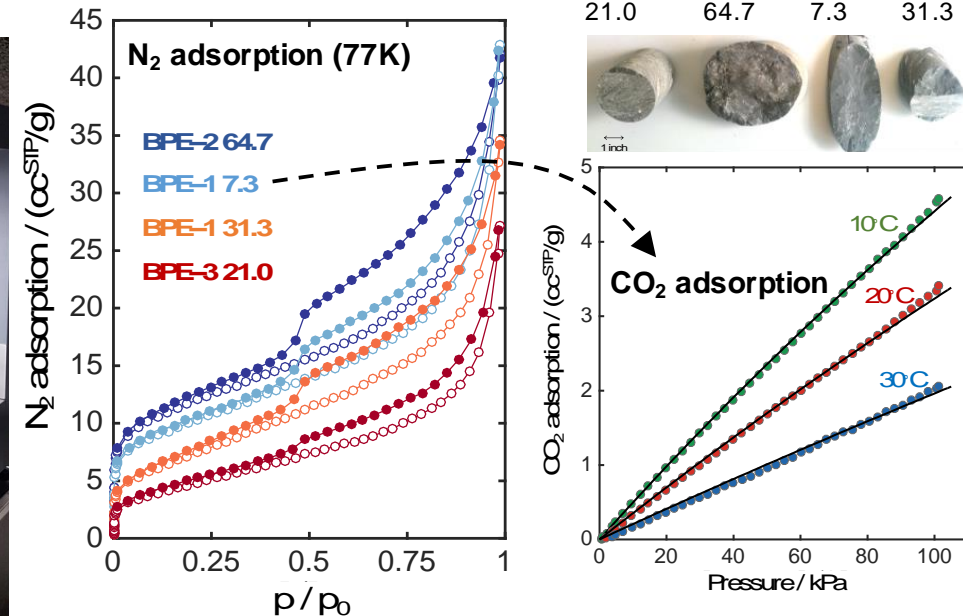
Drilling



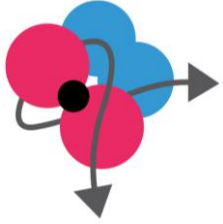
Logging



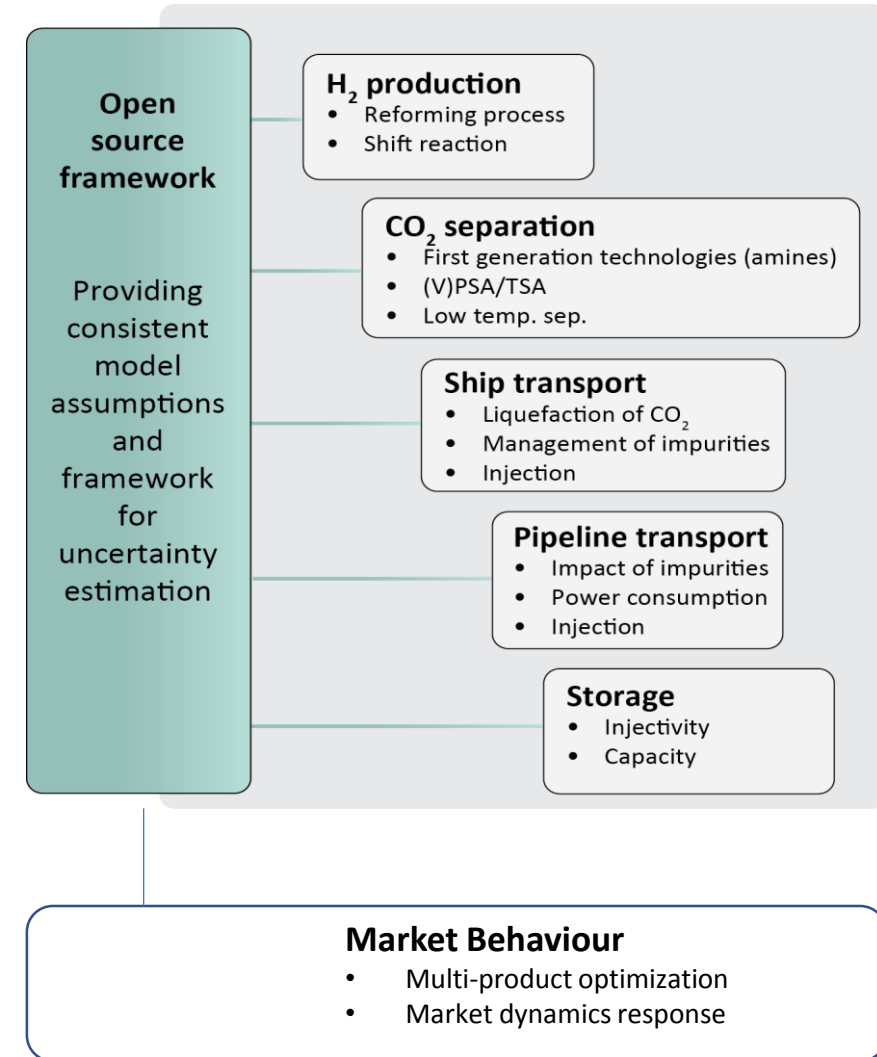
Core scan



H₂-CCS chain tool and evaluation methodologies for integrated chains



- Open-source framework
 - More widespread use
 - More dynamic
- 'Open' or 'closed' modules
- Stationary-design mode
- Dynamic-operation mode
- Multi-scale models for the chain components

