



European Carbon Dioxide Capture and Storage Laboratory Infrastructure
European Research Infrastructure Consortium

ECCSEL ERIC
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2017

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DIRECTOR'S HIGHLIGHTS OF 2017

The European Carbon Dioxide Capture and Storage Laboratory Infrastructure, ECCSEL, has been included on the official European Strategy Forum for Research Infrastructures (ESFRI) Roadmap since 2008.

2017 turned out to be a successful year for ECCSEL, resulting in several major achievements.

Funded by European and national grants since 2011 throughout its preparatory phase, ECCSEL's application for becoming a permanent legal entity, a European Research Infrastructure Consortium (ERIC), was approved by the European Commission in June 2017 (Commission implementing decision (EU) 2017/996 of 9. June 2017).

Thereafter, ECCSEL ERIC with its statutory seat in Trondheim, Norway, was officially registered in the Norwegian and European Register of Businesses.

At the first General Assembly 12th June 2017, the five founding members of ECCSEL ERIC, Norway (host), Italy, United Kingdom, the Netherlands and France agreed on the operational plan, budget and activity plans for five years with corresponding funding commitments.

Overlapping the Horizon 2020 Infradev-3 Implementation Phase project until September 2017, the ECCSEL ERIC organisational structure was initially set up with resources from the partner institutions in addition to national node representatives and advisory boards/committees.

Then, with the management system, administrative procedures as well as internal and external contracts/agreements in place, the day-to-day operations as an ERIC could begin.

Consisting of 56 existing world-class research facilities from Universities, Research Institutes and Industry in the five ECCSEL ERIC member countries, the Consortium provides researchers across the globe open (trans)national access to all those facilities through its website, www.eccsel.org.

Throughout 2017 the ECCSEL facilities were increasingly accessed by different users, ranging from single students to groups of researchers from larger joint research projects. One of the Key Performance Indicators of ECCSEL, is the number of actual users.

Based on a "living" gap analysis and input from the industry and scientific CCS community, a strategy roadmap was prepared followed by a research infrastructure development plan. By 2017 investments in upgrades of ECCSEL facilities already exceeded around 100 million EURO, whilst another 100 million is planned to be invested into the research infrastructure by 2030.



Sverre Quale, Director, ECCSEL ERIC
Photo: Vibeke Ann Pettersen, NTNU

In 2017 initiatives were taken and plans made for further expansion of ECCSEL ERIC with additional members or collaborating partners, including both potential European and overseas states.

By the end of 2017 it was decided to apply for Horizon 2018 - 2020 INFRADEV-3 grants, 1st call being announced in December 2017.

ECCSEL ERIC has been involved in and promoted through numerous publications and events throughout 2017, resulting in increased interest and publicity.

Sverre Quale
Director
ECCSEL ERIC



ECCSEL ERIC inauguration, Trondheim June 12th 2017

From the left: Wolfgang Burtscher, Deputy Director-General of the European Commission's Directorate-General for Research & Innovation, Ingvil Smines Tybring-Gjedde, State Secretary in the Ministry of Petroleum and Energy, Sverre Quale, ECCSEL ERIC director.

Photo: Thor Nielsen/NTNU

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OUR MISSION

ECCSEL vision:

Enabling low to zero CO₂ emissions from industry and power generation to combat climate change.

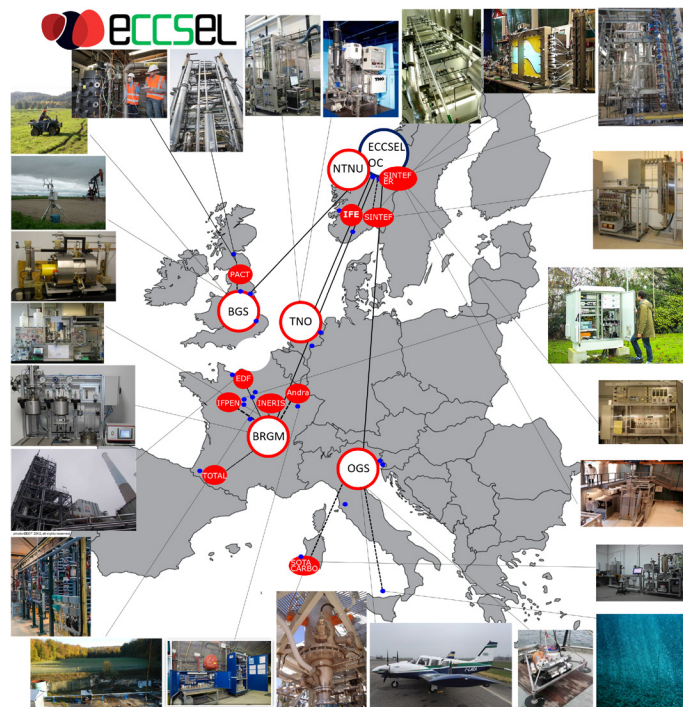
Main objectives:

- Establish and operate a world class distributed CCS Research Infrastructure in Europe
- Integrate, upgrade and construct CCS research facilities
- Enhance European science, technology development, innovation and education in the field of CCS
- Enable spin-off activities and generation of new business

RESEARCH INFRASTRUCTURE

ECCSEL has implemented, operates and develops a distributed, integrated European Research Infrastructure (RI) based on a selection of the best research facilities in Europe for Carbon Capture, Transport and Storage (CCS). The current 56 individual research facilities which are part of the ECCSEL ERIC RI are located in 5 countries and are owned by 13 different facility operators.


The number of countries, operators and facilities will be increasing over time.





ECCSEL ERIC, nodes and facility locations - Photos: Respective facility owners

OUR RESEARCH FACILITIES


The ECCSEL ERIC Research Infrastructure consists of research facilities from Universities, Research Institutes and Industry in the five ECCSEL member countries. ECCSEL ERIC provides researchers across the globe easy access to all those facilities through its website and coordinates facility upgrades and new builds.


COUNTRY	INSTITUTION	CATEGORY	SHORT NAME	LONG NAME
	EDF	Capture	Le Havre CO ₂ capture pilot	CO ₂ Capture Pilot at EDF power plant in Le Havre
	INERIS	Transport	SAFETY	CO ₂ Transport research facility and safety platform: Mont la Ville experimental site in Oise
	Andra	Storage	URL-Andra	Meuse/Haute-Marne Underground Research Laboratory
	BRGM	Storage	BIOREP	BIO-Reactor for Deep Environments. Monitoring of microbiological and geochemical processes in high pressure and dynamic conditions
	INERIS	Storage	CATLAB	CATenoy experimental site and gas-water-rock interactions LABoratory in Oise
	IFPEN	Storage	ESCORT	Equipment for soil CO ₂ origin tracking
	IFPEN	Storage	GasGeochem	Instrumentation and expertise to analyse and interpret gas geochemistry data

COUNTRY	INSTITUTION	CATEGORY	SHORT NAME	LONG NAME
	OGS	Storage	DeepLab	DeepLab Sea Floor Landers for meteoceanographic physical and geochemical data collection
		Storage	Aircraft	Research aircraft equipped with high-tech remote sensing instruments
		Storage	BioMarineLab	Ecological laboratory for mesocosm experiments
		Storage	Panarea NatLab	Panarea Natural Laboratory
		Storage	Latera NatLab	Latera Natural laboratory
		Storage	PITOP	Borehole Geophysical Test Site
		Storage	EXPLORA	Research vessel equipped with geophysical and oceanographic instruments
		Storage	OGS-CTMO	Marine metrology and calibration facility
	SOTACARBO	Capture	COHYGEN	COHYGEN (Coal to Hydrogen Generation) pilot plant with new completed upgrade: Integration of the existing COHYGEN plant with a new column for CO ₂ capture with liquid solvents
		Capture	PEC Lab	Photoelectrochemical reduction laboratory (CO ₂ recovery)
		Capture	XtL Pilot plant	Integrated system with gasification, membrane separation and syngas/CO ₂ -to-liquids
		Capture	IOSTO plant	IOSTO pilot unit for H ₂ S conversion into H ₂ SO ₄ in flue gas from oxy-combustion
		Storage	Rock Analysis Lab	Multi-stage triaxial test system for rock characterization; advanced automatic uniaxial and triaxial test laboratory (rock testing)

COUNTRY	INSTITUTION	CATEGORY	SHORT NAME	LONG NAME
	TNO	Capture	Mini Plant	Mini Plant for solvent preparation & testing
		Capture	Qscan	QSCAN solvent test street
		Capture	CLC	CLC fixed bed facility
		Capture	High-P abs&des	High pressure absorption and desorption pilot
		Storage	MobSeis	Mobile Seismic Array
		Capture	ATCM - Aerosol Test and Counter Measure	Aerosol counter measure development facility at lab scale in Delft

COUNTRY	INSTITUTION	CATEGORY	SHORT NAME	LONG NAME
	NTNU	Capture	MEML	Membrane laboratories include: <ul style="list-style-type: none"> MEM-FAB Facilities to fabricate polymer-based membranes MEM-PERM Facilities to test membrane gas permeation performance Extension of polymer membrane lab
		Capture	ABSL	Absorption laboratories include: <ul style="list-style-type: none"> ABSKIN Absorption Kinetic Studies ABSDEG Solvent degradation laboratory ABSEQ Thermodynamic studies package Extension of lab scale absorption equipment Extension of absorption pilot
	SINTEF ENERGY RESEARCH	Capture	CLC Hot Rig	Chemical Looping Combustion Rig
		Capture	COMBLAB	High pressure Oxy-Fuel Combustion Facility - HIPROX
		Capture	SEPPIL	Low temperature separation pilot - in test phase: Available for access after summer 2018
		Transport	CO ₂ Mix – VLE	Facility for accurate phase equilibrium measurements of CO ₂ -rich mixtures
		Transport	DEPRESS	Depressurization facility - in test phase from May: Available for access after summer 2018
		Transport	VISC-DENS	Viscosity and density apparatus: Test phase in autumn 2018; in operation late 2018
	SINTEF Industry	Capture	SINTEF S/CHLab	Sorbent laboratories SLab for CCS includes: <ul style="list-style-type: none"> High throughput preparation and testing laboratory for materials in CCS related technologies Sorbent based and Chemical looping laboratories Sulphur laboratory for material and component testing Extension of solid sorbent lab CHLab: In situ characterization of solid materials for CCS
		Capture	SINTEF PPLab	Powder processing laboratories for CCS includes: <ul style="list-style-type: none"> Pellet/particle formulation of solids
		Capture	SINTEF Mlab	Membrane laboratories for CCS includes: <ul style="list-style-type: none"> Ceramic- and metallic based membranes laboratories for H₂, O₂ and CO₂ separation Sulphur laboratory for material and component testing Extension of high temperature membrane lab
		Capture	SINTEF SDR	Solvent Degradation Rig
		Capture	SINTEF Tiller Pilot	Tiller Pilot Plant - Tiller Post Combustion Lab pilot
	Transport	Giskås	Pipeline crack arrest test	

COUNTRY	INSTITUTION	CATEGORY	SHORT NAME	LONG NAME
		Storage	SCAL	Core Flood (SCAL) laboratory
		Storage	pVT	Fluid (pVT) laboratory
		Storage	RESLab	SINTEF-NTNU Reservoir laboratory, including μ -CT
		Storage	WILab	SINTEF-NTNU Well Integrity laboratory
		Storage	FPLab	SINTEF Formation Physics laboratory

COUNTRY	INSTITUTION	CATEGORY	SHORT NAME	LONG NAME
	BGS / NERC	Storage	TPRL	Transport Properties Research Laboratory
		Storage	RMPL	Rock Mechanics And Physics Laboratory
		Storage	HTL	Hydrothermal Laboratory
		Storage	Gas Mon	NearSurface Gas Monitoring Facility
		Storage	Micro Lab	Geomicrobiology Laboratory
	PACT	Capture	PACT-PF	PACT 25 kW Air-Oxy Combustion Plant (25kW PF rig)
		Capture	PACT-ACP	PACT 250 kW Air Combustion Plant (ACP)
		Capture	PC17	PACT 250kW Oxyfuel Combustion Plant (OCP)
		Capture	PACT-GMF	PACT Gas Mixing Facility (GMF)
		Capture	PACT-GT	PACT Gas Turbine (GT)
		Capture	PC19	PACT Solvent-based Carbon Capture Plant (SCCP)

INNOVATION AND INVESTMENTS

ECCSEL has performed a gap analysis showing current CCS research gaps as well as existing facility gaps. Based on the gap analysis combined with input from national CCS roadmaps, facility upgrades and new builds have been planned and in many

cases funding has been approved and construction has commenced. In the table below you can see a selection of new facilities and upgrades known to be becoming available over the next 12 months.

	PLANS FOR UPGRADED AND NEW CAPTURE FACILITIES	CATEGORY	COMMENT ON COMPLETION / AVAILABILITY
	SINTEF ER Combustion lab - NO This lab currently consists of facilities COMBLAB (HIPROX) and CLC Hot Rig. One upgrade is being constructed (3 more are planned):		
CP14	High Pressure Oxy-Gas turbine facility – NO (SINTEF ER)	Upgrade	Access in 2018
CP17	Flexible Flue gas source for CO ₂ capture pilot facility in Tiller, (Trondheim) – NO (SINTEF INDUSTRY/NTNU)	Upgrade	Under construction Access: 01.07.2019
CP18	Lab Scale moving bed temperature swing adsorption in Oslo – NO (SINTEF INDUSTRY)	New	Under construction Access: 01.01.2019
CP19	Low Temperature membranes for CO ₂ capture in Tiller, (Trondheim) – NO (SINTEF INDUSTRY)	New	Under construction Access: 01.06.2018
CP20	High temperature membranes for CCS in Oslo – NO (SINTEF INDUSTRY)	Upgrade	Under construction Access: 01.06.2018

	PLANS FOR UPGRADED AND NEW TRANSPORT FACILITIES	CATEGORY	COMMENT ON COMPLETION / AVAILABILITY
	SINTEF ER Thermophysical property lab. - NO This lab currently includes CAT1 facilities CO ₂ Mix – VLE and VISC-DENS. There are large synergies in co-locating the different property measurements. 2 new setups are being constructed (4 additional ones are proposed)		
TP6	- Test rig for solid phase low-temperature equilibria to measure accurate phase equilibria data in the range between -30 and -130 °C in temperature and up to 100 bar in pressure for mixtures relevant for CCS, with capabilities to detect formation of possibly analyse solids and hydrates. Relevant for capture, transport, and injection. Trondheim – NO (SINTEF ER)	New	Under construction (partially) Access: 01.01.2020
TP5	- High pressure phase equilibria apparatus: Phase equilibria up to 500-1000 bar in pressure, -60 to 150 °C in temperature, for CCS relevant fluids including electrolytes. In Trondheim – NO (SINTEF ER)	New	Under construction Access: 01.06.2019

	PLANS FOR UPGRADED AND NEW STORAGE FACILITIES	CATEGORY	COMMENT ON COMPLETION / AVAILABILITY
SP5	AUV-based atmospheric detection of CO ₂ – UK (BGS)	Upgrade	Tested in Lab, will be field tested 2018-19
SP6	Test facilities for developing new subsurface in-reservoir and in-overburden mitigation and remediation technologies to control geologically mediated migration – GeoEnergy Test Bed, UK (BGS)	New	Construction is ongoing
SP15	Upgrading of the CO ₂ Field Laboratory at Svelvik (SINTEF Industry, /UiO/NGI) – NO	Upgrade	Under construction Access: 01.06.2018
SP16	Test tank for CO ₂ monitoring studies (NTNU) – NO	New	Under construction Access: 01.06.2019
SP17	Well integrity lab facilities (SINTEF Industry) – NO	New	Under construction Access: 01.01.2019
SP19	Geochemistry Labs at IFE – NO	Upgrade	Under construction Access: 01.06.2018
SP20	CO ₂ Flow labs upgrade (SINTEF Industry, Reservoir Lab) – NO	Upgrade	Under construction Access: 01.01.2019
SP21	Test tank for trapping mechanisms/fluid flow tank facility (SINTEF Industry) – NO	New	Under construction Access: 01.01.2019
SP22	Sulcis Fault Lab (SOTACARBO, Carbonia) The facility has been funded by the Regional Government of Sardinia through the “Centre of Excellence on Clean Energy – Phase II” project. – IT	New	The Sulcis Fault Lab for CO ₂ injection tests through a fault will be completed by the end of 2019 and fully operational in 2020)

ECCSEL also has created a Research Strategy Document which aims to identify key research challenges and strategic objectives for the ECCSEL Research Infrastructure for the period 2016-2026. The Strategy covers all areas of CO₂ capture, transport and storage (CCS), and will facilitate building a technical activity plan in these areas by providing a prioritised list of research topics to meet predicted user needs up to 2021, as well as a horizon scan to 2026. It is based on contributions from, and therefore reflects the views of, the fourteen partner institutes from the nine countries participating in ECCSEL's Implementation Phase 2015-2017.

The Strategy sets out national research activities and interests before synthesising into key research priorities for capture, transport and storage that will need to be addressed to facilitate broad scale deployment of CCS, and that are of common interest. Where appropriate, the key research infrastructure towards which ECCSEL could usefully focus resource, design and development effort in the medium term are identified and, if appropriate, are ranked according to priority and shortlisted.

Italy: A call dedicated to implement prioritized Research Infrastructures has been launched by the Italian Ministry of University and Research. This is the PON-RI call and consists of national funds, to be spent mainly to implement RIs located in Southern Italy. ECCSEL ERIC, through its Italian representing entity (OGS), is among the eligible beneficiaries, because it is considered strategic at a national level (the Italian national strategy on RIs and several regional strategies prioritize it).

286 M€ is the total budget of the call. Projects will be between 5 M€ and 20 M€ each. The funds will be used to implement the Panarea natural laboratory and some other ECCSEL facilities directly connected with it.

OPERATIONS

Operations Centre

With its statutory seat in Norway, the ECCSEL ERIC Operations Centre is located in Trondheim. Its main responsibilities and tasks are “central management and planning as well as coordination of the infrastructure operations and development”:

- Coordinate the infrastructure at European level
- Coordinate and facilitate the required upgrades and new builds of research infrastructure in support of the scientific and technological objectives of ECCSEL.
- Act as the user entry point for researchers wishing to use the facilities which are part of the ECCSEL RI.
- Strengthen the general identity of ECCSEL
- Facilitate outreach as well as training and mobility for its members, users and internal operators



ECCSEL Operations Centre tasks

National Nodes

Italian Node

Italy joined ECCSEL's first preparatory phase of ECCSEL in 2010 and has remained an ECCSEL partner throughout its second FP7 funded preparatory phase, its transition to the H2020 Infradev-3 Implementation Phase and ultimately became a founding member of ECCSEL ERIC.