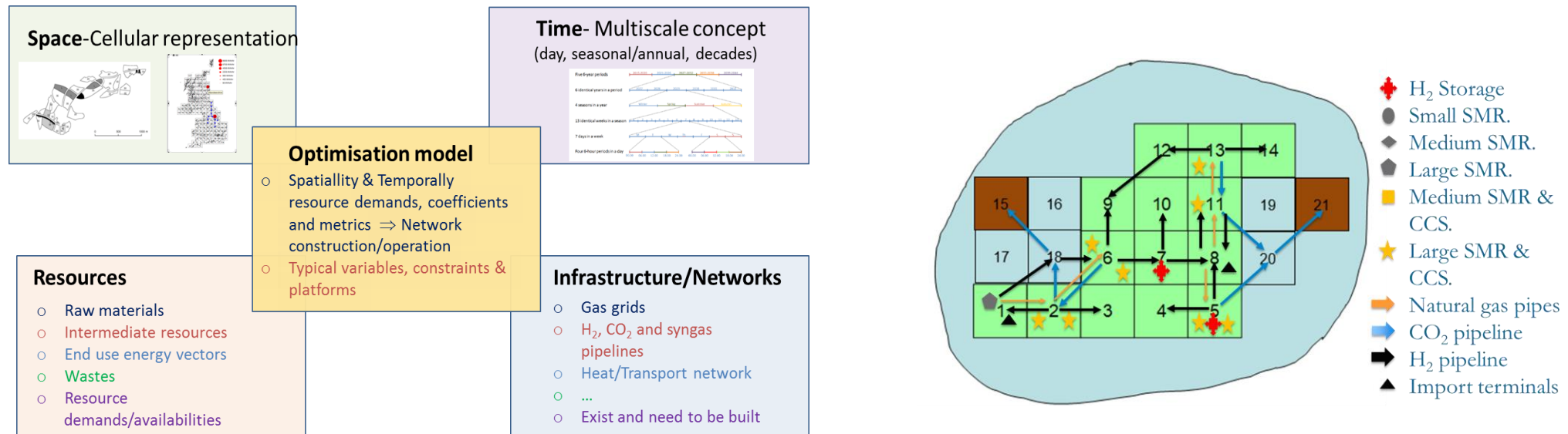


H₂-CCS chain tool

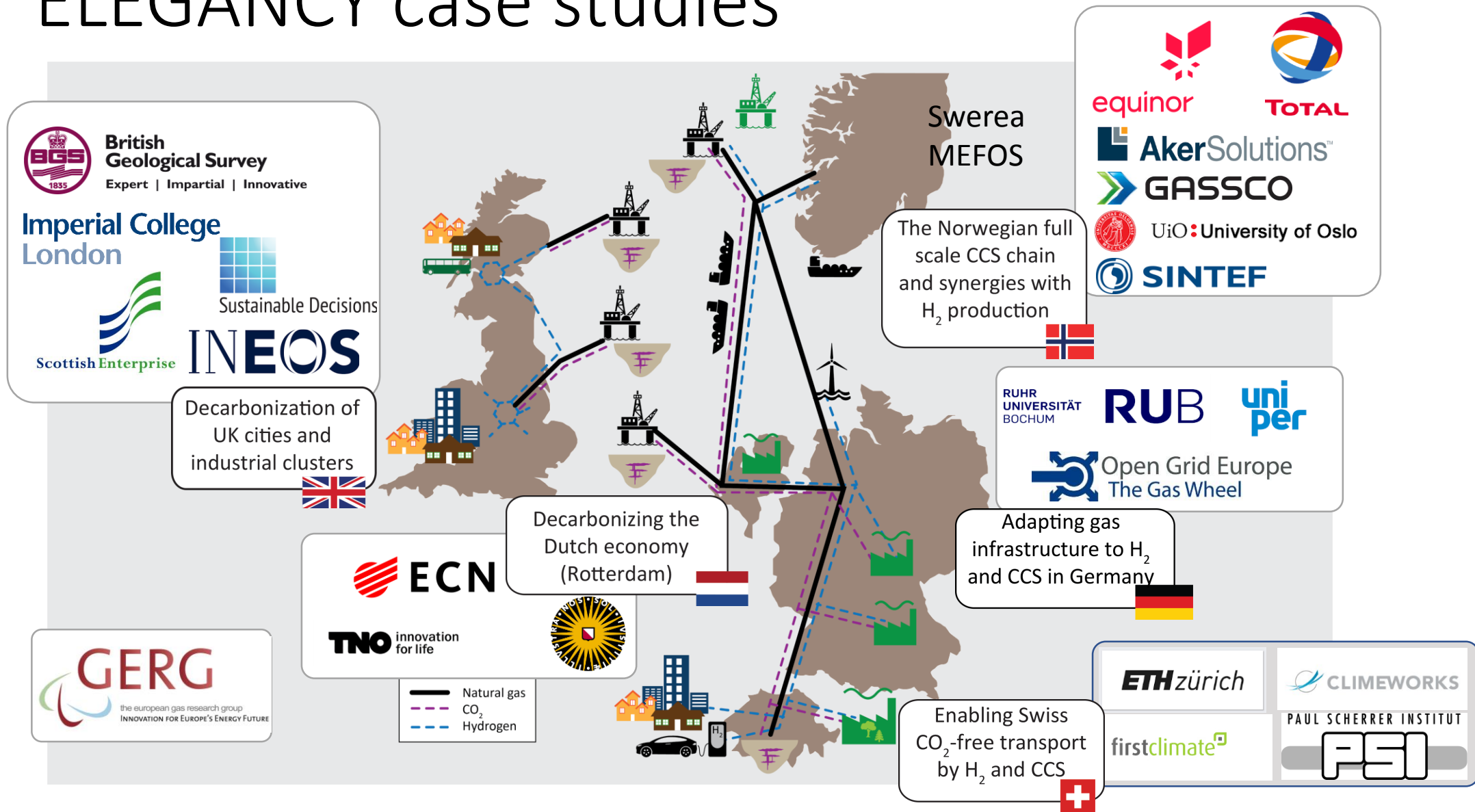
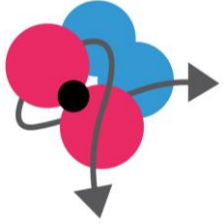
Design mode:

- Able to represent “real world” scenarios using past data.
- Capable of designing infrastructure for all key resources, whilst ensuring that CO₂ emissions are constrained as the total cost of the network is minimized.
- The model incorporates geographical input data relating to H₂ demands, geological storage volumes, natural gas infrastructure, to be used in the optimization.

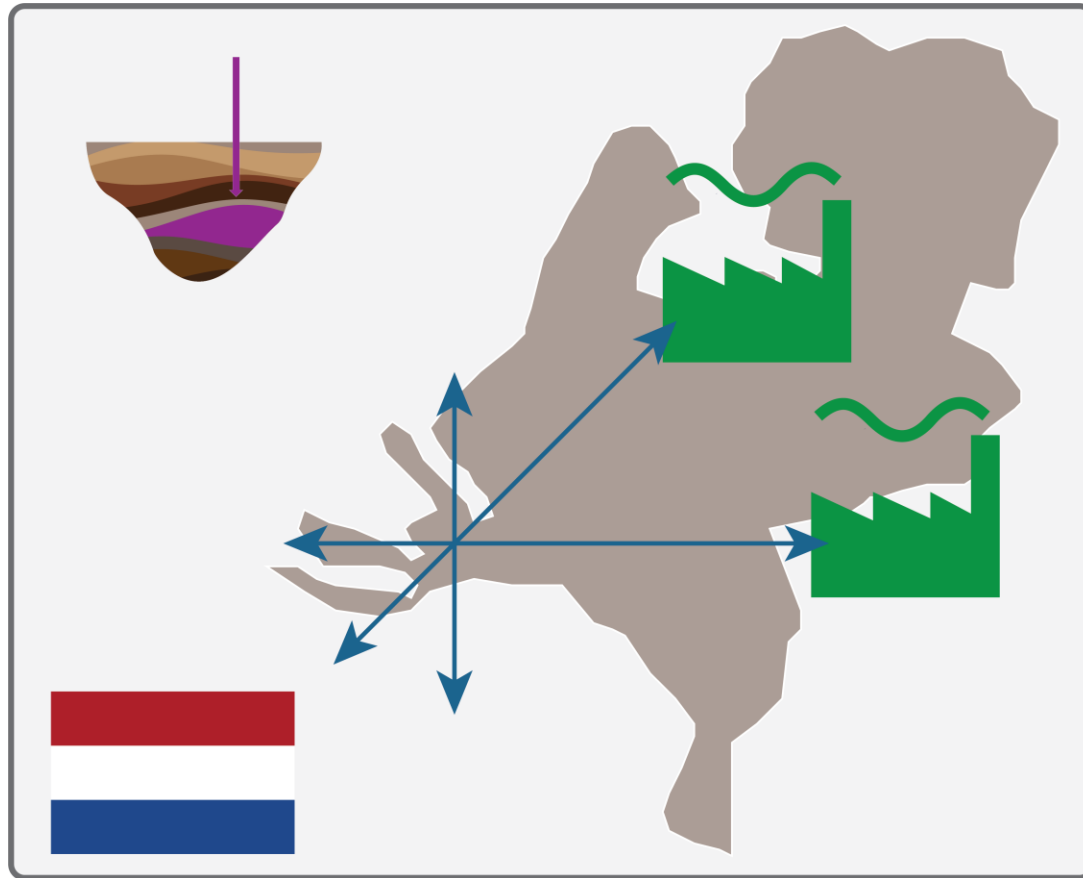
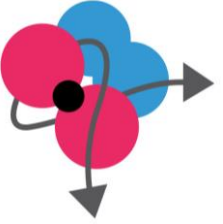
Resource Technology Framework:



ELEGANCY case studies



Decarbonizing the Dutch economy



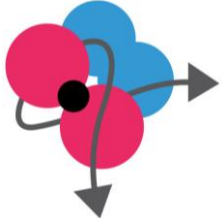
Assesses significant decarbonization of the Rotterdam industry through:

- Introduction of clean H₂ as raw material and energy carrier for its base industries and utilities,
- CO₂ capture at large single point emitters, CO₂ offshore storage and CO₂ utilization.

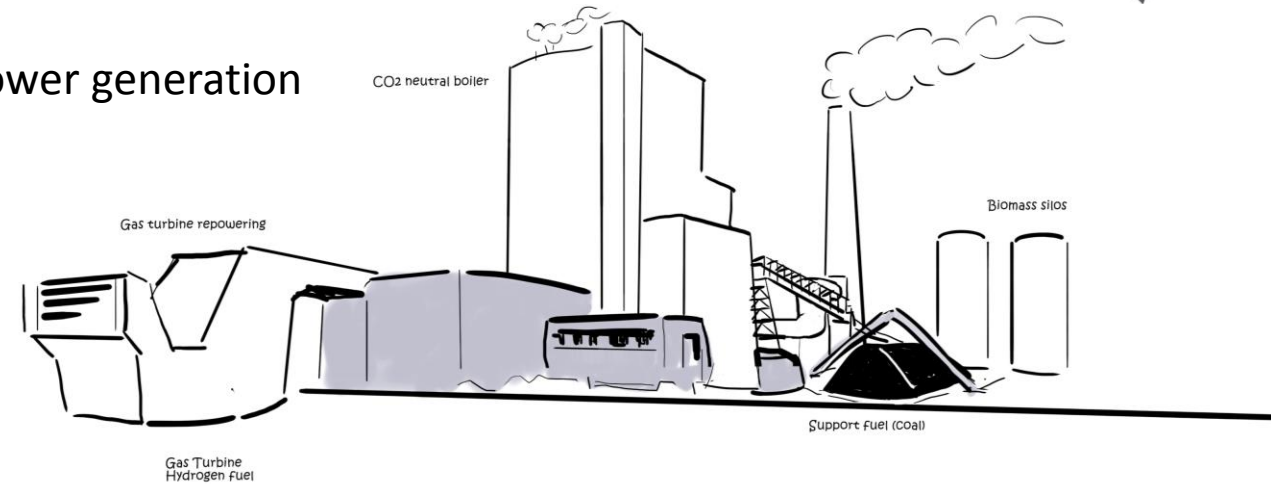
Highlights

- The industrial platform to develop the Roadmap for H₂ and CCS in the Rotterdam port is established:
 - H-vision (pre-pilot study)
 - 12 Industrial partners
 - The two main applications

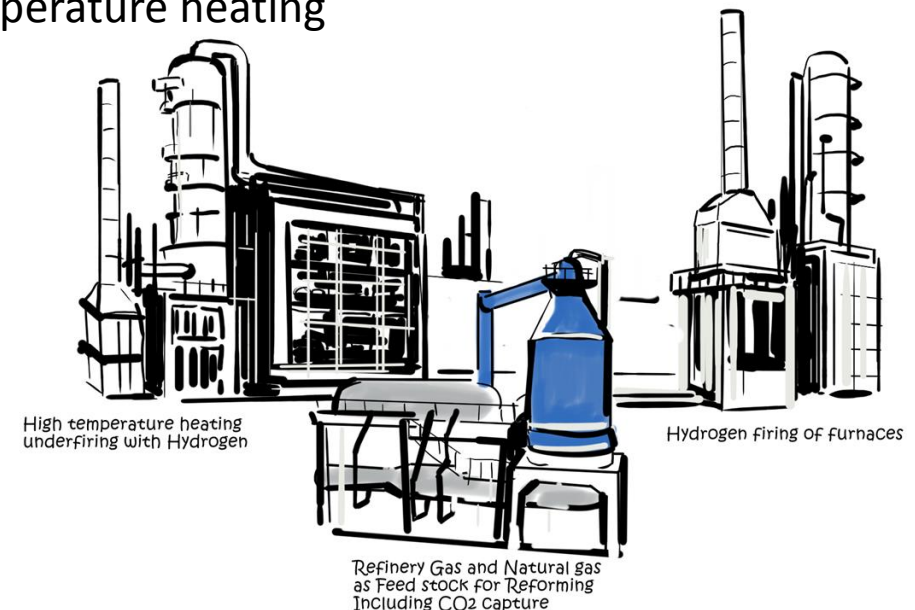
Decarbonizing the
Dutch economy
(Rotterdam)