The Italian node currently consists of thirteen CCS facilities owned and operated by two Italian institutes:

- OGS offers access through ECCSEL to seven CO₂ storage research facilities: DeepLab, Aircraft, BioMarineLab, Panarea and Latera natural laboratories, PITOP, Explora and CTMO.
- Sotacarbo offers access through ECCSEL to four CO₂ capture and one CO₂ storage research facilities: respectively: COHYGEN, PEC lab, XtL Pilot plant, IOSTO plant, Rock Analysis Lab.

Italy holds seats on the General Assembly (OGS) and Research Infrastructure Coordination Committee (OGS and Sotacarbo), and also provides in-kind staff contribution to the ECCSEL Operations Centre in Trondheim.

In the last part of 2017 the Italian National Node, coordinated by OGS, has continued activities started during the INFRADDEV-3 project.

The two National Info days organized in the first half of 2017 brought to the expansion of the Italian network of ECCSEL stakeholders. Contact has followed, especially with ENEA, who are potentially interested to include capture facilities in ECCSEL, and with Sapienza University, who is interested in continuing a scien-

tific collaboration to develop on-shore and off-shore monitoring instruments and techniques. In the meantime, contacts with Sotacarbo, already part of ECCSEL, have been strengthened, especially considering the decision to progress towards inclusion of CO₂ use in the ECCSEL strategy.

New Italian facilities have been included in ECCSEL: three new storage CAT-1s from OGS (PITOP borehole geophysical test site, Explora multidisciplinary research vessel and CTMO metrology and calibration laboratory) and capture and storage CAT-3s from Sotacarbo (including the Sulcis Fault Lab). OGS Latera NatLab has transitioned to a CAT-1 after its official opening (15th September 2017).

Lobbying on the H2020 Infrastructure Work Programme has been conducted by the National Node coordinator through the Italian National Contact Point and the Italian representative in the RI committee, in order to get the maximum results from the last programme's calls. This lobbying action has been coordinated with the other National Nodes.

Unfortunately the tentative action to include Italy in the next ACT call has not been successful, because commitment from the Ministry has not been concluded on time.

The structure of the Italian National Node has been strengthened by assigning three part-time collaborators working on ECCSEL ERIC and CCS issues. This also assures proper coordination with other ongoing national and European initiatives, such as EE-RA-CCS, CO₂GeoNet, Italian Energy cluster, all followed by OGS colleagues. The National Node is also into contact with SET-Plan representatives and informed on its technical group decisions through the Italian member Sotacarbo. Links to national and European groups working on data management have also been established (the EOSC initiative, Italian ICDI).

Contacts with EMSO are ongoing to prepare a joint collaboration document that highlights common priorities and activities, and the possibility to jointly use facilities.

Objectives in line with 2017 priorities have been set for 2018 and related activities have been planned.

French Node

The French node has the largest number of national partners with six facility operators/providers.

France has been involved since 2008 in the development of the ECCSEL RI, through two FP7 preparatory phases and the H2020 Infradev-3 project helping to start the implementation phase. Since 2017, the year of ECCSEL ERIC creation, the French node (ECCSEL-FR) has been officially constituted and structured around four public research institutes (ANDRA, IFPEN, INERIS, BRGM) and two private companies (EDF, TOTAL).

The node is coordinated by BRGM through a partnership agreement and on the behalf of the French Ministry of Research. ECCSEL-FR provides eight facilities. Seven are existing operational facilities (Category 1) while one is still at project level (Category 3). These facilities cover the whole CCS chain, namely capture of CO₂ (EDF CO₂ capture pilot at a coal power plant), transport issues (INERIS SAFETY experimental platform, and planned TOTAL COOTRANS transport loop), storage processes (LS-Andra

Underground Laboratory and BRGM BIOREP reactor), and monitoring approaches (IFPEN ESCORT Mobile equipment, GasGeochem laboratory of gas analysis and INERIS CATLAB CO₂ leakage simulation site).

The node has been very pro-active on national and international levels to promote its extension and the use of all ECCSEL facilities through two national Information Days (in 2016 and 2017), presentations in workshops (2 in 2017) and conferences (2 in 2017) as well as in CCS networks, namely the French CO₂ Club and CO₂GeoNet. The last Information Day was held in March 2017 at the French Ministry of Research and attracted about fifty participants.

ECCSEL-FR was included in the national roadmap for Research Infrastructures published in 2016, with the status "in project". In 2017, the revision of this roadmap for preparing the 2018 edition has begun. The French node of ECCSEL prepared all the documentation requested by the Ministry of Research for this revision. To answer a new request from the Ministry for all RIs, all the ECCSEL-FR partners performed a standardized accounting valuation for each of their facilities. Those assessments have been validated by the French ministry and have helped to structure and refine the cost and price of the services that are provided.

The node, since its creation, meets physically at frequent intervals of time (every 2-3 months) and is strongly involved in the functioning of ECCSEL ERIC with representatives in the RICC (2) and Industry Advisory Group (2). In 2018 one person is providing in-kind contribution to the ECCSEL Operations Centre.

The Norwegian Node

Norway, represented by NTNU and SINTEF together with the Research Council of Norway (RNC) and the Norwegian Ministry of Research and Higher Education (KD), were the initiators of ECCSEL that was posted on the ESFRI Roadmap in 2008 as one of three new RIs within the energy domain. Since 2011, NTNU has coordinated two FP7 Preparatory Phase projects, ECCSEL PP1 (2011-2013) and ECCSEL PP2 (2013-2015), as well as the H2020 funded Implementation Phase project, ECCSEL Infradev-3 (2016-2017). NTNU was the host of the inauguration ceremony of ECCSEL ERIC that took place in Trondheim on 12th June 2017.

The Norwegian node of ECCSEL consists of SINTEF Industry (merger of former SINTEF Materials and Chemistry and SINTEF Petroleum), SINTEF Energy, Institute for Energy Technology (IFE) and the coordinator NTNU. We are continuously working to expand and attract other Norwegian universities and research institutes through national meetings/workshops and research project collaboration.

ECCSEL is on the Norwegian Roadmap for Research Infrastructures. Through the National Research Infrastructure Program, RCN has funded the upgrade of twelve CCS research facilities and the construction of eleven new CCS research facilities. The total budget for these investments is € 21M (NOK 200M). Together with the existing RIs, the partners of the Norwegian node of ECCSEL will, in the near future, be operating more than 20 RIs within carbon capture, transport and storage that are made available for the research community worldwide through ECCSEL ERIC.

The UK node

The UK joined ECCSEL's first preparatory phase of ECCSEL in 2010 and has remained an ECCSEL partner throughout its second FP7 funded preparatory phase, its transition to the H2020 Infradev-3 Implementation Phase and ultimately became a founding member of ECCSEL ERIC.

The UK node, coordinated by BGS, has been proactive in engaging and promoting ECCSEL to policy and research stakeholders, potential RI users and UK CCS facility owners. Information on ECCSEL's ambitions, activities, strategy and future plans have been communicated regularly throughout ECCSEL's evolution at national and international CCS events. The UK has a busy schedule of biannual CCS research and policy events. Aligning with these opportunities has proved extremely successful in securing engagement, participation and buy-in amongst UK stakeholders.

The UK node currently consists of eleven CCS facilities owned and operated by two UK institutes:

- The British Geological Survey (BGS) now offers access through ECCSEL to five CO₂ storage research facilities: Hydrothermal Laboratory, Near Surface Gas Monitoring, Rock Mechanics and Physics and the Transport Properties Research Laboratory, and most recently the Geomicrobiology Facility.
- The Pilot-scale Advanced Capture Technology (PACT) Facilities is a collaboration between six UK universities, all of whom are members of the UK CCS Research Centre (UKCCSRC). PACT now offers access through ECCSEL to six pilot-scale CO₂ capture facilities: 25kW Air-Oxy Combustion Plant, 250kW Air Combustion Plant, 250kW Oxyfuel Combustion Plant, Gas Mixing Facility, Gas Turbine, and Solvent-based Carbon Capture Plant.

Seven of these facilities are new additions to the ECCSEL portfolio since the launch of ECCSEL ERIC. The UK node is also handling enquiries from further UK CCS groups wishing to contribute facilities to ECCSEL, and already has plans to expand the UK node accordingly via the RICC.

The UK holds seats on the General Assembly (BGS and Department for Business, Energy & Industrial Strategy (BEIS)) and Research Infrastructure Coordination Committee, and also provides in-kind staff contribution to the ECCSEL Operations Centre in Trondheim.

The Dutch Node

Netherlands, represented by TNO together with the Dutch RVO (Rijks Dienst voor onderneming Nederland) as representative of the Dutch Ministry of Economic affairs and climate (EZ), were involved from the early phases of ECCSEL. Since 2011 TNO has been involved in the two FP7 preparatory phase projects, ECCSEL PP1 (2011-2013) and ECCSEL PP2 (2013-2015), as well as the H2020 funded Implementation Phase project, ECCSEL Infradev-3 (2016-2017).

The Dutch node of ECCSEL consists of TNO and the Dutch CATO (CCS) program. ECCSEL is on the Dutch research agenda via the CATO program support by RVO. Currently the setup of the Dutch RI is mainly concentrated on solvent base absorption technologies and are located in Delft. The Dutch node will be extended with existing research facilities located in Petten, which will be assessed to be part of ECCSEL. The predominant technical focus is CO₂ adsorption separation technologies.

Currently a large scale CO₂ storage demonstration program is under development.

FACILITY OPERATORS/OWNERS

France

BRGM (National Node Coordinator – France)

BRGM, France's leading public institution in the Earth Science field, has three main activities: scientific research, support for government policy, and international cooperation and development assistance.

BRGM has been among the pioneers in research on geological CO₂ storage, participating from 1993 in the first European research project (Joule II) and in the first pilots worldwide (Sleipner, Weyburn, In Salah, Nagaoka, Ketzin, Hontomin, Lacq-Rousse, etc.).

BRGM also carries out research at natural CO₂ fields, such as Montmiral in France, and at natural CO₂ seepage areas in Italy, Germany and France. Its fields of expertise are site selection and characterization, predictive modelling, risk analysis, monitoring and safety management, thus addressing a wide range of the issues related to CO₂ geological storage.

BRGM also performs some research on CO₂ capture and on CO₂ use.

BRGM is the coordinator of the French node of ECCSEL ERIC, composed of four research institutes (BRGM, IFPEN, INERIS, Andra) and two industrial companies (EDF, TOTAL), as well as the ongoing H2O2O ENOS project, and the completed FP7 ULTimateCO₂ and CGS Europe projects. BRGM is a founding member of the CO₂GeoNet European Network of Excellence on the geological storage of CO₂, initiated in 2004 through an EC FP6 contract, and now a legally registered Association under French law with statutory seat in BRGM offices. BRGM is President of the national Club CO₂ and is deeply involved in CCS international initiatives such as ZEP, EERA CCS JP, CSLF, IEAGHG.



Andra

The French national radioactive waste management agency (Andra) is responsible of the long-term management of radioactive waste produced in France. As part of this mission, Andra puts its expertise and know-how at the service of the State to: find, implement and guarantee safe management solutions for all French radioactive waste in order to protect present and future generations of the risk of this waste. Created in 1979, Andra became a public industrial and commercial establishment by the law of December 30, 1991 whose missions were supplemented by the law of June 28, 2006 relating to the sustainable management of radioactive materials and waste. It is placed under the supervision of the ministers in charge of energy, research and the environment respectively.



EDF

As a global leader in low-carbon energy, the EDF Group covers every sector of expertise, from generation to trading and transmission grids. EDF builds on the expertise of its people, its R&D and engineering skills, its experience as a leading industry operator and the attentive support of its customers to deliver competitive solutions that successfully reconcile economic growth with climate protection.



IFPEN

IFP Energies nouvelles (IFPEN) is a major research and training player in the fields of energy, transport and the environment.

From research to industry, technological innovation is central to all its activities, structured around three strategic priorities: sustainable mobility, new energies and responsible oil and gas.

Mission: As part of the public-interest mission with which it has been tasked by the public authorities, IFPEN focuses on:

- providing solutions to take up the challenges facing society in terms of energy and the climate, promoting the transition towards sustainable mobility and the emergence of a more diversified energy mix;
- creating wealth and jobs by supporting French and European economic activity, and the competitiveness of related industrial sectors.

An integral part of IFPEN, its graduate engineering school – IFP School – prepares future generations to take up these challenges.



INERIS

Established by the French Government in 1990 as the national competence centre for Industrial Safety and Environmental Protection, Ineris has developed expertise in the areas of accidental risks, chronic risks, and ground and underground risks. Ineris is the result of a restructuring of the Centre of Studies and Research of Collieries of France (Cerchar) and the Institute of Applied Chemical Research (Ircha), the Institute capitalises upon nearly 70 years of expertise and know-how. Thus, Ineris has an acknowledged know-how in the fields of mines, energy and chemistry.

Research activities support public policy and services supporting businesses contribute to the evaluation and prevention of the risks that economic activities induce for the environment, health and safety of people and goods. The Institute also accompanies innovation by taking into account upstream the risks generated by ne-products, new technologies or processes. For instance, Ineris has been involved for many years in CCS research projects funded by France or Europe.

Our 24-hour a day operational services such as the Emergency situations support unit (CASU), PRéVair (forecasting pollution at a national scale) and Cenaris (National Monitoring Centre for Ground and Underground risks) illustrate the very operational nature of the Institute's expertise.



Italy

OGS (National Node Coordinator - Italy)

OGS, Istituto Nazionale di Oceanografia e di Geofisica Sperimentale (National Institute of Oceanography and Applied Geophysics) is an internationally oriented public research institute. It operates in the European Research Area (ERA) and internationally, and develops its own mission prioritising basic and applied research fields of oceanography (physical, chemical and biological aspects), geophysics and marine geology, seismology and experimental and explorative geophysics.

OGS owns important multidisciplinary research facilities, such as ECCSEL NatLab-Italy natural laboratories of Panarea and Latera, the oceanic research vessel OGS Explora, the borehole geophysical test site (PITOP), an aircraft equipped for remote sensing, a metrology and calibration laboratory acquisition systems for geophysical data in land and marine-coastal environments, and a centre for processing and archiving of large geophysical data sets.

All these facilities are widely used to boost cooperation and mobility of people and ideas, and bring together the best European and worldwide scientists to strengthen their skills, enhance their career development and create a network of potential future leaders.

Most of these facilities are part of ECCSEL ERIC that OGS has helped implement since its conception. OGS has been one of the project partners in the two Preparatory Phases and in the Implementation Phase and it is now the entity representing Italy in ECCSEL ERIC. OGS has also a strong expertise in CCS; since 2004, it has taken a leading role (as a WP leader) in 13 CCS-related EU projects and it has been the coordinator of 15 national projects.

The Institute works for environmental protection, sustainable economic development and societal inclusion through tailor-made initiatives to evaluate and prevent geological, environmental and climatic risks, with the aim of spreading scientific culture and knowledge, building capacities and transferring knowledge.

All these efforts are also made in collaboration with European and international institutions, with private high-tech industries and qualified enterprises, aimed at developing innovative capacity building activities to attract both industrial stakeholders and the research community.



**ISTITUTO NAZIONALE
DI OCEANOGRAFIA E DI GEOFISICA SPERIMENTALE**

Sotacarbo

Sotacarbo is a research and development company (shareholders: Enea – the Italian National Agency for New Technologies, Energy and Sustainable Economic Development – and Sardinian Regional Administration) on clean energy and carbon capture, utilization and storage (CCS).

Recently, Sotacarbo has been designed by the Sardinian Regional Government as the regional and national reference on the development of technologies for the sustainable use of fossil fuels (coal in particular) and clean energy (including carbon capture and storage), with the aim to collect knowledge and research facilities to support and boost Italy's energy policy. The activities programme of the technological pillar includes theoretical and experimental studies on zero emissions technologies for power generation, production of energy carriers from coal, biomass and CO₂, pre-, post- and oxy-combustion for CCS. Since 1988, Sotacarbo represents Italy in the International Energy Agency – Clean Coal Centre.



The Netherlands

TNO (National Node Coordinator - the Netherlands)

TNO (Netherlands Organisation for Applied Scientific Research) is an independent research organisation whose expertise and research make an important contribution to the competitiveness of companies and organisations, to the economy and to the quality of society as a whole.

TNO's unique position is attributable to its versatility and capacity to integrate this knowledge. In April 2018, TNO will merge with ECN in the Netherlands. This will strengthen the position of TNO in the international CCUS community.

TNO is one of the major contract research organisations in Europe. With a staff of approximately 4,000 and an annual turnover of 600 million Euros, TNO carries out research to achieve impact on the following seven themes: Healthy Living, Industrial Innovation, Mobility, Energy, Built Environment, Information Society, and Defence, Safety and Security.

TNO functions as an intermediary between basic research organisations and industry. By translating scientific knowledge into practical applications, TNO contributes to the innovation capacity of businesses and government. TNO is involved in many international projects (about 30% of the market turnover), including EU-funded collaborations.

Since the early 1990s TNO has been a partner in many international research programs, global research networks and business-to-business consultancy on CO₂ capture from flue gases and CO₂ storage in hydrocarbon reservoirs, coal beds and aquifers. The Oil & Gas and Geo-energy departments are actively involved in all areas to support innovation processes to increase the energy efficiency of industrial processes, to reduce CO₂ emissions, to innovate the process of oil and gas production and to reduce the costs to produce renewable energy. As such, TNO is the leading research institute in the Netherlands on Carbon Capture and Storage, providing state-of-the-art knowledge on the entire chain of CO₂ capture, transport and storage. TNO has been active in many relevant projects on CCS as leader or major partner. Projects

with a strong TNO involvement are: CESAR, OCTAVIUS, iCAP, CAPRICE, ECCSEL, Hipercap, CO2Europipe, CO2ReMoVe, CEMCAP, projects for IEA GHG, and multiple project in the 2016 ERANET ACT call. TNO is coordinator of the largest project in that program (ALIGN CCUS)

TNO is organised around five focus areas. The focus area Energy has been involved in CCS for nearly 20 years and has become a world leader in CO2 capture and underground CO2 storage. Other CCS-related expertise is in clean combustion technologies, materials studies for transport, decision support systems, HSE studies, and monitoring of the climate effect of energy transition by means of in-situ and remote earth observation techniques.

The Geological Survey of The Netherlands, part of TNO Geo Energy, is involved in the pre-qualification study of some 12 CCS pilot plants both on- and off-shore The Netherlands, in aquifers and depleted oil and gas fields.

TNO innovation for life

Norway

NTNU (National Node Coordinator - Norway)

NTNU (The Norwegian University of Science and Technology) is a fully integrated university with emphasis on technology and engineering. It is the main technical university in Norway with over 80% of its Master- and PhD-degrees awarded in science and technology.

Over the last 30 years NTNU and the research institute SINTEF have jointly developed a research area covering 10,000 square metres hosting a € 50M research facility, where 750 people work on mitigating emissions like CO2, NOx, SOx and other greenhouse gases. This includes removing such emissions from oil and gas production processes and from use in industry, buildings and transport. A secondary research line has been to cross-link this research with the development of new clean renewable energy technologies.

NTNU is involved in a series of national projects (BIGCO2, BIGH2, BIGCLC, BIGCCS) and EU projects (ENCAP, DYNAMIS, DECARBit, iCap). NTNU has been the coordinator of the ECCSEL initiative since it first appeared on the official ESFRI Roadmap in 2008 until 2017 when ECCSEL ERIC was established as a legal entity.

NTNU

SINTEF Energy Research

SINTEF Energy Research (SINTEF ER) is an independent Norwegian research institute affiliated under the SINTEF Foundation. Its main office and activities are located in Trondheim, Norway, sharing facilities with the Norwegian University of Science and Technology (NTNU). SINTEF ER has a staff of 244, including more than 190 research scientists. SINTEF ER had an annual turnover of NOK 466 million in 2017.

SINTEF ER covers a full range of energy technologies, both renewable and Oil & Gas as well as related fields (e.g. energy economy and policy). SINTEF ER has been involved in projects related to CCS technologies since 2001, and that it has been the coordinator of several large integrated projects in the field of CCS under the European Framework Programmes (FP4 – FP7) and in H2020. As a major European player on the scene, SINTEF also contributes to actively influence the European R&I agenda, in coordination with Norwegian authorities and industry raising the voice on behalf of Norway in dialogues with the European Commission and other stakeholders.

SINTEF ER has extensive experience from Norwegian and EU CCS projects in FP7 and H2020 projects (ECCSEL Infradev-3, CEMCAP, CHEERS, GATEWAY, ENCAP, Dynamis, DECARBit, ECCO, IMPACTS) as well as the ERANET ACT project ELEGANCY. Most of these projects were coordinated by SINTEF ER. In addition, the research institute has its competence built up over many years in the International CCS Research Centre BIGCCS and the Norwegian CCS Research Centre, NCCS – both hosted by SINTEF ER and being major research efforts on CCS. Through NCCS, SINTEF ER also hosts the Trondheim CCS conferences, which are one of the most important international meeting places within CCS. The research institute has a leading role in Zero Emission Platform (ZEP) and the European Energy Research Alliance' Joint Programme on CCS (EERA JP CCS). SINTEF's Director of Sustainability Nils Røkke is the Chairman of EERA. Within CCS, SINTEF ER has particular focus on CO2 transport, transient and interfacial phenomena between, liquefaction and low-temperature separation technologies, CLC capture, high pressure combustion / oxyfuel technologies, and value chain / techno-economic analysis.

The mission of SINTEF Energy Research is to "shape tomorrow's energy solutions". Their ten areas of focus contribute towards the transition to, and achievement of, future, sustainable, energy systems:

- Energy efficiency
- CCS
- Hydropower
- Offshore windfarms
- Bioenergy
- System integration of renewable energy
- SmartGrids
- Power exchange between Norway and Europe
- Gas technology, LNG and hydrogen
- Subsea power supply and processing

SINTEF Industry

The research institutes SINTEF Materials and Chemistry and SINTEF Petroleum Research merged on 1st January 2018. The new institute is called SINTEF Industry. SINTEF Industry has around 460 employees, with about 90% being scientists and technicians. The Industry division has extensive activities in the fields CO2 capture, transport and storage, and experience from several national and European R&D programs within FP5-7 and H2020 as coordinator and core partner.

SINTEF Industry performs contract research and delivers solutions and services that create value for customers. With their cross-disciplinary knowledge base and advanced laboratories as a base, SINTEF Industry develops – in close collaboration with their customers – technology and solutions within a broad range of research areas and industries:

- Advanced materials
- Oil and gas
- Applied chemistry and biology
- Process industry
- Renewable energy
- Sustainable transport
- Metallurgy
- Manufacturing
- Biotechnology and nanotechnology
- Marine resources and technology

Sustainable development and value creation is fundamental to all their activities.

Tel-Tek Foundation in Porsgrunn merged into SINTEF as a research group in SINTEF

Industry. Through this merger, SINTEF is brought even closer to industry in the region, and brings valuable cutting edge expertise in powder technology, CO₂ capture and storage, early-stage cost estimation and biogas.

SINTEF Industry is part of the SINTEF Group, one of the largest research groups in Europe. SINTEF has more than 1200 employees with international top-level expertise in science and technology and an annual turnover of NOK 1600M (~ € 200M) originating from industrial research contracts as well as European and National research projects. SINTEF is an independent and non-commercial corporation. Any profit from their contract research is invested in new research, scientific equipment and competence.



UK

BGS (National Node Coordinator - UK)

The British Geological Survey is a component organization of the Natural Environment Research Council (NERC), which is the UK's leading body for basic, strategic and applied research and monitoring in the environmental sciences. The British Geological Survey (BGS) was founded in 1835 and is the world's longest established national geological survey. BGS seeks to advance the understanding of the structure, properties and processes of the solid Earth system through interdisciplinary surveys, monitoring and research for the benefit of society.

BGS is a public sector organization responsible for advising the UK government on all aspects of geosciences, as well as providing impartial geological advice to industry, academia and the public. It is the UK's premier provider of objective and authoritative geoscientific data, information and knowledge for sustainable use of natural resources, reducing risk and living with the impacts of environmental change.

BGS is a leading research organisation in the field of geological CO₂ storage. They have a leading research role in a number of major EU/industry and government funded projects. In the last two years BGS have carried out more than forty (40) CO₂ storage projects for the EU, industry and the UK and overseas governments, with an annual CCS budget of over €1M. Recent projects include Weyburn project; Nascent project; CO₂ReMoVe project; monitoring programmes, European storage sites; site monitoring tool, IEAGHG; review of monitoring technologies for CO₂ storage, UK government; reviews of Otway Basin and Gorgon CO₂ storage projects, Australia; Lead Author IPCC Special Report on CO₂ Capture and Guidelines for Compiling National Greenhouse Gas Inventories.

BGS has been the technical advisor for storage for the UK Government, for a full-chain, full-size CCS demonstration project. BGS has led assessments of storage capacities and capability building for the UK Near Zero Emissions China project and has also been involved in the FP6 COACH project. BGS was the coordinator of the FP7 RISC project; has undertaken geological interpretation and modelling of onshore and offshore UK storage sites for the CASSEM project; drilling advice and expertise for the QICS controlled subsea release of CO₂, participant in the UK Storage Capacity Appraisal project and technical lead for the CO₂stored online database, and leader and contributor to two CCS research studies of the opportunities and development of CCS offshore Scotland funded by Scottish Government and industry consortiums and led characterisation and dry-run licence application for an offshore multi-store site for the FP7 SiteChar project.



PACT

PACT is a collaborative activity between the Universities of: Cranfield, Edinburgh, Imperial College, Leeds, Nottingham and Sheffield. It forms part of the UK Carbon Capture & Storage Research Centre (UKCCSRC) (www.ukccsrc.ac.uk) jointly funded by the Department of Energy and Climate Change (DECC) and the Engineering and Physical Sciences Research Council (EPSRC).

The University of Sheffield has a global reputation for pioneering high impact research and is ranked as a world top-100 university with 86% of its research considered as internationally recognized or World leading. Its Engineering departments are ranked in the top five in the UK for the impact and quality of research.

The University of Sheffield is a founder member of the UK CCS Research Centre and manages and operates the UK national CCS test facilities: PACT. The PACT facilities are internationally renowned specialist facilities for R&D in bioenergy, advanced fossil-fuel energy, and carbon capture and storage/utilisation technologies for power generation and industrial applications.

Established in 2012 with funding from UK Department for Business, Energy & Industrial Strategy and the Engineering and Physical Sciences Research Council, PACT has a range of integrated pilot-scale test rigs including: gas/biogas turbine CHP units, pulverised coal/biomass air/oxyfuel combustion rig, biomass grate boiler and synthetic gas mixing facility for modulated/synthetic flue/process gasses; all integrated with 1 tonne a day amine-based post combustion plant; and state of the art online and lab-based analytical facilities; and supporting system and process modelling capability.

The facilities provide a platform for cutting-edge integrated systems R&D, technical feasibility studies and the testing of design concepts for scale-up to enable and catalyse technology development and commercialisation. PACT works with a wide range of stakeholders in the UK and around the world including research organisations, universities, SMEs and large national and multinational companies. It is involved in national and international R&D and training projects with total projects value in excess of over £40m.

PACT is internationally recognised for its work in carbon capture and energy technologies as reflected by its UK-representative membership of ECCSEL and the International CCS Test Centre Network, and the operational management and research service provision for the International Flame Research Foundation with prestigious global membership some 130 organisations representing the power generation, petroleum refining, iron and steel, cement, glass, and chemical manufacturing industries as well as combustion equipment manufacturers, fuels producers and distributors, research institutes, universities, trade associations, and energy policy makers. The University of Sheffield additionally hosts the UK Centre for Carbon Dioxide Utilisation (CDU) and manages CO₂Chem – the world's largest networking and research community for academics and industrialists interested in CO₂ conversion. It is also a partner in the national PhD training centre (Centre for Doctoral Training) for CCS and bioenergy, providing regular training for PhD students and UKCCSRC applicants.



FACILITY ACCESS

Facility usage reporting and monitoring has started in 2017 and mainly focuses on the period after the ECCSEL ERIC establishment. Before that, 13 research projects were carried out using different ECCSEL facilities as part of the EU Horizon 2020

sponsored Transnational Access program. Below is a selection of some of the research projects carried out in 2017 using facilities included in the ECCSEL Research Infrastructure.

PROJECT	FACILITY	FACILITY OWNER	COUNTRY OF FACILITY	COUNTRY (OF RE-SEARCHER)
Enabling technology for the development of moving bed temperature swing adsorption process for post combustion CO ₂ capture	SLab	SINTEF	NO	
Demonstration of the Swing Adsorption Reactor Cluster for simple and cost effective post-combustion CO ₂ capture	SLab	SINTEF	NO	
Tailored encapsulation and Release	PP-lab	SINTEF	NO	
not to be published - commercial sensitive	PP-lab	SINTEF	NO	
Novel molten carbonate/ceramic composite materials for sustainable energy technologies with CO ₂ capture and utilization	M-Lab	SINTEF	NO	
Novel molten/solid composite oxygen transport membranes for CO ₂ capture	M-Lab	SINTEF	NO	
2D materials beyond graphene	M-Lab	SINTEF	NO	
Chinese-European emission-reducing solutions	M-Lab	SINTEF	NO	
Innovative Precipitating Solvent Process for Carbon dioxide removal from various Gas Sources	SDR	SINTEF	NO	
not to be published - commercial sensitive	SDR	SINTEF	NO	
Pilot scale testing of Non-aqueous solvent	Tiller	SINTEF	NO	
Improved performance of CO ₂ EOR and underground storage by mobility control of CO ₂ : CO ₂ mobility control	pVT	SINTEF	NO	
Centre for Doctoral Training - course for doctorate students in Bioenergy, providing hands on experience on large scale facilities simulating industrial installations and process monitoring, analysis and research	PACT 250kWth PF Air-Oxyfuel Plant	PACT - University of Sheffield	UK	UK/EU
Same as above	PACT 330kWth CHP Gas Turbines	PACT - University of Sheffield	UK	UK/EU
Project on comparative assessment of CO ₂ Post Combustion Capture performance, energetics and emissions between standard 30% MEA and concentrated 40% MEA solution.	PACT Post Combustion Capture Plant	PACT - University of Sheffield	UK	UK/ international
The Scientific Diving training course of the TU Bergakademie Freiberg offer topics in the field of geology, gas and water chemistry, microbiology, engineering, heat and material transport or photo and video documentation, allowing students and scientists to qualify as "Scientific Diver" or "Advanced Scientific Diver"	Panarea NatLab Italy	OGS	Italy	Germany

PROJECT	FACILITY	FACILITY OWNER	COUNTRY OF FACILITY	COUNTRY (OF RE-SEARCHER)
2° Scientific Diving Summer School: The summer school organized by OGS, University La Sapienza of Rome, INGV of Palermo and Stazione Zoologica Anton Dohrn, offers scientific training for researchers, professionals and volunteers to study ocean acidification and CCS related topics in the Panarea natural CO2 system. The school has different aims, including research activities, knowledge transfer and technology development.	Panarea NatLab Italy	OGS	Italy	Italy
The activities conducted on the ECCSEL facility are part of the subproject "Maritime Technologies" of RITMARE and are focused on the maintenance of the probes of the observatory buoy of INGV, utilized to monitor the physico- and geo-chemical parameters of the hydrothermal system of Panarea	Panarea NatLab Italy	OGS	Italy	Italy
Performed triaxial testing at room temperature and 3 confining pressures, namely 5-30-70 MPa, to determine the impact of brine presence on the failure behaviour of limestone samples as representative reservoir and caprocks for CO2 storage. Well-known potential CO2 storage sites in limestone include Ekofisk (North Sea) and Weyburn (Canada), where in the latter they use CO2 as to enhance oil recovery.	Rock Mechanics and Physics Laboratory	British Geological Survey	UK	Norway
Not to be published - commercial sensitive	Gas Monitoring	BGS	UK	UK
ELEGANCY: Enabling a Low-Carbon Economy via Hydrogen & CCS: testing of geochemical and microbial impact of H2 in CO2-rich stream	BGS Micro lab / HTL	BGS	UK	div.
ENOS - Enabling onshore CO2 storage in Europe: Development of fibre optic monitoring techniques to identify CO2 leaks - indirect monitoring by detection of pH changes cause by CO2 dissolution	HTL	BGS	UK	div.
Impact of oxygen impurities on microbes in CCS environment	BGS Micro lab	BGS	UK	UK
Not to be published - commercial sensitive	BGS Micro lab	BGS	UK	UK
Biological transformation of H2 and CO2 into CH4 in reservoirs to perform H2 and CO2 storage (CCUS project).	BIOREP	BRGM	France	Argentina / France

Italy

A request to access the Panarea NatLab has been officially received on January 2018, but after contacts occurred in the last part of 2017. The purpose of the project (self-funded by NOC, Southampton) is to test new techniques for the quantification of gas bubbles, using acoustic and optical techniques and to quantify bubble flux from some of the vent sites. The experiment will be conducted in May 2018; OGS technologists will jointly conduct experiments with NOC and the University of Southampton.

Follow up of the TA occurred in the BioMarine lab in 2016. One PhD student from OGS visited Jožef Stefan Institute (Ljubljana) in order to jointly interpret the results obtained during the TA experience at the BioMarine lab and to talk about future collaborations.

UK

The BGS Near-Surface Gas Monitoring facility was deployed to Latera and Ailano in the summer of 2017 to carry out instrument intercomparisons with researchers from

University of Rome La Sapienza. The project was jointly funded by ECCSEL's Implementation Phase H2020 Infradev-3 Transnational Access Programme, along with the European Commission project Enabling Onshore CO2 Storage in Europe.

University of Oslo intend to complete access to the BGS Rock Mechanics and Physics Laboratory (RMPL) that started under the H2020 Infradev-3 Transnational Access Programme, but was cut short due to equipment failure. The access will be self-funded by BGS and is scheduled to take place early in 2018.

France

The IPGP has realized an access to the BIOREP facility (BRGM) during October 2017 for a CCS project. The same facility was also used for CCU project during December 2017 by an Argentina company (HYCHICO), this activity is still going on in 2018.

LOOKING AHEAD

The balance of the first four months is positive for ECCSEL ERIC. Activities set up during the implementation phase (the last H2020 Infradev-3 project) have continued, in line with agreed plans.

Objectives have been adapted according to the last GA decision, particularly the potential future inclusion of CO₂ Use among the priorities and in the research strategy.

The new Infradev-3 proposal preparation offers the opportunity to balance targeted goals, re-think ECCSEL objectives and adjust the strategy.

Particularly, these are future plans for ECCSEL:

- increase accessibility to the excellent network of facilities now established for a wider user group, connected to the research and industrial community;
- assess the needs for future development in research and innovation of its facilities, to meet future user requirements;
- facilitate access to national and regional funds for enhancing existing and building new research facilities and/or performing research and innovation activities;
- better anchor ECCSEL ERIC in national and regional policies;
- increase ECCSEL ERIC membership;
- secure the long term financial sustainability of ECCSEL ERIC;
- implement the ECCSEL strategy.

Some actions have already been continued in order to rapidly meet these goals.

Discussions are running between ECCSEL Director and Japanese Ministry representatives that may lead to formal collaboration between Japan and ECCSEL ERIC.

A research strategy update is ongoing, not least in order to best fit any inclusion of CO₂ Utilization and to assure the proper innovation, technology, and gap filling.

To have attractive and innovative facilities to offer to the users is the key to success for an RI and in this way ECCSEL wants to move forward. Goal is to increase the use of the ECCSEL facilities substantially; attractiveness should be better highlighted through extensive promotion, using a wide range of channels. Communication must also be better targeted in the future, even though it has already brought good results (for example, ECCSEL was promoted also through EPOS newsletter, in October 2017).

Planned funding delineates the future of ECCSEL. A coordinate action is needed in order to better set up priorities and define the future of ECCSEL. The participation of Member States in this process is key for success.

FINANCIAL SUMMARY

This is the first Annual Financial Report since the creation of ECCSEL ERIC. Even though ECCSEL ERIC was formally established in June 2017, Income (Membership contributions) and Expenses (personnel and other costs) started accruing from 1st September 2017. This was due to the financing provided by the H2020 Infradev-3 "ECCSEL Implementation" project, which was running until the end of August 2017. The Annual Financial Report 2017 was prepared by the Authorised Accountant "SpareBank 1 Regnskapshuset SMN AS", Kjøpmannsgata 50, 7010 Trondheim, Norway.