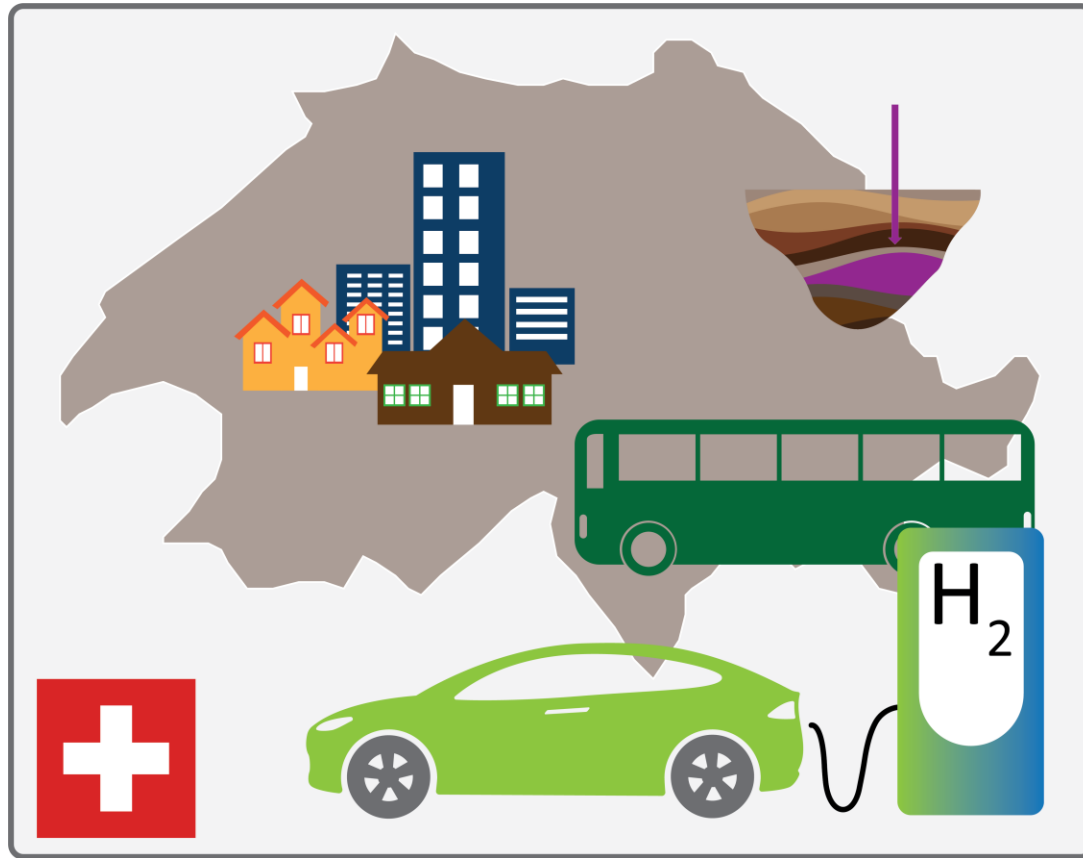
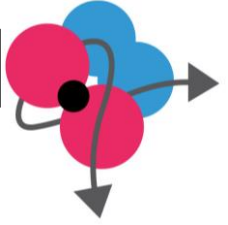
Power generation



High temperature heating



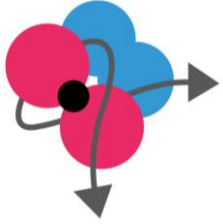
Enabling Swiss CO₂ –free transport by H₂ and CCS



Explores the zero-carbon supply chain of H₂ for road transport decarbonization and accelerates the Swiss roadmap for the geological sequestration of CO₂

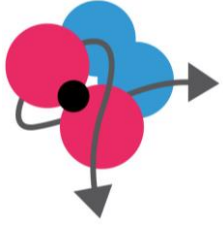
Highlights

Enabling Swiss
CO₂-free transport
by H₂ and CCS



- Optimization of distributed hydrogen production for transport sector:
 - Refined LCA framework for H₂-based transportation in Switzerland and inclusion of H₂-technologies in Swiss TIMES Energy Systems Model (STEM)
- Acceleration of the Swiss roadmap for storage of CO₂:
 - Stakeholder workshop on site selection and risk assessment for geological CO₂ storage in Switzerland arranged in September 2018
- Carbon negative technology advancement:
 - Climeworks' demonstrator for direct air capture for storage applications designed, built and commissioned.

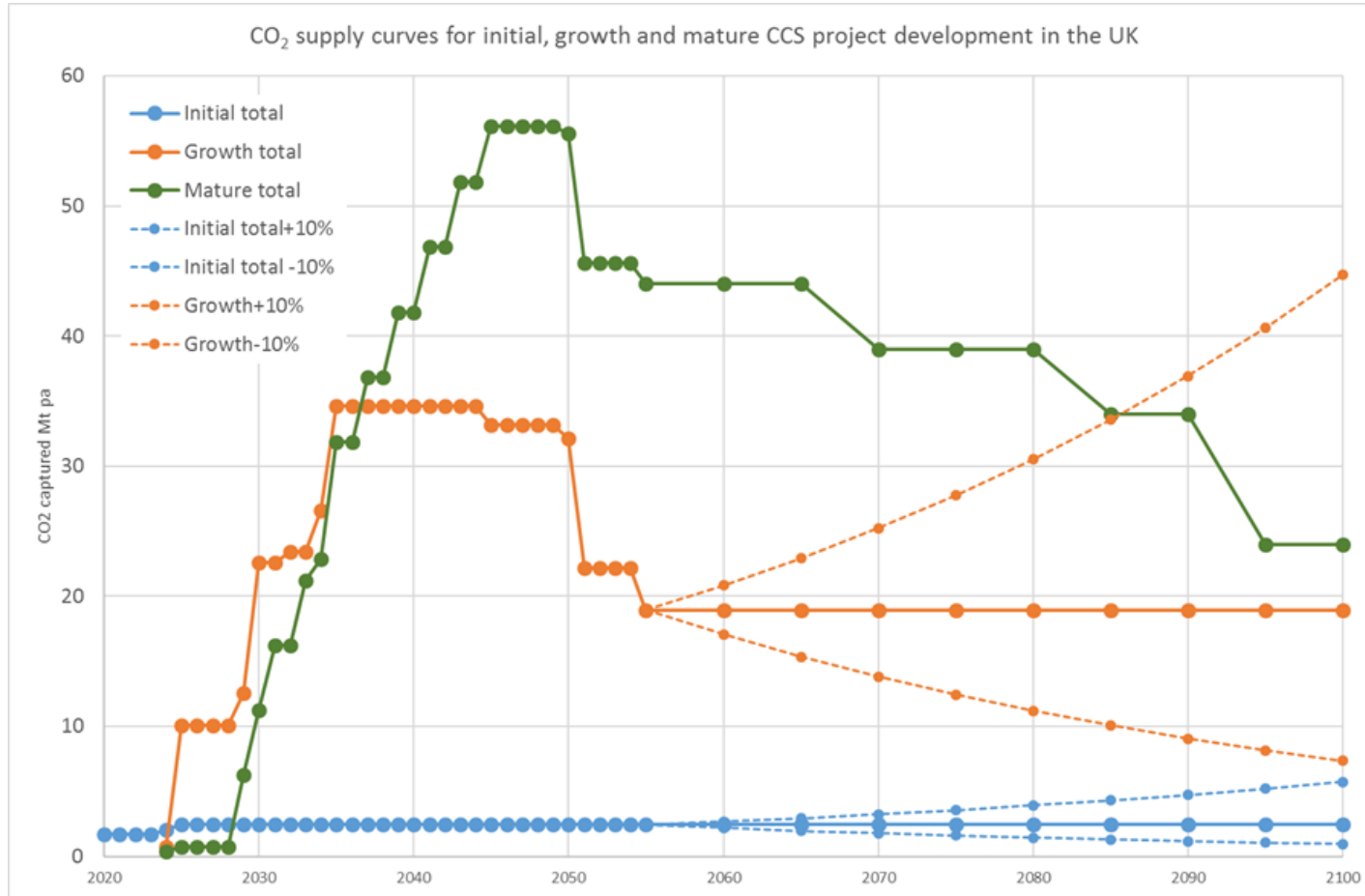
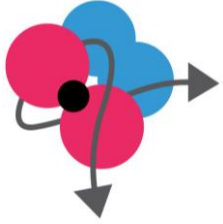
Decarbonization of UK cities and industrial clusters