The Annual Financial Report 2017 is included in the Annex of this annual report. All accounts have been audited by the External Auditor "BDO AS", Klæbuveien 127B, 7031 Trondheim, Norway. BDO AS was nominated as auditor by the ECCSEL ERIC General Assembly during their first meeting on 12th June 2017.

The Report of the External Auditor is included at the Annex of this annual report. The Annual Financial Report 2017 highlights the financial status of ECCSEL ERIC. There were no unexpected income or expenses during 2017.

Budget

The Budget for the start-up year 2017 was agreed during the first ECCSEL ERIC General Assembly meeting on 12. June 2017. The approved budget for 2017 was €160,000. Norway, as the hosting country of the ERIC has agreed to pay 1/3 of the total membership fees. The remaining 2/3 are split equally between the other member countries. It was agreed that two countries (Italy and the UK) would provide a 1/2 in-kind position each to the OC. The membership fee would accordingly be discounted by €13,333 for those two countries in 2017 (value of the in-kind contribution). Foreseen total income (from membership fees) was therefore €133,334. Membership fees were split as per table below.

2017 Budget (4 months) Membership fees (Euro) including in-kind contributions

MEMBER	CASH	VALUE OF IN-KIND	TOTAL
Norway (1/3 as host)	53 332		53 332
France	26 667		26 667
The Netherlands	26 667		26 667
Italy*	13 334	13 333	26 667
UK*	13 334	13 333	26 667

*2 countries providing 1/2 in-kind position each at/for the OC, paying 1/2 of the membership fee in cash

2017 budget with for membership fees and in-kind distribution

Against those earnings, expenses of €160,000 were foreseen.
Budgeted expenses for 2017 and foreseen breakdown are visible in the table below.

PLANNING PERIOD	2017	2018	2019	2020	2021	2017-2021
	start-up year*	full operational phase				
EXPENDITURES						
Operations Centre Personnel**	110 000	500 000	600 000	600 000	600 000	2 410 000
IT system	10 000	20 000	25 000	25 000	25 000	105 000
Office renting***		20 000	30 000	30 000	30 000	110 000
Travel	15 000	40 000	50 000	50 000	50 000	205 000
Total Expenditures	160 000	700 000	850 000	850 000	850 000	3 410 000

INCOME						
Hosting Country (Norway); 1/3 payment	53 333	233 334	284 000	284 000	284 000	1 138 667
Member & Observer States; 2/3 payment	106 667	466 666	566 000	566 000	566 000	2 271 333
Total income	160 000	700 000	850 000	850 000	850 000	3 410 000

COSTS PER MEMBER						
Number of Members and Observers (excl.host)	4	6	8	10	12	
Costs per Member/Observer	26 667	77 778	70 750	56 600	47 167	

*) Start-up budget year from 1st September (4 months) after INFRADEV-3 HORIZON 2020 funding ends.

**) Start-up with secondment of Director and administrative personnel from NTNU + In-kind and/or seconded Scientific partner resource

***) Office renting provided and covered by NTNU as part of personnel secondment contracts

Annual costs and income contributions (€) for the first 5 years of implementation and operation of ECCSEL ERIC (as per 12.6.2017. Future budget for 2018 and subsequent years was revised in November 2017)

Actual Income and Expenses

The annual accounts have shown a total operating revenue of €134,715 and total operating expenses of €101,129.

€133,334 of the total operating revenue of €134,715 came from membership fees. The remaining amount of €1,381 came from exchange rate profits related to the operational revenue.

Total operating expenses for 2017 were €101,129. This was slightly below the budgeted expenses mainly due to lower than budgeted travel expenses, meeting expenses and office rental expenses. The main expense for 2017 was salary, which accounted for €97,008. This was for the secondment of Sverre Quale (100%), Volker Röhling (100%) and Debbie Koreman van den Berg (50%). The amount covers salaries and related costs (like insurance and pension), IT systems and support and travel.

Other expenses were for meetings (meeting room and catering), travel of OC staff (in-kind staff), payment to auditor (€906) and accountant and for use of the online accounting system. In 2018 increased travel and meeting expenses are foreseen using the unused funds from 2017.

Other Income

No other income was generated in 2017.

Procurement and Tax Exemption

According to Article 16 of the Statutes, shall ECCSEL ERIC shall treat procurement candidates and tenderers equally and in a non-discriminatory way, independent of whether or not they are based in the European Union. During 2017 no major investments were done. Office space was made available from NTNU as part of the secondment of personnel. There was no charging in 2017 for the office space.

In accordance with the ERIC Regulation (Official Journal L 206, 2009) and the Norwegian ERIC law ("ERIC loven") shall an ERIC benefit from tax exemption. Article 16 of the ECCSEL ERIC Statutes states that tax exemptions based on Norwegian Act relating to value added tax of 19. June 2009 No. 58, § 10-3 be limited to the value added tax for such goods and services which are for official and exclusive use by ECCSEL ERIC and are wholly paid and procured by ECCSEL ERIC or by Members States of ECCSEL ERIC. ECCSEL ERIC requests quarterly the refunding of any paid value added tax. For 2017, ECCSEL ERIC got refunded the in Norway paid value added tax.

FACTS

ECCSEL ERIC Member States, representing Entities and National Nodes

MEMBER STATE	MEMBER STATES' REPRESENTING ENTITY	NATIONAL NODE COORDINATOR
Norway (ERIC statutory seat)	Norwegian University of Science and Technology (NTNU) together with SINTEF Energy Research (SINTEF ER)	Morten Grønli (NTNU)
France	The French Geological Survey (BRGM)	Isabelle Czernichowski-Lauriol (BRGM)
Italy	National Institute of Oceanography and applied Geophysics (OGS)	Michela Vellico (OGS)
The Netherlands	Netherlands Organisation for Applied Scientific Research (TNO)	Jan Hopman (TNO)
United Kingdom	British Geological Survey (BGS)	Helen Taylor (BGS)

ECCSEL GENERAL ASSEMBLY

MEMBER COUNTRY	NAME	FROM	TYPE	ROLE
Norway (ERIC statutory seat)	Åse Slagtern	The Research Council of Norway (RCN)	Ministry	Chair
Norway	Sverre Quale	ECCSEL ERIC	ERIC Management	ECCSEL ERIC Director
France	Xavier Montagne	Ministry of Education, Higher Education and Research (MESRI)	Ministry	Member
France	Pierre Toulhoat	BRGM	Representing Entity	Member
Italy	Salvatore La Rosa	Ministry of Education, University and Research (MIUR)	Ministry	Member
Italy	Michela Vellico	OGS	Representing Entity	2nd Vice Chair
The Netherlands	Gerdi Breembroek	Netherlands Enterprise Agency (RVO)	Ministry	Member
The Netherlands	Jan Hopman	TNO	Representing Entity	Member
Norway	Espen Bernhard Kjærgård	Norwegian Ministry of Petroleum and Energy (OED)	Ministry	Member
Norway	Nils Røkke	SINTEF ER	Representing Entity	Member
United Kingdom	Brian Allison	Department for Business, Energy and Industrial Strategy (BEIS)	Ministry	Member
United Kingdom	Jonathan Pearce	BGS	Representing Entity	Vice Chair

ECCSEL RESEARCH INFRASTRUCTURE COORDINATION COMMITTEE (RICC)

The task of the Research Infrastructure Coordination Committee is to strengthen the cooperation between the facilities and their contributions to experimental research. This is done by overseeing the implementation of ECCSEL ERIC's strategies and plans, by contributing to them, and by proposing measures that can enhance the functioning of ECCSEL ERIC.

MEMBER STATE	INSTITUTE	ECCSEL RICC MEMBERS
Norway (ERIC statutory seat)	Norwegian University of Science and Technology (NTNU)	Morten Grønli (NTNU)
France	The French Geological Survey (BRGM)	Sébastien Dupraz (BRGM)
Italy	National Institute of Oceanography and applied Geophysics (OGS)	Cinzia De Vittor (OGS)
The Netherlands	Netherlands Organisation for Applied Scientific Research (TNO)	Peter van Os (TNO)
United Kingdom	British Geological Survey (BGS)	Keith Bateman (BGS)

OTHER ECCSEL ADVISORY BOARDS AND COMMITTEES

Ethics and Environmental Advisory Board (EEAB)

The EEAB is a group of three to five eminent, independent and experienced scientists. Its main tasks are:

- Review and approve a document with Ethics guidelines which apply as a minimum standard to all facilities that are part of ECCSEL and also to all research being done through ECCSEL.
- Review any ethics and environmental issues that arised during research performed through ECCSEL national or transnational access.

NAME	COUNTRY	INSTITUTE	INVOLVEMENT
			Associate Professor Ethics of Technology, Faculty of Technology, Policy and Management, Delft University of Technology.
Behnam Taebi (Ph.D.)	The Netherlands	Delft University of Technology	Associate, Belfer Center for Science and International Affairs, Kennedy School of Government, Harvard University.
			Member of The Young Academy of the Royal Netherlands Academy of Arts and Sciences (KNAW)
Derek Taylor	Belgium / UK	DMT Energy Consulting sprl	DMT Energy Consulting sprl & Honorary Professor of Geo-Energy (Nottingham University)
Øyvind Mikkelsen	Norway	NTNU	Chair of "The National Committee for Research Ethics in Science and Technology (NENT)

INDUSTRY ADVISORY GROUP (IAG)

The IAG consists of senior industry representatives. Its role is to provide an effective interface between the industry group and the ECCSEL community, to provide guidance on industrial topics and priorities and to report progress to the ECCSEL Operational Centre.

NAME (FIRST, LAST)	INSTITUTE / COMPANY / UNIVERSITY	COUNTRY
Oscar Graff	AkerSolutions	Norway
Ghislain Husson	TOTAL	France
Valerie Czop	EDF	France
Hege Rognø	Statoil	Norway
Andy Read*	ROAD	Netherlands
*until Dec. 2017		

SCIENTIFIC ADVISORY BOARD (SAB)

The Scientific Advisory Board is a permanent Committee that reports through the Director to the General Assembly. Its main task is to provide input to the GA through (solicited and unsolicited) advice on the scientific quality of the services offered by ECCSEL ERIC, the RI's scientific policies, procedures and future plans.

NAME (FIRST, LAST)	INSTITUTE / COMPANY / UNIVERSITY	COUNTRY
Axel Liebscher	Deutsches GeoForschungsZentrum GFZ Potsdam (Helmholtz-Zentrum Potsdam)	Germany
Adam Smolinski	Central Mining Institute GIG (Główny Instytut Górnictwa)	Poland
Sergio Persoglia	Independent	Italy
Eric Favre	University of Lorraine	France

ECCSEL OC STAFF

In 2017:

NAME	ROLE	ORGANISATION
Sverre Quale	Director	ECCSEL ERIC
Volker Röhling	Manager	ECCSEL ERIC
Debbie Koreman van den Bergh	50%	NTNU / ECCSEL ERIC
Helen Taylor	50% position (in kind)	BGS
Michela Vellico	50% position (in kind)	OGS

From 1.1.2018:

NAME	ROLE	ORGANISATION
Sverre Quale	Director	ECCSEL ERIC
Volker Röhling	Manager	ECCSEL ERIC
Debbie Koreman van den Bergh	50%	NTNU / ECCSEL ERIC
Helen Taylor	25% position (in kind)	BGS
Michela Vellico	25% position (in kind)	OGS
Sebastien Dupraz	25% position (in kind)	BRGM
Robert de Kler	20% position (in kind)	TNO

SVERRE QUALE



Sverre was coordinator and Project Director for the ECCSEL preparatory and implementation phases for 5 years until summer 2017 when he was appointed Director of ECCSEL ERIC. Previously he has held several senior positions in both the petroleum industry and the transport sector, including as head of HSE in Saga Petroleum, Director of the National Accident Investigation Board, CEO at the major Engineering company Multiconsult and CEO of the Norwegian Airports and Air Traffic Control.

MICHELA VELLICO



Michela is a senior technologist working for OGS since 2003. She is the Italian National Node coordinator of ECCSEL ERIC and holds a 25% in kind position at ECCSEL ERIC Operations Centre. She is also co-vice chair in the ECCSEL ERIC GA and is responsible for the Italian project "ECCSEL NatLab Italy", aimed at the implementation of two ECCSEL Italian facilities.

VOLKER RÖHLING



Volker is Manager of Administration of ECCSEL ERIC since its implementation on the 9th June 2017. Before that, he was Project Manager at NTNU responsible for the ECCSEL Infradev-3 (H2020) and ECCSEL PP2 (FP7) projects

SEBASTIEN DUPRAZ



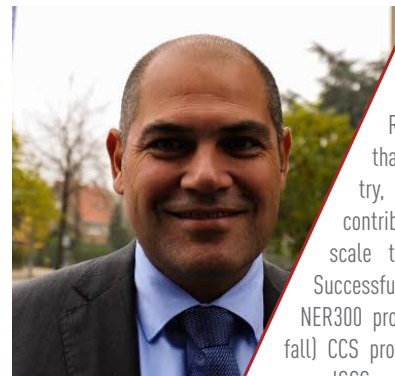
Sebastien is attached to the Laboratory Directorate of BRGM. He is an (bio)-geochemist expert on reservoir issues and the RICC representative for the French Node. Since 2018, he holds a 25% in position at ECCSEL ERIC Operation Centre on matters related to the coordination and access to ECCSEL ERIC Facilities. In May 2018, he was also appointed co-vice chairman of the ECCSEL ERIC RICC.

DEBBIE KOREMAN VAN DEN BERGH



Debbie is a Higher Executive Officer working for the Department of Energy and Process Engineering at NTNU since 2009. She works currently 50% of her time for the ECCSEL ERIC Operations Centre as Administrative Coordinator. Before she already worked a small percentage of her time in the ECCSEL Infradev-3 and ECCSEL PP2 projects as in-kind of NTNU-EPT.

ROBERT DE KLER



Robert has been active for more than 20 years in the power industry, including CCS activities. His main contributions & experiences are large scale technology demonstration projects. Successfully managed: an industrial CCS NER300 project application, the Nuon (Vattenfall) CCS programme - pilot test plant at Buggenum IGCC and a full scale demo at the Magnum plant (2006-2009). He has been almost for 10 years responsible for the research and development activities at Nuon (Vattenfall). Currently Mr. de Kler is involved in several innovations, including CCUS projects and developments of new technology pathways.

HELEN TAYLOR



Helen has been a geochemist with BGS since 2001 and now manages the ECCSEL CAT-1 facility BGS Near Surface Gas Monitoring. She is the UK National Node coordinator of ECCSEL ERIC and holds a 25% in kind position at ECCSEL ERIC Operations Centre. She is also responsible for coordinating ECCSEL's Research Strategy Document.

PUBLICATIONS AND EVENTS

Below is a selection of publications and events. More extensive information can be found on the ECCSEL website.

Italy

Publications:

Massimiliano Molari, Katja Guilini, Christian Lott, Miriam Weber, Dirk de Beer, Stefanie Meyer, Alban Ramette, Gunter Wegener, Frank Wenzhöfer, Daniel Martin, Tamara Cibic, Cinzia De Vittor, Ann Vanreusel, Antje Boetius
"CO₂ leakage alters biogeochemical and ecological functions of submarine sands", *Science Advances*. February 2018

Relitti F., Ogrinc N., Giani M., Cerino F., De Vittor C., Urbini L., Krajnc B., Del Negro P.
"Stable carbon isotopes in phytoplankton as a tool to monitor CO₂ leakages at Carbon Capture and Storage sites", Under review on: *Environmental Science and Pollution Research*.

Presentations at conferences:

Vellico M., Quale S., Röhling V.
"Implementation of the European CCS Research Infrastructure ECCSEL - Experiences and Remaining Activities", 12th CO₂GeoNet Open Forum, 8th-9th May 2017, (Presentation given by Michela Vellico)

Relitti F., Ogrinc N., Giani M., Cerino F., De Vittor C., Krajnc B., Del Negro P.
"Stable carbon isotopes in phytoplankton as a tool to monitor CO₂ leakage at Carbon Capture and Storage sites", XIII INCONTRO DEI DOTTORANDI IN ECOLOGIA E SCIENZE DEI SISTEMI ACQUATICI. 3th – 5th May 2017, Palermo, (Presentation given by Federica Relitti)

Relitti F., Ogrinc N., Giani M., Cerino F., De Vittor C., Urbini L., Krajnc B., Del Negro P.
"Stable carbon isotopes in phytoplankton as a tool to monitor CO₂ leakages at Carbon Capture and Storage sites", Gruppo di Algologia – Società Botanica Italiana. 10th-11th November 2017, Trieste, (Presentation given by Federica Relitti)

Posters at conferences:

De Vittor C., Vellico M., Kralj M., Pavan A. "ECCSEL NatLab Italy – one of the Italian components of ECCSEL RI", 12th CO₂GeoNet Open Forum, 8th-9th May 2017

Giani M., Relitti F., Ogrinc N., Cerino F., De Vittor C., Urbini L., Krajnc B., Del Negro P.
"Monitoring CO₂ leakage at Carbon Capture and Storage sites using stable carbon isotopes in phytoplankton", XXIII AIOL Conference. 26th-28th September 2017, Cagliari.

Events:

- Organization of two National Info Days: Rome, 2nd March 2017 and Trieste, 6th July 2017
- Organization of one training course on Research Infrastructures for CO₂ storage, with specific focus on monitoring and natural laboratories: Rome, 29th March 2017
- Opening of the ECCSEL NatLab Italy laboratory of Latera: 15th September 2017

France

Presentation of ECCSEL at international conferences:

12th CO₂GeoNet Open Forum, 8th-9th May 2017: poster presentation
Czernichowski-Lauriol I., Czop V., Dupraz S., Farret R., Gombert P., Husson G., Le Thiez P., Rouchon V., Schumacher S.

CO₂ capture, transport and storage research facilities from the French node of ECCSEL available for access by the European scientific community.

9th "Trondheim Conference on CO₂ Capture, Transport and Storage" (TCCS-9), Jun 2017, Trondheim, Norway: oral presentation

Czernichowski-Lauriol I., Czop V., Dupraz S., Farret R., Gombert P., Husson G., Le Thiez P., Rouchon V., Schumacher S.

"CO₂ capture, transport and storage research facilities from the French node of ECCSEL available for access by the European scientific community".

<https://www.sintef.no/projectweb/tccs-9/>

Presentation of ECCSEL at national events:

- 2nd ECCSEL National InfoDay, 6 March 2017, Paris: various oral presentations.
- Pôle AVENIA General Assembly, 26 June 2017, Pau: oral presentation by Isabelle Czernichowski-Lauriol. "ECCSEL, une Infrastructure de Recherche européenne sur le Captage et Stockage de CO₂" AVENIA is the French competitiveness cluster in the geosciences sector.
- Mission Innovation CCUS National Seminar, 19 December 2017, Paris : oral presentation by Isabelle Czernichowski-Lauriol. "ECCSEL, une Infrastructure de Recherche européenne sur le Captage et Stockage de CO₂"

UK

Events:

- Presentation on ECCSEL, UK-ESFRI working group, Swindon UK
- ECCSEL - EPOS working group meeting
- Hosted ECCSEL ERIC RICC meetings and General Assembly, November 2017.

CCS Publications:

Koukouzas, N.K., Kypritidou, Z., Vasilatos, C., Tsoukalas, N., Rochelle, C.A. and Purser, G. (2017). Geochemical modelling of carbonation of hydrated oil well cement exposed to CO₂-saturated brine solution. *Applied Geochemistry*, 85, 35–48.

Bentham, M., Williams, G., Vosper, H., Chadwick, A., Williams, J. and Kirk, K. (2017). Using pressure recovery at a depleted gas field to understand saline aquifer connectivity. *Energy Procedia*, 114, 2906–2920.

Akhurst, M., Mallows, T., Pearce, J. and Mackay, E. (2017). Assessing interactions between multiple geological CO₂ storage sites to optimize capacity in regionally extensive storage sandstones. *Energy Procedia*, 114, 4571–4582.

Vincent, C.J., Bentham, M.S., Kirk, K.L., Akhurst, M.C. and Pearce, J.M. (2017). Evaluation of barriers to national CO₂ geological storage assessments. *Energy Procedia*, 114, 4750–4756.

Gent, C.M.A. (2017) CO₂ Storage Potential of the Eocene Tay Sandstone, Central North Sea. Poster presentation, EGU, Vienna, Austria.

Monaghan, A. A., Arsenikos, S., Quinn, M. F., Johnson, K. R., Vincent, C. J., Vane, C. H., Kim, A. W., Uguna, C. N., Hannis, S. D., Gent, C. M. A., Millward, D., Kearsey, T. I.,

Williamson, J. P. (2017). Carboniferous petroleum systems around the Mid North Sea High, UK. *Marine and Petroleum Geology*, 88, 282-302.

Hayden Morgan, David Large, Keith Bateman, David Hanstock and Simon Gregory (2017). The effect of variable oxygen impurities on microbial activity in conditions resembling geological storage sites. *Energy Procedia* 114: 377-3087

Harrington, J.F., Cuss, R.J., and Talandier, J. (2017). Gas transport properties through intact and fractured Callovo-Oxfordian mudstones. In Rutter, E.H., Mecklenburgh, J. & Taylor, K.G. (eds) *Geomechanical and Petrophysical Properties of Mudrocks*. Geological Society, London, Special Publications, 454, <https://doi.org/10.1144/SP454.7>

Cuss, R.J., Harrington, J.F., Sathar, S., Norris, S. and Talandier, J., (2017). The role of the stress- path and importance of stress history on the flow of water along fractures and faults; an experimental study conducted on kaolinite gouge and Callovo-Oxfordian mudstone. *Applied Clay Science*, 150, pp.282-292.

Elena Diego M, Bellas J-M & Pourkashanian M (2017). Process Analysis of Selective Exhaust Gas Recirculation for CO₂ Capture in Natural Gas Combined Cycle Power Plants Using Amines. *Journal of Engineering for Gas Turbines and Power*, 139(12).

Xie P, Lu X, Yang X, Ingham D, Ma L & Pourkashanian M (2017) Characteristics of liquid flow in a rotating packed bed for CO₂ capture: A CFD analysis. *Chemical Engineering Science*, 172, 216-229.

Diego de Paz M, Akram M, Bellas J-M, Finney K & Pourkashanian M (2017). Making gas-CCS a commercial reality: The challenges of scaling up. *Greenhouse Gases: Science and Technology*, 7(5), 778-801.

Ali U, Font-Palma C, Akram M, Agbonghae EO, Ingham DB & Pourkashanian M (2017). Comparative potential of natural gas, coal and biomass fired power plant with post-combustion CO₂ capture and compression. *International Journal of Greenhouse Gas Control*, 63, 184-193.

Simoes MC, Hughes KJ, Ingham DB, Ma L & Pourkashanian M (2017). Temperature Dependence of the Parameters in the Pitzer Equations. *Journal of Chemical & Engineering Data*, 62(7), 2000-2013.

Simoes MC, Hughes KJ, Ingham DB, Ma L & Pourkashanian M (2017) Estimation of the Thermochemical Radii and Ionic Volumes of Complex Ions. *Inorganic Chemistry*, 56(13), 7566-7573.

Ali U, Font-Palma C, Nikpey Somehsaraei H, Mansouri M, Akram M, Finney K, Best T, Mohd Said NB, Assadi M & Pourkashanian M (2017) Benchmarking of a micro gas turbine model integrated with post-combustion CO₂ capture. *Energy*, 128, 475-487.

Erete JI, Hughes KJ, Ma L, Fairweather M, Pourkashanian M & Williams A (2017) Effect of CO₂ dilution on the structure and emissions from turbulent, non-premixed methane-air jet flames. *Journal of the Energy Institute*, 90(2), 191-200.

Bhava A, Taylor RHS, Fennell P, Livingston WR, Shah N, Dowell NM, Dennis J, Kraft M, Pourkashanian M, Insa M, Jones J, Burdett N, Bauen A, Beal C, Smallbone A & Akroyd J (2017). Screening and techno-economic assessment of biomass-based power generation with CCS technologies to meet 2050 CO₂ targets. *Applied Energy*, 190, 481-489.

Li J, Ingham D, Ma L, Wang N & Pourkashanian M (2017). Numerical Simulation of the Chemical Combination and Dissociation Reactions of Neutral Particles in a Rarefied Plasma Arc Jet. *IEEE Transactions on Plasma Science*, 45(3).

Ali U, Hughes KJ, Ingham DB, Ma L & Pourkashanian M (2017) Effect of the CO₂ enhancement on the performance of a micro gas turbine with a pilot-scale CO₂ capture plant. *Chemical Engineering Research and Design*, 117, 11-23.

Norway

CCS Publications:

Alessio Masala, Jenny G. Vitello, Giorgia Mondino, Carlos A. Grande, Richard Blom, Maela Manzoli, Marc Marshall and Silvia Bordiga.

"CO₂ Capture in Dry and Wet Conditions in UTSA-16 Metal-Organic Framework", *Applied Materials & Interfaces*, 2017, 9, 455-463. DOI: 10.1021/acsami.6b13216

Lind, Anna; Thorshaug, Knut; Andreassen, Kari-Anne; Blom, Richard; Arstad, Bjørnar "The role of water during CO₂ adsorption by Ca-based sorbents at high temperature.", *Ind. Eng. Chem. Res.*, 2018, 57, 2829-2837. DOI: 10.1021/acs.iecr.7b04052

G. N. Kalantzopoulos, F. Lundvall, S. Checchina, A. Lind, D. S. Wragg, H. Fjellvåg, B. Arstad "In Situ Flow MAS NMR Spectroscopy and Synchrotron PDF Analyses of the Local Response of the Brønsted Acidic Site in SAPO-34 during Hydration at Elevated Temperatures", *ChemPhysChem*, 2018, 19, 519-528. DOI: 10.1002/cphc.201700973

B. Arstad, R. Blom, T. Didriksen, M. Frøseth, R. H. Heyn and S. Øien-Ødegaard "NMR spectroscopic investigation into the mechanism of absorption and desorption of CO₂ by (trispyridyl) amine Zn complexes" *J. CO₂ Utilization*, 2017, 19, 58-67. DOI: 10.1016/j.jcou.2017.02.007

Peters, T.A., Rørvik, P.M., Sunde, T.O., Stange, M., Roness, F., Reinertsen, T.R., Ræder, J.H., Larring, Y., Bredeesen, R., "Palladium (Pd) membranes as key enabling technology for pre-combustion CO₂ capture and hydrogen production", *Energy Procedia*, 114 (2017) 37-45.

Acronyms and Abbreviations

CCS:	Carbon (Dioxide) Capture, Transport and Storage
ECCSEL:	European Carbon Dioxide Capture and Storage Laboratory Infrastructure
EEAB:	Ethics and Environmental Advisory Board
ERIC:	European Research Infrastructure Consortium
ESFRI:	European Strategy Forum for Research Infrastructures
GA:	General Assembly
IAG:	Industry Advisory Group
Node:	ECCSEL ERIC country node responsible for coordinating activities on country level
OC:	ECCSEL Operations Centre
RI:	Research Infrastructure
RICC:	ECCSEL Research Infrastructure Coordination Committee
SAB:	Scientific Advisory Board

APPENDIX
FINANCIAL REPORT
AUDITORS REPORT

ECCSEL
ERIC

Financial Statements 2017 for ECCSEL European Research Infrastructure Consortium

Organization no. 919298243



Prepared by:
Sparebank 1 Regnskapshuset Smn AS
Authorised accountant company
Søndre gate 4
7011 TRONDHEIM
Organization no. 936285066

Income statement

Currency: EUR	Note	Jun-Dec 17	Budget 2017
OPERATING REVENUE AND EXPENSES			
Operating revenue			
Revenue	1	134 715	160 000
Total operating revenue		134 715	160 000
Operating expenses			
Other operating expenses	2	101 129	160 000
Total operating expenses		101 129	160 000
OPERATING PROFIT OR LOSS		33 586	0
FINANCIAL INCOME AND EXPENSES			
Financial income			
Other financial income		1 479	0
Total financial income		1 479	0
Financial expenses			
Other interests		1	0
Other financial expenses		117	0
Total financial expenses		118	0
NET FINANCIAL INCOME AND EXPENSES		1 361	0
ORDINARY RESULT BEFORE TAXES		34 947	0
Tax on ordinary result		0	0
ORDINARY RESULT		34 947	0
APPLICATION AND ALLOCATION			
To/from other equity	3	34 947	0
TOTAL APPLICATION AND ALLOCATION		34 947	0

Balance sheet as at 31.12.2017

Currency: EUR	Note	31.12.2017
ASSETS		
CURRENT ASSETS		
Receivables		
Trade receivables		106 896
Other short-term receivables	4	24 275
Total receivables		131 171
Bank deposits, cash in hand, etc.	5	24 679
TOTAL CURRENT ASSETS		155 850
TOTAL ASSETS		155 850
EQUITY AND LIABILITIES		
EQUITY		
Retained earnings		
Other equity	3	34 287
Total retained earnings		34 287
TOTAL EQUITY		34 287
LIABILITIES		
CURRENT LIABILITIES		
Accounts payable		121 375
Other current liabilities	4	188
TOTAL CURRENT LIABILITIES		121 563
TOTAL LIABILITIES		121 563
TOTAL EQUITY AND LIABILITIES		155 850

Trondheim 19/6.2018


Sverre Quale
CEO

Notes 2017

Accounting principles

The annual financial statements have been prepared in accordance with the Accounting Act and Good accounting practice for small enterprises.

Current assets and current liabilities

Current assets and current liabilities generally include items due for payment within one year after the last day of the accounting year, as well as items related to the product cycle. Current assets are valued at the lower of cost and assumed fair value.

Fixed assets and long-term liabilities

Fixed assets comprise assets intended for permanent ownership and use. Fixed assets are valued at acquisition cost. Tangible fixed assets are capitalized and depreciated over the expected economic life of the asset. Tangible fixed assets are subject to a written-down to recoverable amount in case of impairment, which is not expected to be temporary. The write-down is reversed when the basis for the write-down is no longer present.

Recognition

Revenue from the sale of goods and services takes place at the time of delivery. The share of sales revenues related to future services is capitalized as unearned income and is subsequently recognized as income in accordance with delivery of the service.

Receivables

Trade receivables are capitalized at nominal value after deduction of deposition for expected losses. Deposition for expected losses are made based on an individual assessment of the individual receivables. In addition, for other accounts receivable, an unspecified deposition is made to cover expected losses.

Tax

The company is not taxable.

Notes 2017

Note 1 - Member Countries

Member Country	Member Countries Representing Entity
Norway (ERIC Statutory seat)	Norwegian University of Science and Technology (NTNU) together with SINTEF Energy Research (SINTEF ER)
France	The French Geological Survey (BRGM)
Italy	National Institute of Oceanography and Experimental Geophysics (OGS)
The Netherlands	Netherlands Organisation for Applied Scientific Research (TNO)
United Kingdom	British Geological Survey (BGS)

Operating revenue provided by ECCSEL ERIC annual member fees.

Note 2 - Other operating expenses

The company has three employees seconded from NTNU from September 2017 (equivalent to two and a half full time positions). The paid salary cost is EUR 97 008 excl. VAT.

The company has paid remuneration to the auditor with the following amounts:

	This year
Audit	906
Total	906

Note 3 - Other equity

	Other equity	Sum equity
Pr incorporation 09.06.17	0	0
Applied from annual results	34 947	34 947
Currency differences	-660	-660
Pr 31.12.	34 287	34 287

Notes 2017

Note 4 - Receivables and debt

	2017
Receivables due later than one year after the balance sheet date	0
Liabilities due later than five years after the balance sheet date	0

Note 5 - Bank deposits

The bank deposits do not include any restricted funds.

Independent Auditor's Report

To the General Meeting of Eccsel ERIC

Report on the Audit of the Financial Statements

Opinion

We have audited the financial statements of Eccsel ERIC which comprise the balance sheet as at 31 December 2017, the income statement for the year then ended, and notes to the financial statements, including a summary of significant accounting policies.

In our opinion, the accompanying financial statements are prepared in accordance with law and regulations and give a true and fair view of the financial position of the Company as at 31 December 2017, and its financial performance for the year then ended in accordance with the Norwegian Accounting Act and accounting standards and practices generally accepted in Norway.

Basis for Opinion

We conducted our audit in accordance with laws, regulations, and auditing standards and practices generally accepted in Norway, including International Standards on Auditing (ISAs). Our responsibilities under those standards are further described in the *Auditor's Responsibilities for the Audit of the Financial Statements* section of our report. We are independent of the Company as required by laws and regulations, and we have fulfilled our other ethical responsibilities in accordance with these requirements. We believe that the audit evidence we have obtained is sufficient and appropriate to provide a basis for our opinion.

Responsibilities of the Managing Director for the Financial Statements

The Managing Director (management) are responsible for the preparation in accordance with law and regulations, including fair presentation of the financial statements in accordance with the Norwegian Accounting Act and accounting standards and practices generally accepted in Norway, and for such internal control as management determines is necessary to enable the preparation of financial statements that are free from material misstatement, whether due to fraud or error.

In preparing the financial statements, management is responsible for assessing the Company's ability to continue as a going concern, disclosing, as applicable, matters related to going concern. The financial statements use the going concern basis of accounting insofar as it is not likely that the enterprise will cease operations.

Auditor's Responsibilities for the Audit of the Financial Statements

Our objectives are to obtain reasonable assurance about whether the financial statements as a whole are free from material misstatement, whether due to fraud or error, and to issue an auditor's report that includes our opinion. Reasonable assurance is a high level of assurance, but is not a guarantee that an audit conducted in accordance with laws, regulations, and auditing standards and practices generally accepted in Norway, including



ISAs will always detect a material misstatement when it exists. Misstatements can arise from fraud or error and are considered material if, individually or in aggregate, they could reasonably be expected to influence the economic decisions of users taken on the basis of these financial statements.

As part of an audit in accordance with laws, regulations, and auditing standards and practices generally accepted in Norway, including ISAs, we exercise professional judgment and maintain professional scepticism throughout the audit. We also:

- identify and assess the risks of material misstatement of the financial statements, whether due to fraud or error. We design and perform audit procedures responsive to those risks, and obtain audit evidence that is sufficient and appropriate to provide a basis for our opinion. The risk of not detecting a material misstatement resulting from fraud is higher than for one resulting from error, as fraud may involve collusion, forgery, intentional omissions, misrepresentations, or the override of internal control.
- obtain an understanding of internal control relevant to the audit in order to design audit procedures that are appropriate in the circumstances, but not for the purpose of expressing an opinion on the effectiveness of the Company's internal control.
- evaluate the appropriateness of accounting policies used and the reasonableness of accounting estimates and related disclosures made by management.
- conclude on the appropriateness of management's use of the going concern basis of accounting and, based on the audit evidence obtained, whether a material uncertainty exists related to events or conditions that may cast significant doubt on the Company's ability to continue as a going concern. If we conclude that a material uncertainty exists, we are required to draw attention in our auditor's report to the related disclosures in the financial statements or, if such disclosures are inadequate, to modify our opinion. Our conclusions are based on the audit evidence obtained up to the date of our auditor's report. However, future events or conditions may cause the Company to cease to continue as a going concern.
- evaluate the overall presentation, structure and content of the financial statements, including the disclosures, and whether the financial statements represent the underlying transactions and events in a manner that achieves fair presentation.

We communicate with the Managing Director regarding, among other matters, the planned scope and timing of the audit and significant audit findings, including any significant deficiencies in internal control that we identify during our audit.



Report on Other Legal and Regulatory Requirements

Opinion on Registration and Documentation

Based on our audit of the financial statements as described above, and control procedures we have considered necessary in accordance with the International Standard on Assurance Engagements (ISAE) 3000, *Assurance Engagements Other than Audits or Reviews of Historical Financial Information*, it is our opinion that management has fulfilled its duty to produce a proper and clearly set out registration and documentation of the Company's accounting information in accordance with the law and bookkeeping standards and practices generally accepted in Norway.

Trondheim, 27 June 2018
BDO AS

A handwritten signature in blue ink, appearing to read 'Arve Sunde'.

Arve Sunde
State Authorised Public Accountant

APPENDIX
RESEARCH
INFRASTRUCTURE

ECCSEL
ERIC

INFRASTRUCTURE NAME:	BRGM BIOREP
LOCATION:	ORLEANS, FRANCE
WEB SITE ADDRESS:	WWW.BRGM.FR
INFRASTRUCTURE'S OPERATOR:	BRGM
CATEGORY:	STORAGE

Description of the facility: The BIOREP facility is a high pressure set up to perform percolation and transfer experiments on fluid-rock interactions under a large range of pressure and temperature conditions, while continuously monitoring geochemical and bio-geochemical evolution. The facility is particularly adapted to monitor biological system evolution during the experiment. The range of pressure and temperature of BIOREP allows simulating conditions that are typical for CO₂ storage or for CO₂ leakage, along a deep well or in the overburden.