Supports the H21 Roadmap project, for large-scale deployment of H₂-CCS through the wider application of the H21 Leeds City Gate findings to many UK cities

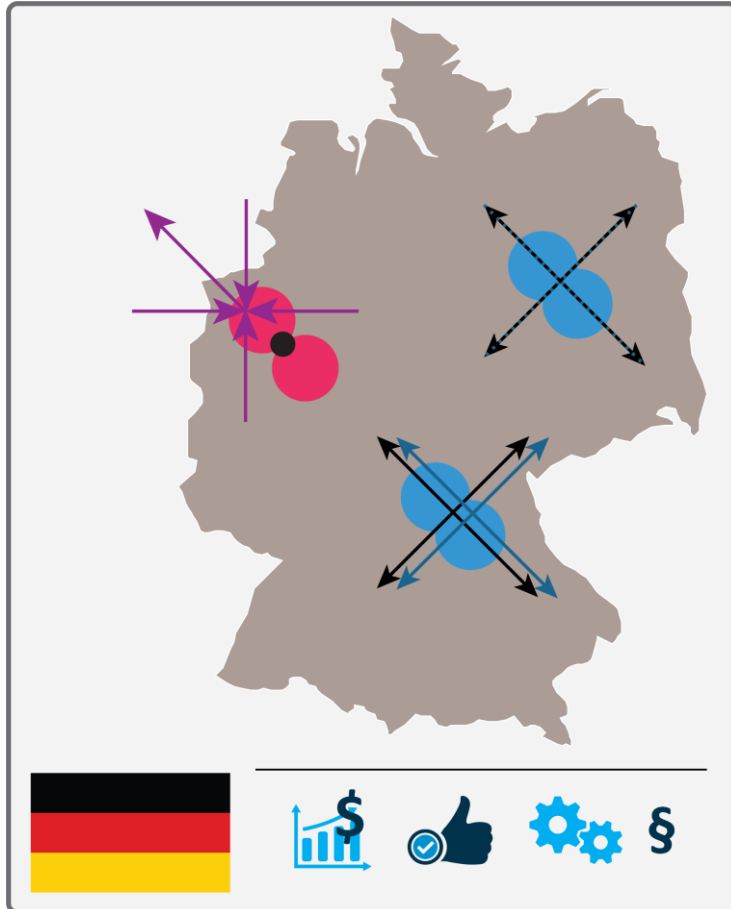
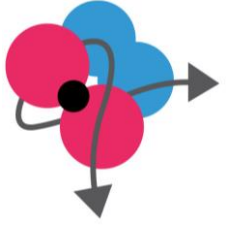
Highlights

Decarbonization of
UK cities and
industrial clusters



- Joint work between ELEGANCY and ALIGN-CCUS
- Analysis of the regional and national requirements for CO₂ storage from H₂ and CCS and low-carbon industrial growth with CCS
- The supply curves will be used to evaluate
 - Injectivity and stability owing to variable rate of supply (ELEGANCY)
 - CO₂ storage options to meet variations in demand (ALIGN-CCUS)

Adapting gas infrastructure to H₂ and CCS in Germany

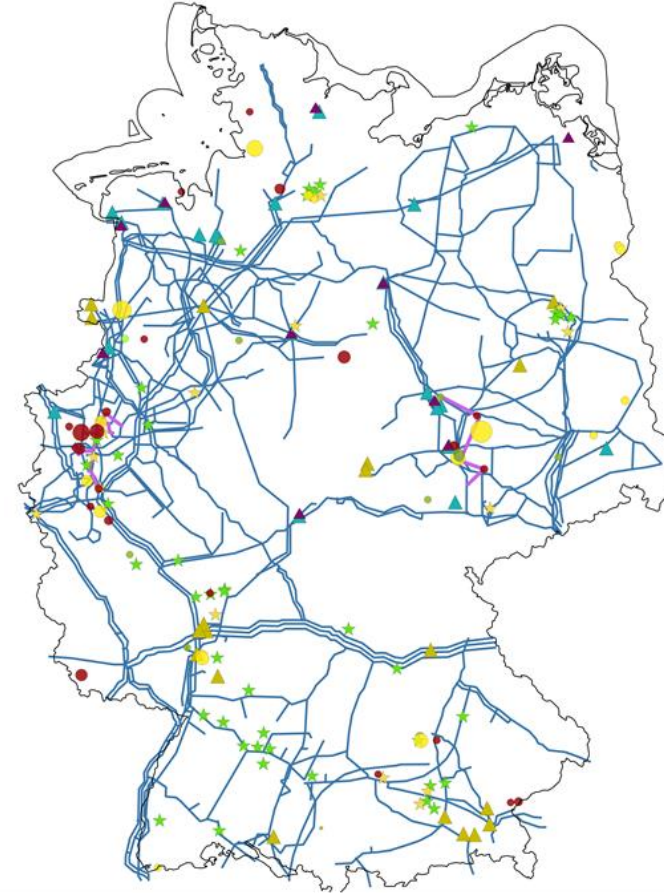
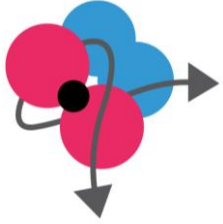


Enables the accelerated (partial) decarbonization of gas infrastructure through H₂-CCS chains, and paves the road to introduction of increasing amounts of renewably generated H₂ by establishing an infrastructure adapted to large amounts of H₂