State of the art: BIOREP allows the monitoring of microbiological systems in high pressure and dynamic conditions, which is unique. In particular, BIOREP differs from other facilities in respect of the biologic neutrality of the containment and limit the risk of bio-corrosion associated.

Services offered: Thanks to its modular and compartmentalized conception, BIOREP allows a wide range of experiment to study microbiological and geochemical processes with in situ conditions – typical for CO₂ storage or related to (well, overburden condition).



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INFRASTRUCTURE NAME:	URL-ANDRA
LOCATION:	BURE, FRANCE
WEB SITE ADDRESS:	WWW.ANDRA.FR
INFRASTRUCTURE'S OPERATOR:	ANDRA - FRENCH NATIONAL RADIOACTIVE WASTE MANAGEMENT AGENCY
CATEGORY:	STORAGE

Description of the facility: The site selected is located on the eastern boundary of the Paris Basin. Its claystone formations, due to in particular a very low permeability and high confining properties, are suitable for CO₂ studies. In this region, the Callovo-Oxfordian formation lies between around 420 m to 600 m deep, and its thickness is at least about 130 m. The Callovo-Oxfordian formation is surrounded by two main calcareous formations. The site has opened for CO₂ studies in the framework of ECCSEL. The MHM URL consists of 2 shafts of 500 m and 1 drift 40 m long at –445m. More than 11 000 sensors have been installed in the rock, inside boreholes, in the drifts, in the shafts, allowing a continuous monitoring at distance. The type of sensors tested is very large according to concerned Thermal, Hydraulic, Mechanical, Chemical and Radiological domains.

State of the art: In France, the MHM URL is the only facility accessible for in situ experiments in a deep clay formation at 500 m depth, with a hydraulic pressure of 46 bars and a vertical stress of 12 MPa, allowing to perform different tests from small scale to large scale and in representative conditions of these ones of a cap-rock for capture and storage CO₂ concept. The geological environment is already well defined.

Services offered: The MHM URL benefits from the support of Andra's technicians and engineers: 40 scientists of Andra specialized in geology, rock mechanics, hydrogeology, chemistry, fluid transfer, biology, corrosion, sensors and data acquisition system, work on site. A specific team provides support in designing and setting up experiments. Full range of support can be provided.

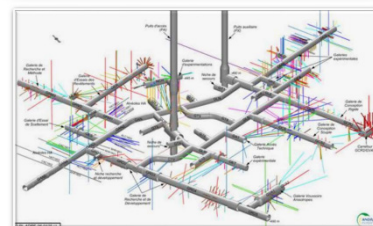


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INFRASTRUCTURE NAME:	LE HAVRE CO ₂ CAPTURE PILOT
LOCATION:	LE HAVRE, FRANCE
WEB SITE ADDRESS:	WWW.EDF.FR
INFRASTRUCTURE'S OPERATOR:	EDF
CATEGORY:	CAPTURE

Description of the facility: Post-combustion CO₂ capture pilot on coal power plant flue gas. This facility allows all post-combustion processes testing on coal flue gas: with minor modifications for solvent based processes, more important for other processes. The CO₂ contained in flue gas contains is 12 vol% and the facility can capture 25 t CO₂/day (or less). The present equipment is a 'classical' solvent based process pilot. This equipment can be adapted to host different processes without building totally a new pilot.

State of the art: A rare post-combustion CO₂ capture pilot in an operational 600 MW Power Plant in Europe.

Services offered: Can be adapted to the user's needs.



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INFRASTRUCTURE NAME:	SAFETY
LOCATION:	CATENNOY, FRANCE
WEB SITE ADDRESS:	WWW.INERIS.FR
INFRASTRUCTURE'S OPERATOR:	INERIS
CATEGORY:	TRANSPORT

Description of the facility: Reference site allowing trials on various types of pipes and gases (namely CO₂), including massive gas leakages and the measurement of their thermodynamic behaviour. The site enables to manage gases under high pressures (between 100 and 200 bars) and to simulate gas leakages or breaches on industrial equipment on pipes with diameters of 1 to 3 inches.

State of the art: This permanent equipment on the site of Montlville are widely recognized for safety purposes in the industry. It is possible to adapt the equipment to answer specific problems connected to the industrial safety for toxic and flammable gases – either to study the gas behaviour, to improve modeling tolls or to test risk prevention barriers. This reference site is unique in France and well-known in Europe, allowing experiments on various types of pipes and gases.

Services offered: Located 3 km from INERIS, the site can easily be operated and monitored.



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INFRASTRUCTURE NAME:	CATLAB
LOCATION:	CATENOY, FRANCE
WEB SITE ADDRESS:	WWW.INERIS.FR
INFRASTRUCTURE'S OPERATOR:	INERIS
CATEGORY:	STORAGE

Description of the facility: An injection site in underground environment with controlled conditions and **in situ measurements devices**, coupled with advanced laboratory facilities at INERIS to measure gaz-water-rock interaction. **9 piezometers of 25 m depth**, in the chalky aquifer of Paris Basin. It comprises 4 less deep "piezairs" of 11 m (in the not saturated zone), a technical shed including station dedicated to continuous gas monitoring and a meteo station. CO₂ can be injected in the chalk aquifer at a depth to be chosen between 13 and 25 m, in order to simulate a leakage from a gas storage that is supposed to be located beneath.

State of the art: The injection site can be operated at low cost. The aquifer and its natural flow were thoroughly characterized through previous projects. The use of such a site for monitoring for direct CO₂ injection and for push-pull experiments is unique in France and probably in Europe.

Services offered: The injection site can easily be operated and monitored. Besides the in-situ measurement, dedicated samplings and lab measurements can be carried out.

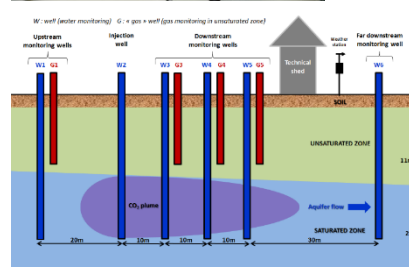


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INFRASTRUCTURE NAME:	ESCORT
LOCATION:	FRANCE
WEB SITE ADDRESS:	WWW.IFPENENERGIESNOUVELLES.FR
INFRASTRUCTURE'S OPERATOR:	IFPEN
CATEGORY:	STORAGE

Description of the facility: The ESCORT station, an equipment for Soil CO₂ Origin Tracking is dedicated to the monitoring of the natural gas exchange between the atmosphere and the soil vadose zone and thus provides the description of the time dependent natural baseline of soil gases. It involves both an equipment and a data treatment software. A baseline model is then defined and may be used as a reference for further monitoring of underground CO₂ leakage. The station may be deployed on pilot or industrial sites if required, in order to define soil baseline conditions and leakage monitoring.

State of the art: ESCORT comprises all necessary equipment in a single station for an autonomous, long-term CO₂ baseline survey. It thus minimizes personnel costs and enhances data representativeness.

Services offered: The scientific team at IFPEN can provide technical/scientific support for the development of soil gas monitoring technologies, and/or design of test sites



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INFRASTRUCTURE NAME:	GASGEOCHEM
LOCATION:	FRANCE
WEB SITE ADDRESS:	WWW.IFPENERGIESNOUVELLES.FR
INFRASTRUCTURE'S OPERATOR:	IFPEN
CATEGORY:	STORAGE

Description of the facility: The gas geochemistry lab at IFPEN combines the instrumentation and expertise to analyse and interpret gas geochemistry data including: Major gas composition including CO₂, N₂, O₂, He, methane, ethane, propane, butane, H₂, H₂S; Stable isotopic composition of carbon in CO₂, methane, ethane, propane, butane; Stable isotopic composition of H in H₂, methane, ethane, propane, butane
Noble gas concentration of traces of He, Ne, Ar, Kr, Xe; Isotopic composition of He (3He/4He ratio) and Ar (40Ar/36Ar ratio).

State of the art: State of the art analyses of gas geochemistry. Unique for this lab is the full integration of data production across different instruments on a single sample aliquot with great care to maximise data consistency from major gas composition to fine isotopic compositions of trace compounds.

Services offered: The sampling equipment may be provided if necessary. Assistance during sampling campaigns can be provided. Field gas analysers can be brought to sampling sites in order to give first estimates of gas compositions and presence of hazardous compounds.



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INFRASTRUCTURE NAME:	RESEARCH AIRCRAFT EQUIPPED WITH HIGH-TECH REMOTE SENSING INSTRUMENTS
LOCATION:	TRIESTE, ITALY
WEB SITE ADDRESS:	WWW.OGS.TRIESTE.IT
INFRASTRUCTURE'S OPERATOR:	OGS (ISTITUTO NAZIONALE DI OCEANOGRAFIA E DI GEOFISICA SPERIMENTALE)
CATEGORY:	STORAGE

Description of the facility: The Piper Seneca III aircraft is property of OGS and managed by a team of expert researchers and technicians. It is equipped with the most advanced remote sensing instruments. The performance of the installation is very high.

State of the art: The fully instrumentally equipped Piper Seneca III is part of EUFAR (European Facility for Airborne Research). Its instrumental equipment has been used for remote sensing surveys in several European projects. This aircraft is unique because it integrates different instruments on board and can accommodate additional new equipment provided by group of researchers.

Services offered: The aircraft can operate over the whole European territory. Accurate remote sensing surveys over wide areas, onshore and offshore can be done. Flight crews organise all logistics of the flights and decide, in consultation with the users the time and atmospheric conditions for the acquisition of their data. Training on processing and analysis of remote sensing data can be provided, as well as support for the inclusion of new routines into the base processing packages.



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INFRASTRUCTURE NAME:	ECOLOGICAL LABORATORY FOR MICROCOSM/ MESOCOSM EXPERIMENTS (BIOMARINELAB)
LOCATION:	TRIESTE, ITALY
WEB SITE ADDRESS:	WWW.OGS.TRIESTE.IT
INFRASTRUCTURE'S OPERATOR:	OGS (ISTITUTO NAZIONALE DI OCEANOGR- FIA E DI GEOFISICA SPERIMENTALE)
CATEGORY:	STORAGE

Description of the facility: The BioMarineLab offers a wide range of laboratories and technical and scientific facilities. This installation is equipped for studies in the marine biology field concerning biogeochemical analysis of sediments and overlayer water, characterization of plankton, identification of the role of biological activities in the release or uptake of CO₂ in the water column and at the sediment-water interface, evaluation of microbial activities variation as consequence of CO₂ concentration changes, toxicological and physiological responses of invertebrates. The equipment and expertise in the installation allow determining the main parameters necessary to describe both the carbonate system and the organic carbon cycle in order to fully characterized marine sites in terms of leakage detection and quantification.

State of the art: This installation is "unique" due to its proximity to the sea, the availability of running seawater and the existing collection of planktonic organisms. Field work at storage sites and natural CO₂ seeps that serve as analogues for potential CO₂ leaks, can be supported by large range of laboratory experiments. The installation has been and is used for national and EC-funded research.

Services offered: All analytical activities carried out in the Microbiological, Ecology, Primary Productivity, Molecular Biology and Biogeochemistry Laboratories are offered by this installation. The technical and logistic support offered to the users will be guaranteed both inside the laboratories as during the field activities.



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INFRASTRUCTURE NAME:	PANAREA NAT LAB
LOCATION:	ITALY (PANAREA)
WEB SITE ADDRESS:	WWW.OGS.TRIESTE.IT
INFRASTRUCTURE'S OPERATOR:	OGS (ISTITUTO NAZIONALE DI OCEANOLOGRAFIA E DI GEOFISICA SPERIMENTALE)
CATEGORY:	STORAGE

Description of the facility: Panarea is a natural laboratory where thermo-magmatic CO₂ is leaking at substantial rates from the seafloor at water depths ranging from 5 to 30 m. The majority of this CO₂ is released in an area 3 km to the East of Panarea. This natural CO₂-release field (c. 3 km²) has been active for centuries, with gas emanating from a series of NW-SE and NE-SW trending fractures. This natural laboratory provides the opportunity to study gas migration in different structural and geological settings. It can be used to study the ascent of CO₂ through sedimentary strata, to decipher the dynamics of gas bubble and droplet plumes, to understand the impact of CO₂ on benthic organisms and marine ecosystems, and to test and improve CO₂ monitoring techniques.

State of the art: The system is relatively stable in both gas chemistry (e.g. 98% CO₂, 1.7% H₂S plus other trace gases) and flux rates (7-9 x 10⁶ l/d). Based on the range of depths and relatively high and persistent gas flow rates, the occurrence of both gas only and gas-water seepage, and its close proximity to shore, Panarea represents an exceptional location to study natural processes and impacts related to shallow seabed CO₂ leakage. Due to the unique characteristics of this site, the Italian Ministry MIUR financed the setting up of a permanent laboratory, which offers logistical and scientific support to the researchers utilising the site.

Services offered: Scientists also have access to a well-equipped computer and electronics lab. The on land installation will also be equipped to maintain, calibrate and in real time connect the permanent sensor network, which will be installed in correspondence of the natural CO₂ leakages.



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INFRASTRUCTURE NAME:	LATERA NAT LAB
LOCATION:	ITALY (LATERA)
WEB SITE ADDRESS:	WWW.OGS.TRIESTE.IT
INFRASTRUCTURE'S OPERATOR:	OGS (ISTITUTO NAZIONALE DI OCEANOLOGRAFIA E DI GEOFISICA SPERIMENTALE)
CATEGORY:	STORAGE

Description of the facility: The laboratory is located within the Latera caldera (central Italy), a volcanic structure that has not been active for over 0.16 Ma but which still maintains a very high geothermal gradient. It is this elevated heat flow that results in the thermo-metamorphic alteration of buried carbonate units and associated production of natural CO₂ and associated traces gases like CH₄, H₂S, and H₂. This laboratory represents the ideal location to conduct experiments on on-shore monitoring and their impacts on terrestrial ecosystems.

The caldera can simulate a CCS scenario, where CO₂ escapes. Some innovative monitoring techniques can be easily tested, thanks to the high CO₂ concentration of the gas fluxes over the area. The laboratory has an operations room, equipped with facilities dedicated to real time data control and data post processing. Three fixed stations, located in the caldera, continuously measure CO₂, temperature and pH. Portable systems for CO₂, temperature and humidity measurements are available in the lab, to perform some surveys in the Latera area.

State of the art: The possibility to test and calibrate innovative monitoring techniques, including remote sensing, in an area where CO₂ leakages are present, is a key aspect for the CCS frontier improvement. Latera NatLab valorises the area and adds an important value to CCS studies.

Services offered: OGS is responsible for the Latera NatLab and manages this permanent laboratory, offering logistical and scientific support to the researchers utilising the site.



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INFRASTRUCTURE NAME:	PITOP
LOCATION:	ITALY (TRAVESIO)
WEB SITE ADDRESS:	WWW.OGS.TRIESTE.IT
INFRASTRUCTURE'S OPERATOR:	OGS (ISTITUTO NAZIONALE DI OCEANO- OGRAFIA E DI GEOFISICA SPERIMENTALE)
CATEGORY:	STORAGE

Description of the facility: The OGS geophysical-drilling testing site (PITOP) was set up with the purpose of providing a framework facility for studying and testing geophysical methods, technologies and borehole/surface tools in realistic conditions. This facility mainly consists of a scaled-down version of a drilling yard in which four wells were drilled in Quaternary alluvial sediments lying on Miocene conglomerates. Two of the wells are instrumented by permanent sensors (3-C geophones and DAS fibre optic sensors) cemented outside the casing. Two of the existing wells are potentially available for further drilling phases, and all wells are available for downhole instrumentation testing.

Permanent Laboratories equipped with instrumentation for data recording, in-field quality control (QC), real-time signal processing and conditioning, including remote satellite data transmission and acquisition control, are available at the well site.

State of the art: The site has the unique characteristic to be drillable, to realize tests useful to improve monitoring well technologies, and usable at the same time for geophysical and instrumental monitoring, also with easy access to the surrounding area.

Services offered: Geophysical and technical support for project preparation, planning and execution. Support for in-field quality control (QC) and subsequent data analysis and processing.

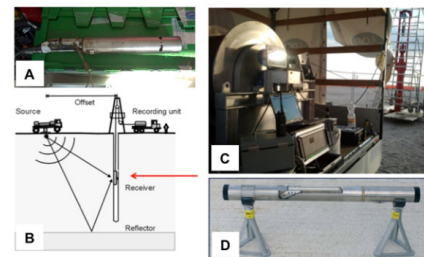


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INFRASTRUCTURE NAME:	EXPLORA
LOCATION:	TRieste, ITALY
WEB SITE ADDRESS:	WWW.OGS.TRIESTE.IT
INFRASTRUCTURE'S OPERATOR:	OGS (ISTITUTO NAZIONALE DI OCEANO- OGRAFIA E DI GEOFISICA SPERIMENTALE)
CATEGORY:	STORAGE

Description of the facility: The Research Vessel OGS Explora is an ice-class oceanic research vessel equipped with the most advanced geophysical and oceanographic instruments owned by OGS.

State of the art: The ship offers to both the European and the international earth and marine science communities a wide range of capabilities, including geophysical, marine geology and oceanographic facilities, laboratories and equipment.

Services offered: The oceanographic equipment allows the study of the physical, chemical and biological characteristics of water column and surface sediments. The geophysical equipment allows the study of the seafloor and the sub-seafloor at different scale of resolution and penetration. All the collected data are georeferenced and can be integrated with other data for joint analyses and interpretation. OGS will provide the personnel to carry out the surveys and to process and interpret the data.



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INFRASTRUCTURE NAME:	OGS-CTMO
LOCATION:	TRIESTE, ITALY
WEB SITE ADDRESS:	WWW.OGS.TRIESTE.IT
INFRASTRUCTURE'S OPERATOR:	OGS (ISTITUTO NAZIONALE DI OCEANO- OGRAFIA E DI GEOFISICA SPERIMENTALE)
CATEGORY:	STORAGE

Description of the facility: The Centro di Taratura e Metrologia Oceanografica (CTMO) is the marine metrology and calibration facility of the Oceanography Department of OGS. It provides the Department with the scientific and technical infrastructure necessary for making and guaranteeing high-quality observations of the marine environment in a way that continuously meets recognized international standards of excellence. A key element of the services offered is the ability to calibrate and maintain sea-going instrumentation efficiently. The facility is run applying relevant international guidelines and protocols as much as practically possible in order to assure conformity or, at least, compatibility, with the regulatory standards governing this kind of activity worldwide. The CTMO has a small team of experienced personnel, which also oversees the facility's continuous scientific and technological development.