Highlights

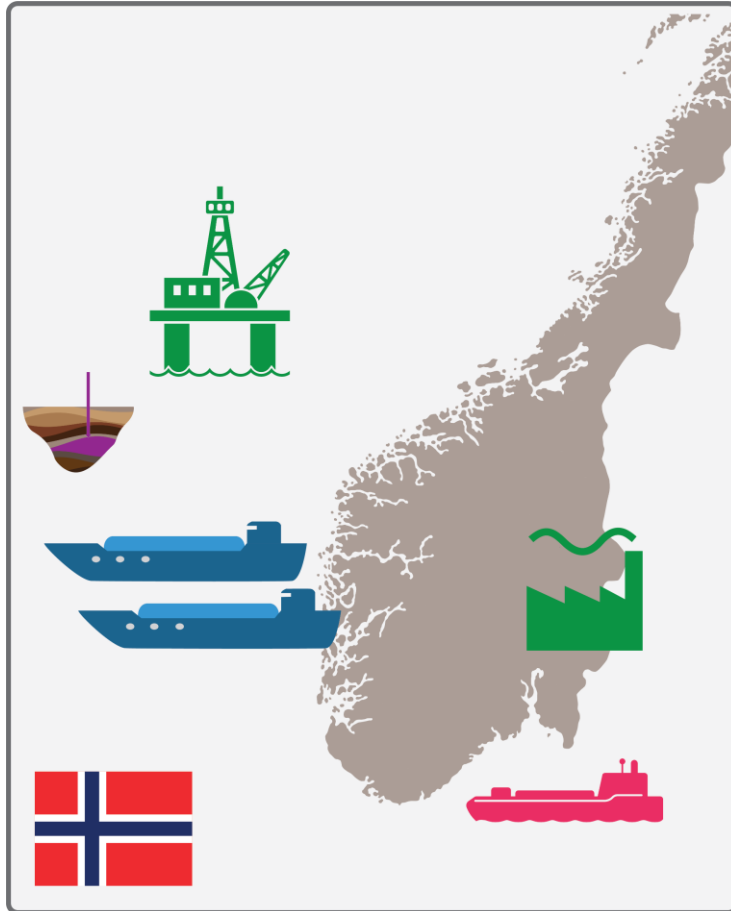
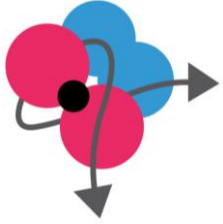
- Technical: GIS Tool is progressing well, data collection for CO₂ part is nearly finished.
- Legal: Analysis of applicable law to H₂ pipelines almost completed; first policy recommendations.
- Social: First results of stakeholder perspectives (stakeholder interviews) concerning the case study options and their acceptance.
- Macroeconomics: Scenario development in progress: step 1/4 completed.

Adapting gas
infrastructure to H₂
and CCS in Germany



H₂ Admixture GIS Project

The Norwegian full scale CCS chain and synergies with H₂ production



Evaluates the benefit of converting Norway's large natural gas resources to H₂ with CCS to satisfy the expected growth in worldwide demand of H₂ as an energy carrier.

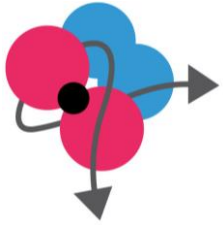
Mitigates emissions in off-shore platforms, the transport and industrial sectors.

Studies the possible synergies with the Norwegian full-scale CCS project.

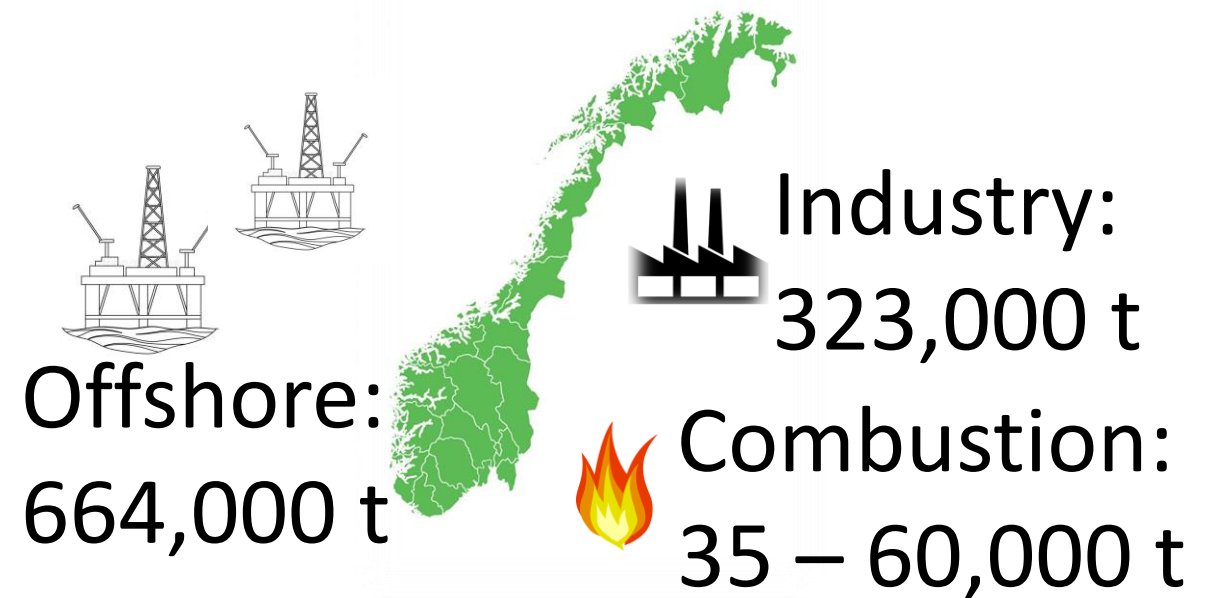
Highlights

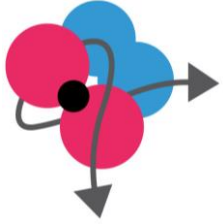
- Analysis of the potential for H₂ utilization in Norway performed
- H₂ utilization in the following sectors analyzed:
 - Transportation: land and sea
 - Industry: H₂ as fuel for high temperature heat supply, reducing agent in metal industry
 - Power: H₂ as fuel for gas turbines for offshore applications

The Norwegian full scale CCS chain and synergies with H₂ production



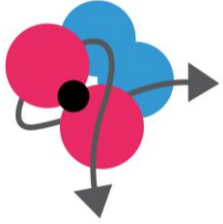
Hydrogen utilization potential in Norway - 2030





Internal collaboration

- At and between the various levels; researcher / task / WP / project
- Using the most efficient communication; phone / e-mail / skype / physical meeting

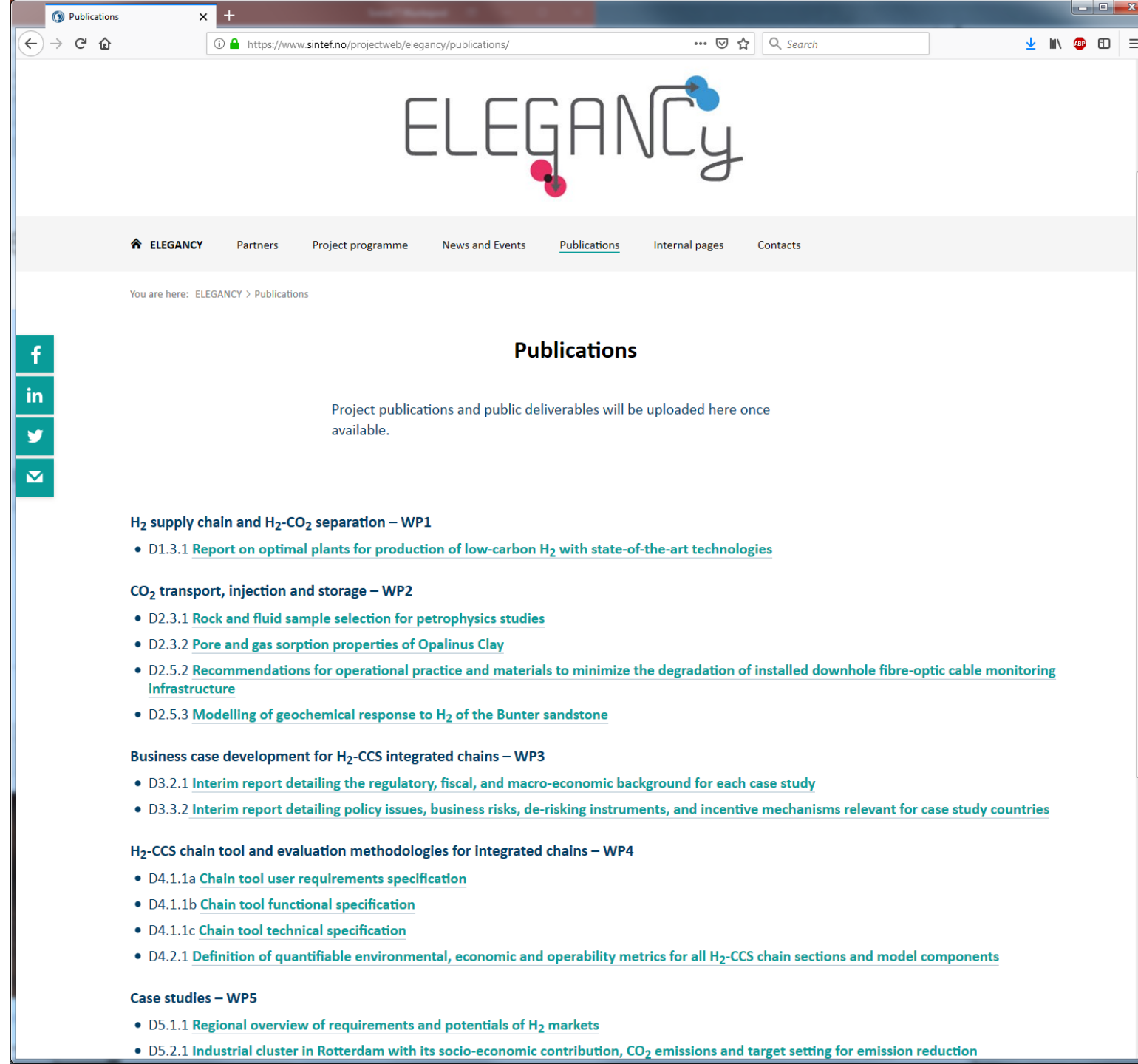


Collaboration with other ACT projects

- ALIGN-CCUS
 - Regular contact, particularly in the Netherlands and the UK
 - Work programmes designed to be complementary
- DETECT
 - Dialogue regarding Mt Terri experiments and modelling
- ALIGN-CCUS/ACORN/ELEGANCY/ECOBASE
 - Social science teleconference

Web page

- Deliverables



Web page

- News

The screenshot shows a web browser displaying the 'News and Events' page of the ELEGANCY project. The browser's address bar shows the URL <https://www.sintef.no/projectweb/elegancy/news/>. The page features a navigation bar with links to 'ELEGANCY', 'Partners', 'Project programme', 'News and Events' (which is highlighted), 'Publications', 'Internal pages', and 'Contacts'. Below the navigation bar, a breadcrumb trail indicates 'You are here: ELEGANCY > News and Events'. On the left side, there is a vertical stack of social media icons for Facebook, LinkedIn, Twitter, and Email. The main content area is titled 'News and Events' and 'ELEGANCY news'. It displays three news items in a grid. The first item is titled 'ELEGANCY researcher, Marco Mazzotti, chairs Gordon Research Conference on CCUS' and is dated '23 October 2018'. The second item is titled 'Updates from the Mont Terri experiment: Studying Caprock and Fault Sealing Integrity' and is dated '17 October 2018'. The third item is titled 'Joint workshop on CCS risk and liability sharing' and is dated '25 September 2018'. At the bottom right, there is a link to 'Read previous ELEGANCY news items >'. The footer of the page shows the URL <https://blog.sintef.com/sintefenergy/ccs-risk-liability-sharing/>.

News and Events

ELEGANCY news

ELEGANCY researcher, Marco Mazzotti, chairs Gordon Research Conference on CCUS

23 October 2018

The Gordon Research Conference (GRC) series are known for their high quality research presentations and the outstanding networking opportunities for representatives from science...

Updates from the Mont Terri experiment: Studying Caprock and Fault Sealing Integrity

17 October 2018

The geological storage of CO₂ is an essential component for enabling the efficient generation of emission-free hydrogen (H₂) as a transport fuel. The...

Joint workshop on CCS risk and liability sharing

25 September 2018

On 18 September 2018, Work Package 3 (WP3) of the ELEGANCY-project held a joint workshop on CCS risk and liability sharing in Brussels, Belgium,...

[Read previous ELEGANCY news items >](#)

<https://blog.sintef.com/sintefenergy/ccs-risk-liability-sharing/>

Web page

- News/blog

The screenshot displays the SINTEFblog website. The browser's address bar shows the URL <https://blog.sintef.com/sintefenergy/updates-mont-terri-experiment/>. The page features a dark blue header with the SINTEF logo and the title "#SINTEFblog". Below the header, a navigation bar lists various categories: #ENERGY, #BUILDING, #OCEAN, #DIGITAL, #HEALTH, #SOCIETY, and #INDUSTRY. The main content area is titled "Updates from the Mont Terri experiment: Studying Caprock and Fault Sealing Integrity" and is categorized under #ENERGY and GAS TECHNOLOGY. The article is attributed to "BY SINTEF" and dated "OCTOBER 17, 2018". The text discusses the geological storage of CO₂ as a component for enabling the efficient generation of emission-free hydrogen (H₂) as a transport fuel. It mentions that the large volumes of CO₂ produced in the natural gas reforming H₂ manufacture require a coupling with direct CO₂ separation techniques, and safe geological storage. A section titled "Guest authors:" lists five contributors: Alba Zappone (Swiss Seismological Service & Department of Mechanical Engineering, ETH Zurich, Switzerland), Michèle Marti (Swiss Seismological Service, ETH Zurich, Switzerland), Melchior Grab (Department of Earth Sciences, ETH Zurich), Quinn Wenning (Department of Earth Sciences, ETH Zurich), and The SCCER-SoE team. The article continues with a paragraph stating that for the latter it is important to guarantee both quality and security of storage, for example ensuring adequate injection rate, long term containment, and robust monitoring tools. The experimental approach plays an essential role, both at laboratory and at pilot test scale. The first scale provides input parameters for numerical simulations on the behavior of CO₂ and hosting rocks at depth; the second validates modeling, and proves the technology at a scale that is small enough to be safe for experimental testing, but large enough to be significant. A key challenge for geological storage is played by the integrity of the caprock. Within ELEGANCY, this challenge is addressed by executing a decameter-scale experiment at the Mont Terri Underground Rock Laboratory (URL) in Switzerland. The pilot scale experiment will provide intact samples for laboratory tests both on the fault and on the host rock. The article concludes with the sentence "The Mont Terri experiment enters its operational phase". On the right side of the page, there is a search bar and a section titled "Subscribe to Newsletter" with a list of newsletters to subscribe to, including SINTEF Energi - Nyhetsbrev, Brukermøte Produksjonsplanlegging - Nyhetsbrev, SINTEF Energy Research - Newsletter, Bioenergy Innovation Award - Newsletter, CEMCAP - Newsletter, GAFT - Gasification And FT-Synthesis Of Lignocellulosic Feedstocks - Newsletter, GATEWAY - Newsletter, HighEFF - Newsletter, Hydro Power Scheduling Workshop - Newsletter, and NCCS - Newsletter.