State of the art: Thermally-regulated and humidity-controlled, the CTMO is currently equipped with primary physical standards, secondary transfer standards and support equipment for performing high-quality calibrations of devices or sensors measuring temperature and conductivity (salinity) able to meet the demanding oceanographic measurement specifications for these parameters. It also has a number of instruments for making standard electrical measurements of various kinds and functional tests, evaluations and validations of sensors used for measuring some other commonly monitored marine environmental parameters.

Services currently offered by the infrastructure: Various setups for temperature calibration, conductivity/salinity calibration and other related tests and sensors.



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INFRASTRUCTURE NAME:	COHYGEN PILOT PLANT
LOCATION:	CARBONIA, SOUTH-WEST SARDINIA, ITALY
WEB SITE ADDRESS:	HTTP://WWW.SOTACARBO.COM/
INFRASTRUCTURE'S OPERATOR:	SOTACARBO SOCIETÀ TECNOLOGIE AVANZATE CARBONE SPA
CATEGORY:	CAPTURE

Description of the facility: The COHYGEN (Coal to Hydrogen Generation) pilot plant was developed in 2008 in order to study and optimize a syngas treatment process for combined production of hydrogen and electrical energy with CO₂ capture. The COHYGEN pilot plant is based on a 300 mm diameter fixed-bed up-draft gasifier, equipped with several sections for syngas treatment and both power generation and hydrogen production with CO₂ capture. The plant is extremely flexible and suitable for several kinds of experimental tests. The plant includes a gasification section; syngas washing system; power generation line; hydrogen production line; process control and analysis system; auxiliaries.

State of the art: The plant has been widely tested (about 2500 hours) and, together with ZECOMIX (Enea Research Centre in Casaccia), it is one of the most important infrastructures involved in the Italian CCS national programme, mainly for studying capture technologies (both pre- and post-combustion) in power plants fed with low rank coal.



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INFRASTRUCTURE NAME:	PEC LAB
LOCATION:	CARBONIA, SOUTH-WEST SARDINIA, ITALY
WEB SITE ADDRESS:	HTTP://WWW.SOTACARBO.COM
INFRASTRUCTURE'S OPERATOR:	SOTACARBO SOCIETÀ TECNOLOGIE AVANZATE CARBONE SPA
CATEGORY:	CAPTURE

Description of the facility: The main objective of the PECO₂ (Photoelectrochemical reduction of CO₂) facility is to convert CO₂ into methanol using energy that is not produced from fossil fuels. The photoelectrochemical (PEC) reduction of carbon dioxide is an innovative method that does not only remove CO₂ from effluent gases but also converts it into value-added chemicals and fuels, such as methanol. Moreover, the integration of renewable energy might lead this technology to be a potential candidate for an environmentally sustainable CO₂ utilization that can support the storage both to reduce total costs and whenever storage sites are away from emission sources and are not compatible with the volumes involved. The infrastructure, due to its flexibility, can be also used for experimental tests on electrochemical regeneration of amine-based solvents used for CO₂ capture. The experimental procedures for this operation mode is still under development.

State of the art: The photoelectrochemical reduction of CO₂ has been suggested to be one of the best ways of storing energy and solving both global warming and energy crisis problems to a great extent.

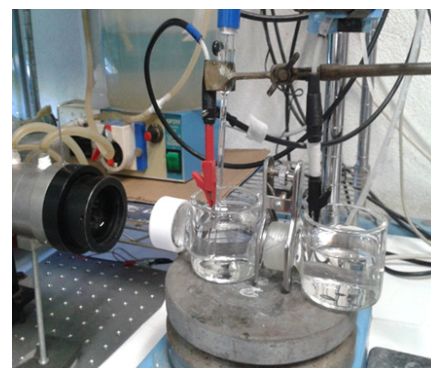


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INFRASTRUCTURE NAME:	XTL PILOT PLANT
LOCATION:	CARBONIA, SOUTH-WEST SARDINIA, ITALY
WEB SITE ADDRESS:	HTTP://WWW.SOTACARBO.COM
INFRASTRUCTURE'S OPERATOR:	SOTACARBO SOCIETÀ TECNOLOGIE AVANZATE CARBONE SPA
CATEGORY:	CAPTURE

Description of the facility: The plant is composed by three different (and independent) sections, a micro gasification pilot plant, a CO₂ separation system with membranes and a catalytic reactor for CO₂ utilization. The whole CCU unit is equipped with a membrane-based CO₂ separation system. The main objective of the section is to characterize different kinds of membranes for the separation of H₂ and CO₂ (provided by the gasification section or by bottles) in typical pre-combustion conditions. The facility is built up with a great operational flexibility to allow the study of pure polymeric membranes and mixed matrix membranes.

State of the art: Among the various strategies to reduce carbon dioxide emissions, novel process technologies for CO₂-recycling are currently attracting a great scientific and technological interest. If the captured CO₂ is used as "reagent" through its hydrogenation in the production of a marketable product, its capture and sale could become not only economically viable but also a profitable business. The Sotacarbo plant was initially conceived and designed for the production of methanol from CO₂. However, the system is extremely flexible and can be used for the production of a wide range of chemicals and liquids fuels



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INFRASTRUCTURE NAME:	IOSTO PLANT
LOCATION:	CARBONIA, SOUTH-WEST SARDINIA, ITALY
WEB SITE ADDRESS:	HTTP://WWW.SOTACARBO.COM
INFRASTRUCTURE'S OPERATOR:	SOTACARBO SOCIETÀ TECNOLOGIE AVANZATE CARBONE SPA
CATEGORY:	CAPTURE

Description of the facility: The objective of the facility is sulphur recovery from flue gas from oxy-combustion processes. The facility is an atmospheric bench-scale unit (0.2 barg) with nominal capacity of 3 Nm³/h, designed to treat a simulated flue gas (prepared through a feeding system based on 4 Burkert mass flow meters for CO₂, O₂, H₂O and SO₂) characterized by a high CO₂ concentration (around 60% by volume) and a SO₂ concentration up to 2%. The unit is equipped with a PLC control system and a real time monitoring system to analyse the gas composition (O₂, CO₂, SO₂).

State of the art: Oxy-combustion is one of the main effective alternatives for CO₂ capture. The high temperature pressurized oxy-flameless combustor allows to burn low rank coals, particularly high sulphur coals. The main feature of the system is the purification of the CO₂ stream with the production of a high value added chemicals. The facility allows validating and optimizing the process of H₂SO₄ production already in the market applying it to gas streams with different conditions and compositions.

Services offered: Availability of basic services as air, gas, electricity supply; extended online monitoring and data acquisition; gas and liquid analysis equipment; laboratories for off line analysis of solid materials.

INFRASTRUCTURE NAME:	ROCK ANALYSIS LAB
LOCATION:	CARBONIA, SOUTH-WEST SARDINIA, ITALY
WEB SITE ADDRESS:	HTTP://WWW.SOTACARBO.COM
INFRASTRUCTURE'S OPERATOR:	SOTACARBO SOCIETÀ TECNOLOGIE AVANZATE CARBONE SPA
CATEGORY:	STORAGE

Description of the facility: Geological models to calculate CO₂ storage capacity need a characterization of reservoir implemented with a large number and type of details and variables coming from geological analysis, carried through on site researches and laboratories tests. This system provides many elements related to the stress and strain properties of the tested material, which can be used to implement the geological static model. The facility is made up of two different units. The first one is a servo hydraulic unit for controlling up four test frames for compression, flexure and indirect tensile tests with load, displacement and deformation control; it manages strain-controlled load-unload ramps automatically. The second one has been specifically designed for triaxial rock testing and works as a remotely-controlled pressure unit, manage by the rock control console. The system is equipped with a specific laboratory to prepare rock samples.

State of the art: Rock samples are used in the laboratory to study and define stress conditions: the stress-strain diagram can show behaviours of non-linearity also for very small strains, hysteresis, anisotropy, fluage conditions.

Services offered: This system provides a complete range of test for the determination of Elastic Modulus and strength characteristics of rock specimen in uniaxial and triaxial conditions.

INFRASTRUCTURE NAME:	TNO MINI PLANT FOR SOLVENT PREPARATION & TESTING
LOCATION:	NETHERLANDS
WEB SITE ADDRESS:	WWW.TNO.NL
INFRASTRUCTURE'S OPERATOR:	TNO
CATEGORY:	CAPTURE

Description of the facility: The setup of the Mini Plant consists of a skid with process equipment: absorber (exchange with membranes is possible), desorber, heat exchanger, pump, pipes, CO₂ analyzers, flow meters and controller and other small equipment, an automatic data logging/operation system, and a computer (unit). The Mini Plant is located at the TNO lab in Delft and can be relocated to another location. The Mini Plant supports the initial steps, i.e. preparation of the solvents and testing of the solvent stability. The absorption-desorption setup is used to determine the absorption and desorption capacity of CO₂ capture solvents. The gas feed system setup is flexible. The phosphoric acid setup is used for analysis of the CO₂ content of the absorption solvents.

State of the art: With the Mini Plant it is possible to really demonstrate new solvent types within reasonable timescales. The Mini Plant is equipped with the latest technologies regarding process monitoring and process measurement. Furthermore, the pilot plant offers good accessibility, user friendly operations and a smart process data collection system.



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INFRASTRUCTURE NAME:	TNO QSCAN SOLVENT TEST STREET
LOCATION:	NETHERLANDS
WEB SITE ADDRESS:	WWW.TNO.NL
INFRASTRUCTURE'S OPERATOR:	TNO
CATEGORY:	CAPTURE

Description of the facility: The Mini AutoClave (MAC) for quick scan purposes is a set-up for medium throughput vapour-liquid-equilibrium (VLE) equipment where six experiments can be performed simultaneously. All six reactors can run independently of each other and can be started and stopped at any time. The test set-up is divided into two temperature sections.

State of the art: A variety of analytical equipment is available to determine gas and liquid composition. Modelling tools are available to perform simulations of the underlying separation principles (thermodynamics, kinetics). Software tools are available to perform process design and development (flow sheeting and scale-up) as well as to perform technical and economic evaluations



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INFRASTRUCTURE NAME:	TNO CLC FIXED BED FACILITY
LOCATION:	NETHERLANDS
WEB SITE ADDRESS:	WWW.TNO.NL
INFRASTRUCTURE'S OPERATOR:	TNO
CATEGORY:	CAPTURE

Description of the facility: The chemical looping combustion (CLC) fixed bed facility consists of a tubular fixed bed reactor, with various sizes possible (up to 1 kW), and all required peripheral equipment. Continuous operation of the system alternately produces streams of hot depleted air and CO₂/H₂O. The CLC fixed bed facility is located at the TNO lab in Delft and can be relocated to another location

State of the art: With the CLC fixed bed facility it is possible to demonstrate the looping of various metal/metal oxide beds through oxidizing and reducing conditions. Various fuels and gas mixtures can be fed for the reducing step, including components such as CH₄, CO, H₂, and CO₂.

Services offered: The facility is successfully used for Business to Business projects and other research programmes such as Greenhouse applications, Production of gases Materials testing w/ international collaboration.

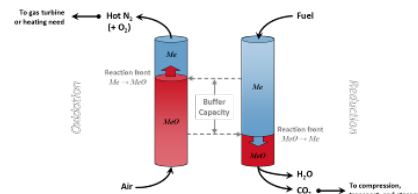


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INFRASTRUCTURE NAME:	TNO HIGH PRESSURE ABSORPTION AND DESORPTION PILOT
LOCATION:	NETHERLANDS
WEB SITE ADDRESS:	WWW.TNO.NL
INFRASTRUCTURE'S OPERATOR:	TNO
CATEGORY:	CAPTURE

Description of the facility: The pilot plant consists of an absorber and a conventional desorber and a membrane gas desorption unit (MGD), which can be operated in continuous cycle mode. The pilot test is skid mounted and is easily relocated, due to its compact design. The gas supply setup is flexible and easy to adjust to specific needs. The desorber can be equipped with commercial structured packing material.

With the high pressure absorber and desorber pilot plant it is possible to demonstrate new solvents and their stability at different process conditions. The high pressure absorber and desorber pilot plant is equipped with the latest technologies regarding process monitoring and process measurement. Furthermore, the pilot plant offers good accessibility, user friendly operations and a very user friendly process data collection system.

State of the art: With the high pressure absorber and desorber pilot plant it is possible to demonstrate new solvents their stability at different process conditions. The high pressure absorber and desorber pilot plant is equipped with the latest technologies regarding process monitoring and process measurement. Furthermore the pilot plant offers good accessibility, user friendly operations and a very user friendly process data collection system.



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INFRASTRUCTURE NAME:	MOBSEIS
LOCATION:	NETHERLANDS
WEB SITE ADDRESS:	WWW.TNO.NL
INFRASTRUCTURE'S OPERATOR:	TNO
CATEGORY:	STORAGE

Description of the facility: The mobile seismic array allows TNO to acquire their own seismic data which fits their position as an independent research institute. The equipment can be applied for different domains (Carbon Capture and Storage, Geothermal, Energy storage and production), and to evaluate new technologies. The set-up of the mobile seismic array currently consists of 33 self-contained stations that can operate both stand-alone basis as well as in an array. Therefore the station spacing and layout of the network is flexible and can be tailored for the specific target to be addressed. Seismic data can be acquired both continuously and periodically and data is wirelessly transferred from the stations to a data server.

State of the art: The mobile seismic array allows acquisition of accurate and continuous seismic data, both to accurately monitor subsurface processes and to evaluate new production strategies. TNO has broad experience with the operation of permanent seismic arrays and analysis of both passive and active seismic data. The seismic array has a flexible character, such that it can be used both for continuously acquiring passive seismic data to monitor earthquakes and subsurface processes, as well as for acquiring active seismic surveys for subsurface characterization studies.

Services offered: Seismic acquisition, processing, interpretation, reporting

INFRASTRUCTURE NAME:	ATCM - AEROSOL TEST AND COUNTER MEASURE
LOCATION:	NETHERLANDS
WEB SITE ADDRESS:	WWW.TNO.NL
INFRASTRUCTURE'S OPERATOR:	TNO
CATEGORY:	CAPTURE

Description of the facility: Emission monitoring and control with respect to aerosols has not been studied at any large extent connected to CCS.

This is a crucial aspect to address. With the infrastructure, we are able to study the phenomena in detail.

State of the art: A unique infrastructure has been developed to generate H₂SO₄ aerosol droplets in-house, simulating the aerosols as observed in power and industrial plants. A wide range of H₂SO₄ concentrations and thus, particle number and size distribution can be obtained from this setup. A heated ELPI+, combined with a special heated probe, is used for particle characterisation.

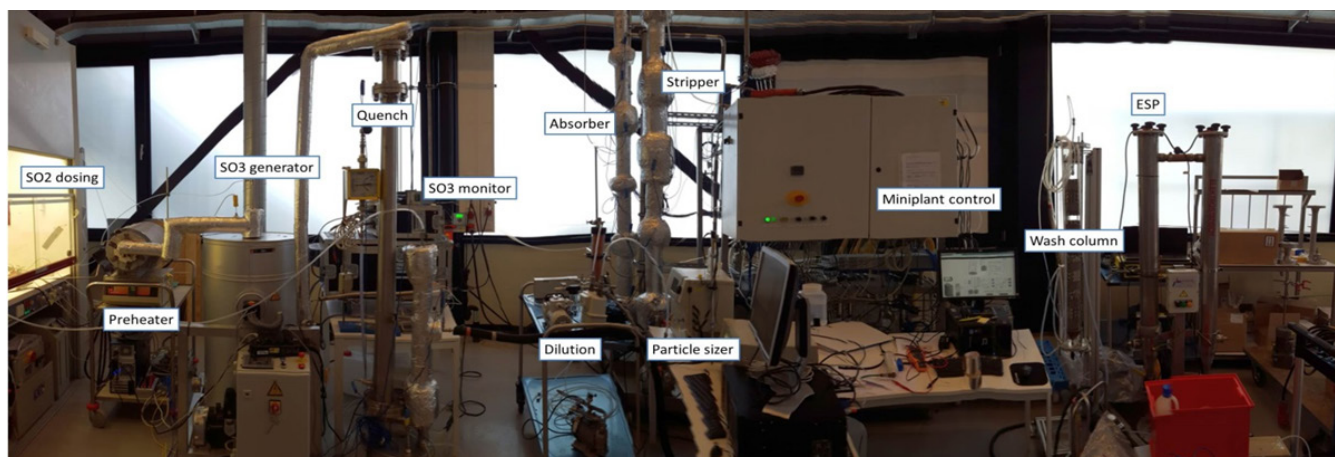
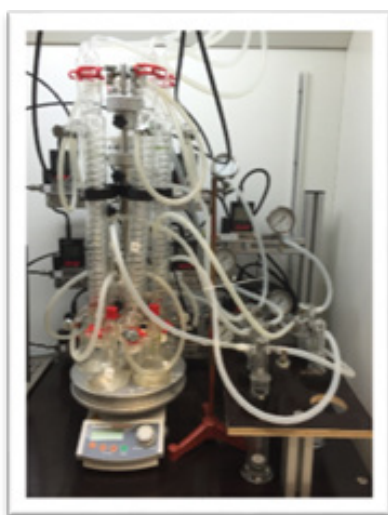


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INFRASTRUCTURE NAME:	ABSORPTION LABORATORIES
LOCATION:	TRONDHEIM, NORWAY
WEB SITE ADDRESS:	WWW.NTNU.NO
INFRASTRUCTURE'S OPERATOR:	NORWEGIAN UNIVERSITY OF SCIENCE AND TECHNOLOGY
CATEGORY:	CAPTURE

Description of the facility (area ABSKIN): Absorption kinetics are crucial for realistic process simulations and process design (height of the absorber). Additionally to absorption rate data, data for physical properties are needed to model the kinetics. Therefore, this facility offers:

- Three setups for measurement of kinetics: string of discs, wetted wall column and stirred cell. Both unloaded and loaded solutions can be measured.
- Viscosity and density measurements
- The possibility to measure the physical solubility of CO₂ using N₂O analogy.



Oxidative degradation apparatus (left) and a stirred cell apparatus (right).