Updates from the Mont Terri experiment: Studying Caprock and Fault Sealing Integrity

BY SINTEF
OCTOBER 17, 2018

COMMENTS

The geological storage of CO₂ is an essential component for enabling the efficient generation of emission-free hydrogen (H₂) as a transport fuel. The large volumes of CO₂ produced in the natural gas reforming H₂ manufacture require a coupling with direct CO₂ separation techniques, and safe geological storage.

Guest authors:

- Alba Zappone (Swiss Seismological Service & Department of Mechanical Engineering, ETH Zurich, Switzerland)
- Michèle Marti (Swiss Seismological Service, ETH Zurich, Switzerland)
- Melchior Grab (Department of Earth Sciences, ETH Zurich)
- Quinn Wenning (Department of Earth Sciences, ETH Zurich)
- The SCCER-SoE team

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A key challenge for geological storage is played by the integrity of the caprock. Within [ELEGANCY](#), this challenge is addressed by executing a decameter-scale experiment at the Mont Terri Underground Rock Laboratory (URL) in Switzerland. The pilot scale experiment will provide intact samples for laboratory tests both on the fault and on the host rock.

The Mont Terri experiment enters its operational phase

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SEARCH

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Twitter

ELEGANCY
@ELEGANCY_ACT

ELEGANCY - an ACT funded project aiming at fast decarbonization of Europe's energy system through hydrogen production combined with capture and storage of CO₂

Joined October 2018

9 Photos and videos

Tweets **Tweets & replies** **Media**

ELEGANCY @ELEGANCY_ACT · Nov 9
Jorgo Chatzimarkakis, @H2Europe : «Green hydrogen» is good, but the technological development is too slow to use it in decarbonizing Europe's energy system. To do that we need hydrogen with CCS.

ELEGANCY @ELEGANCY_ACT · Nov 8
The ELEGANCY Conference is over. Blogs and videos will follow, stay tuned! Great presentations on the project and results from its first year of operation and interesting perspectives and insight from external stakeholders. #H2CCS @Equinor @Total @Gassnova @SINTEF

ELEGANCY @ELEGANCY_ACT · Nov 8
Anne Obermann from @ETH explaining how they research sealing integrity and CO₂ storage capacity in the Mont Terri Laboratory, using the mountain's day formations. Very interesting presentation, we can't wait to see more results! @SINTEFenergy @Equinor @Total @Gassnova

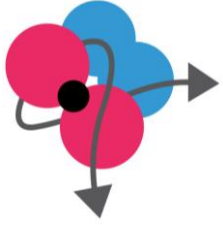
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- #4Corners 5,387 Tweets
- #BuenLunes 3,227 Tweets
- エレちゃん 18.6K Tweets
- Manuel Marchena 5,342 Tweets
- Milne 3,219 Tweets
- Guthrie 1,944 Tweets
- Jennie Kim 17.1K Tweets

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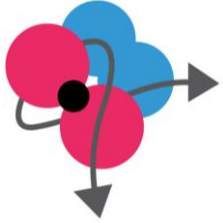


Outreach

- Tekna CO₂ Conference, Oslo, January 2018
- ZEP Network Technology meeting, Brussels, February 2018
- CSLF Meeting, Venice, April 2018
- Joint workshop on CCS risk and liability sharing, Brussels, September 2018
- ELEGANCY event, GHGT-14, Melbourne, October 2018
- CCUS Summit, Edinburgh, November 2018

ELEGANCY Conference

Brussels, 8 November 2018 – pictures & videos upcoming on Twitter and homepage

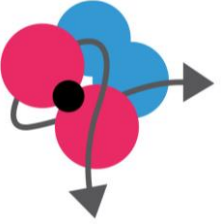


09:00	Registration
09:30	<ul style="list-style-type: none"><i>Welcome, HSE and introduction</i> Nils A. Røkke, SINTEF/EERA
09:50	<ul style="list-style-type: none"><i>ELEGANCY overview</i> Svend T. Munkejord, SINTEF<i>Low carbon solutions</i> Steinar Eikaas, Equinor
10:40	Coffee break & Poster session
11:00	<ul style="list-style-type: none"><i>H21</i> Dan Sadler, Northern Gas Networks<i>ELEGANCY case studies</i> Gunhild A. Reigstad, SINTEF<i>Climate effects of various CCU and CCS measures</i> Ana Serdoner, Bellona
12:30	Lunch

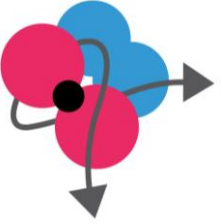
13:30	<ul style="list-style-type: none"><i>H2@Scale</i> Bryan Pivovar, National Renewable Energy Laboratory<i>Laboratory studies to understand the controls on flow and transport for subsurface CO₂ storage</i> Ronny Pini, Imperial College London Anne Obermann, ETH Zürich
14:30	Coffee break & Poster session
15:00	<ul style="list-style-type: none"><i>Accelerating the energy transition – EU perspective</i> Vassilios Kougionas, European Commission<i>Economic and legal barriers and opportunities</i> Catherine Banet, University of Oslo<i>Blue hydrogen: The future role of decarbonised gases in Europe</i> Jorgo Chatzimarkakis, Hydrogen Europe
16:30	End of session
19:30	Dinner at Conference Hotel Restaurant

ELEGANCY consortium meeting

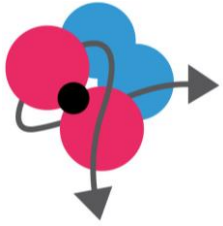
GERG headquarters,
Brussels, 9 November 2018



Conclusion



- ELEGANCY aims to fast-track Europe's energy system by combining CCS and H₂
 - By overcoming specific scientific, technological and economic/legal barriers
 - By undertaking five national case studies adapted to the conditions in the partner countries.



Acknowledgement

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<http://www.elegancy.no/>