Photos ©NTNU, all rights reserved

Description of the facility (area ABSDEG): Solvent degradation and corrosion can be a show-stopper for process and solvent development. Amount of degradation is one of the factors that dictate the need for solvent make-up. In addition to degradation contributing to higher cost connected to solvent make-up, some of the degradation compounds formed have unwanted properties as high corrosivity or high volatility. Understanding the connection of different process parameters and degradation compounds present is of high interest. The facility contains setups to study solvent degradation. This installation includes 3 apparatuses.

- **The oxidative degradation in a batch reactor** is suitable for degradation studies at absorber temperatures (45-60oC). The setup is suitable for example for testing of effect of loading and oxygen concentration on degradation. Also effect of metals can be studied.
- **Thermal degradation** tests in metal cylinders up to 150oC. The amount of CO₂ and access to metals can be controlled by placing a glass tube inside the cylinder. These tests also give some indication on the corrosivity of the solvent.
- With the screening apparatus for oxidative degradation, it is easy to test degradation and corrosion inhibitors, or degradation with varying solvent concentration.

Description of the facility (area ABSEQ): Understanding the chemical and physical equilibria (VLE) behaviour of the solvent system is maybe the most important data needed for process development and process simulations. The setups available in this infrastructure can be divided into 3 categories:

- Low and medium pressure VLE setups
- High pressure VLE setup (up to 150bar)
- Calorimeters for heat of absorption and heat of crystallization / dissolution studies.

We have basic analytical possibilities (amine and CO₂ titration methods and TOC/TIC/NT) available in our labs.



Pictures of low pressure VLE apparatus (left), reactor calorimeter (middle) and high pressure VLE apparatus (right).

Photos ©NTNU, all rights reserved

Description of the facility (area Post combustion Lab pilot (NTNU/SINTEF)): The pilot, owned by NTNU and SINTEF Industry together, was built in 1998 and upgraded in 2004. The gas treating capacity of the pilot plant is approximately 150 m³/h. The absorber has an internal diameter of 0.15m and a packing height of 4.23 m whereas for the stripper the height and diameter are 3.57m and 0.1m. Both columns have Sulzer BX-packing. The pilot is fully automated with continuous logging of the liquid and gas flows, the temperature profiles in the packed columns (7 probes in the absorber and 5 probes in the stripper), the CO₂ concentrations in and out the absorber, the reboiler heat duty and temperatures and pressures in the pipes. The absorber is connected to a water wash section with height of 2.1m and internal diameter of 0.15m (packing type SULZER 250Y). Total amount of liquid solution needed for operation is ~180l. The pilot is operated continuously (24-hours) and no operator is needed present in the evenings/nights. The plant is specially designed for solvent testing in post combustion and can be used for

- Testing of new potential solvents
- Testing degradation in long term running (it is possible for example to add NO/NO₂ into the gas phase)
- Water wash experiments testing of new technics related to emission control.

State of art: The installations are designed for CO₂ capture research. The laboratory has a close co-operation with external analytical laboratory (SITNEF Industry) offering services to analyse liquid samples for degradation products and specific amines.

Services offered: Measurement of thermodynamic data, like VLE and heat of absorption, needed for example in process modelling can be performed. Absorption kinetics including measurement of physical properties is needed for sizing of absorber. Degradation studies will give fundamental understanding of the solvent as well as indicate the solvent make-up costs.

INFRASTRUCTURE NAME:	MEMBRANE LABORATORIES
LOCATION:	TRONDHEIM, NORWAY
WEB SITE ADDRESS:	WWW.NTNU.NO
INFRASTRUCTURE'S OPERATOR:	NORWEGIAN UNIVERSITY OF SCIENCE AND TECHNOLOGY
CATEGORY:	CAPTURE

The laboratories include MEM-FAB Facilities to fabricate polymer-based membranes, MEM-PERM Facilities to test membrane gas permeation performance and an polymer membrane lab extension:

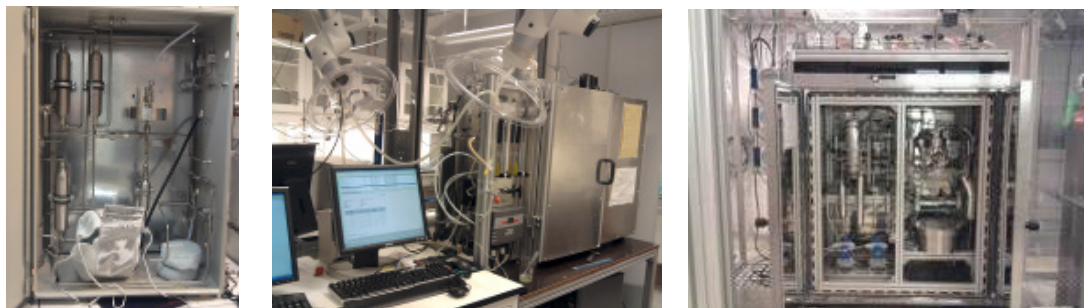
Description of the facility (Mem-FAB area): This infrastructure provides facilities and methods to fabricate polymer-based membranes in lab scale and pilot scale, including the spinning of hollow fiber membranes, carbonization to prepare carbon membranes and coating of thin composite membranes on flat sheet or hollow fiber supports.



Pictures of the (1) spinning machine for hollow fiber fabrication and coating; (2), carbonization rig and (3) the pilot scale flat sheet coating device
Photos ©NTNU, all rights reserved

State of the art: The well-equipped facilities support broad techniques for the fabrication of polymer-based membranes, providing researchers the opportunity for 'one-stop' works in developing novel membranes of various materials or unique morphology that enhance the CO₂ separation performance. The facilities are updated and easy to operate, which enables users to conduct high quality researches.

Description of the facility (Mem-PERM area): This infrastructure provides facilities and methods to test membrane gas permeation performance in lab scale and pilot scale in different conditions, including single gas, mixed gas, gas separation in humidified conditions and at high pressures, with either flat sheet or hollow fiber membrane modules.



Pictures of (1) membrane gas permeation test rig for single/mixed gas (GC for gas analysis), (2) membrane permeation test rig for humidified conditions (GC for gas analysis) and (3) membrane permeation test rig for mixed gas at high pressures (MS for gas analysis)
Photos ©NTNU, all rights reserved

State of the art: The facilities provided are advance and updated, equipped with automatic controlling and indication system as well as devices for auto-sampling and auto data-recording, providing researchers the opportunity to test membrane gas permeation performances in different conditions with reliable and high quality data.

Services offered: There is a widespread interest from users in other countries to conduct research in developing new and more efficient membranes for CO₂ separation, and in testing gas permeation of membranes in different conditions.

INFRASTRUCTURE NAME:	CLC HOT RIG
LOCATION:	TRONDHEIM, NORWAY
WEB SITE ADDRESS:	WWW.SINTEF.NO
INFRASTRUCTURE'S OPERATOR:	SINTEF ENERGI AS
CATEGORY:	CAPTURE

Description of the facility: The CLC rig is a Double Loop Circulating Fluidized Bed reactor system used for research on chemical looping combustion. The design values are 150 kW gaseous fuels input and reactor temperature of 1000°C. The rig consists of an Air Reactor (AR) and a Fuel Reactor (FR), interconnected by divided loop-seals and a bottom lifter. The reactor design is flexible as the reactors can be run individually because of the divided loop seals, and the fuel reactor can both be run as a CFB and as a bubbling bed because of the possibilities of using the bottom lifter.

State of the art: The CLC Rig is a rather large test facility for CLC with nominal fuel input of 150 kW and reactors height of 6 meters. Both the fuel reactor and the air reactor are based on circulating fluidized bed (CFB) technology and the fuel reactor diameter is smaller than the air reactor because of the smaller gas flow.

Services offered: The SINTEF ER CLC Rig offers assessment of fuel conversion, oxygen carrier's attrition and other important characteristics of the CLC process through exhaust gas emission measurements and particle sampling during operation. Oxygen carrier particle samples can be analysed mechanically and chemically by another department at the campus. They can also contribute with some preparation of the oxygen carrier particles, especially on particle size classification.



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INFRASTRUCTURE NAME:	COMBLAB (HIPROX)
LOCATION:	TRONDHEIM, NORWAY
WEB SITE ADDRESS:	WWW.SINTEF.NO
INFRASTRUCTURE'S OPERATOR:	SINTEF ENERGI AS
CATEGORY:	CAPTURE

Description of the facility: The High Pressure Oxy-fuel combustion facility (HIPROX) is a pressurized combustion rig for the study of combustion in oxy-fuel atmospheres, i.e. CO₂ and O₂ oxidizers. However, the facility is also in conventional air supported combustion. The combustion chamber is particularly suited for gas turbine type combustion systems, where the gas streams can be distributed between primary and dilution zones. The flexibility of the installation is such as custom design burner can be adapted to the pressurized unit, allowing external users to bring a burner provided it has been followed our construction specifications and necessary approval. The fixed monitoring of the unit is composed of dynamic pressure and static pressure, heat flux probe, internal chamber wall temperature, exit gas temperature, and an averaging sampling probe that can be coupled with conventional gas analyzers or FTIR unit. Two combustor modules are available: one fully optically accessible for visualization (high speed, filtered imaging, laser diagnostics), and a metal one preferred for emissions characterization. **State of art:** HIPROX has the possibility of using one stream of pure oxygen and 2 streams of pure CO₂ at controlled mass flow and pre-heat temperature in a pressurized environment, and offers flexibility in the gas streams management. Several options are possible for generating complex fuel mixtures that can be distributed to up to three lines. When used with the FTIR analyser, there is possible to measure several species simultaneously. The facility is particularly well suited for combustion studies with gas mixtures that can be found in oxy-fuel combustion processes and able to monitor all parameters necessary for the operation of a gas turbine engine. Current projects have used hydrogen and ammonia as fuels. **Services offered:** The HIPROX infrastructure offers assessment of the general combustion performance of oxy-fuel related processes, through the measurements of pollutants emissions or impurities, flame stability, thermo-acoustic instabilities, and in-chamber heat transfer. It is particularly well suited for burner development and emission characterisation. The parameters that can be easily varied are the CO₂ and oxygen distribution, individual stream temperature, fuel composition and distribution, and the all combustion parameters (power, equivalence ratio).



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INFRASTRUCTURE NAME:	CO ₂ MIX – VLE
LOCATION:	TRONDHEIM, NORWAY
WEB SITE ADDRESS:	WWW.SINTEF.NO
INFRASTRUCTURE'S OPERATOR:	SINTEF ENERGI AS
CATEGORY:	SYSTEM WIDE (CAPTURE-TRANSPORT-STORAGE)

Description of the facility: Installation 1 - Phase equilibrium setup: The CO₂Mix phase equilibrium facility is specifically designed for highly accurate phase equilibrium measurements. An analytical technique is used, where the composition of all fluid phases present in the cell at equilibrium is measured. The facility is primarily designed for vapor-liquid equilibrium (VLE). Material selections and ventilation are adapted to the most relevant impurities in CCS, which could include toxic, moderately corrosive as well as explosive impurities. Installation 2 - Setup for accurate gravimetric preparation of CO₂-rich mixtures: Adjacent to the phase equilibrium setup there is a setup for gravimetric preparation of gas mixtures. It is used to prepare mixtures for calibration of the phase equilibrium setup, but could also be used independently to prepare gases for other types of measurements.

State of art: The installation 1 and 2 are both extremely accurate. The former has delivered phase equilibrium measurements with unsurpassed accuracy, while the latter has an accuracy down to below 10 ppm, basically limited by adsorption in the gas cylinders and purity of the source gases.

Services offered: Highly accurate phase equilibrium measurements and preparation of calibration gas mixtures involving CO₂ and impurities typically found in CCS. For each new system to be studied, composition measurements used in the VLE setup should be calibrated with a set of calibration gas mixtures. The facility is located in the thermal laboratories of NTNU/SINTEF with its available infrastructures and services and directly adjacent to the offices of leading scientists in the field of SINTEF and NTNU.

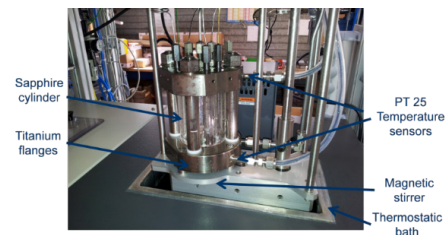


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INFRASTRUCTURE NAME:	SEPPIL
LOCATION:	TRONDHEIM, NORWAY
WEB SITE ADDRESS:	WWW.SINTEF.NO
INFRASTRUCTURE'S OPERATOR:	SINTEF ENERGI AS
CATEGORY:	CAPTURE

Description of the facility: This is a lab-pilot experimental facility suitable for CO₂ separation and purification from gas mixtures originating from pre-combustion applications such as hydrogen production, oxy-fuel processes, and pre-separated flue gases from post-combustion applications in industry and power generation. The main purpose of the rig is to demonstrate the capture efficiency (CO₂ capture ratio and purification) from various types of above-mentioned relevant gas mixtures by cooling and condensation.

State of the art: The RI is the first of its kind with the given process design. The RI fits very well with the national R&D priorities on CCS. Specifically, the CLIMIT strategy and program plan calls for multiple CCS technologies for CO₂ capture to reduce costs and energy use. With the growing focus on hydrogen production from natural gas, the RI can be used to investigate separation of syngas with CO₂ capture, which can become a relevant processing step in combination with dense metallic membranes (e.g. palladium), pressure-swing adsorption and other hydrogen production technologies.

Services offered: Located in the thermal laboratories of SINTEF/NTNU with its available infrastructures and services

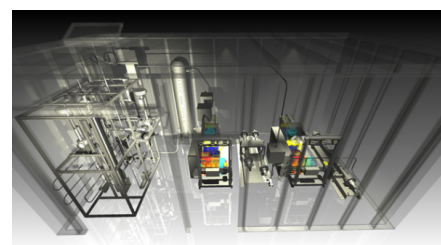


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INFRASTRUCTURE NAME:	DEPRESS
LOCATION:	TRONDHEIM, NORWAY
WEB SITE ADDRESS:	WWW.SINTEF.NO
INFRASTRUCTURE'S OPERATOR:	SINTEF ENERGI AS
CATEGORY:	TRANSPORT

Description of the facility: This facility is specifically designed to investigate transient phenomena related to CO₂ transport. Robust simulation for CCS-relevant mixtures is currently not supported by common engineering tools, and the facility enables development and verification of models that can.

Installation 1: Depressurization pipe: 60 m long, straight pipe with 40 mm ID, initial state < 200 bar, designed for sudden release of pressure from one end, restricted or full bore

Installation 2: Depressurization Tank: 1 m high, 30 cm diameter, initial state < 150 bar, depressurization through rapid valve at top, heat transfer through walls, and density and mass of outlet flow measured

State of the art: The pipe has a better and denser instrumentation than any other known depressurization facility, and no other facility we are aware of has the means to directly detect phase behaviour. Care has been made in the design to allow upscaling of models, and to achieve full opening without inducing artificial shock waves. As far as we know, there is no facility available worldwide similar to the depressurization tank.

Services offered: Located in the thermal laboratories of NTNU/SINTEF with its available infrastructures and services and directly adjacent to the offices of leading scientists in the field of SINTEF and NTNU. Further advanced facilities for flow experiments are planned adjacent to this facility.

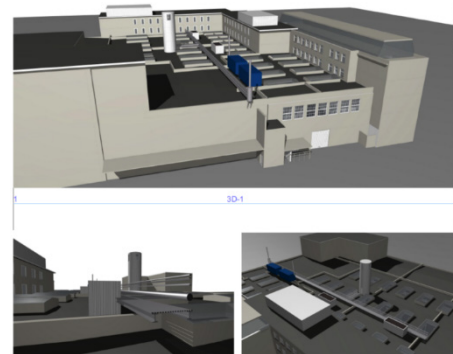


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INFRASTRUCTURE NAME:	VISC-DENS
LOCATION:	TRONDHEIM, NORWAY
WEB SITE ADDRESS:	WWW.SINTEF.NO
INFRASTRUCTURE'S OPERATOR:	SINTEF ENERGI AS
CATEGORY:	CAPTURE

Description of the facility: This viscosity facility has been designed for very high accuracy implying careful design and advanced instrumentation. The infrastructure is unique due to its particular adaptation to CCS applications, and is qualified for toxic, explosive and moderate corrosive mixtures. The temperature range of the facility is between -60 and 200 °C, and it is designed for up to 1 000 bar in pressure. A version of a viscosity ratio measurements using capillaries are being used. Integrated in the facility is a commercial density meter.

State of the art: The facility can measure viscosity with very high accuracy, and is particularly useful for liquid CO₂ mixtures where very little data is available.

Services offered: The facility is located in the thermal laboratories of NTNU/SINTEF with its available infrastructures and services. Specifically, it could be a great advantage to utilize the ECCSEL CO₂Mix setup for accurate gravimetric preparation of CO₂-rich mixtures. The facility is also directly adjacent to the offices of leading scientists in the field of SINTEF and NTNU. Further advanced facilities for property measurements are planned in the same room.

INFRASTRUCTURE NAME:	SINTEF S/CHLAB SORBENT LABORATORIES FOR CCS
LOCATION:	NORWAY, OSLO AND TRONDHEIM
WEB SITE ADDRESS:	WWW.SINTEF.NO
INFRASTRUCTURE'S OPERATOR:	SINTEF AS
CATEGORY:	CAPTURE

Sorbent laboratories SLab for CCS includes high throughput preparation and testing laboratory for materials in CCS related technologies, sorbent based and Chemical looping laboratories, sulphur laboratory for material and component testing, solid sorbent lab extension and CHLab for in situ characterization of solid materials for CCS:

Description of the facility (Slab area):

High Throughput material preparation and characterization. Robots are used for material preparation by various techniques (impregnation, precipitation, etc.) where also solid handling is possible. A 48 samples in parallel format is used. Individual thermal treatment of 48 samples can be carried out using individual thermal treatment sequences. **High throughput solid material testing.** 8 solid samples can be tested in a fully automated breakthrough unit (0.4 g of each sample) working at temperatures up to 800°C and at pressures up to 30 atm. An automated gas feeding and mixing system (H₂, CO₂, CO, CH₄, N₂, H₂O, H₂S, misc.) is used. Effluent gas analyses are done by online IR or MS analysis. **Volumetric adsorption Isotherm measurement units (From vacuum to 100 bar).** A series of Belsorp instruments (Mini, Max, HP and VC) are used to measure single and dual component adsorption/desorption isotherms on solids with gases such as H₂, CO, CO₂, CH₄, N₂, Ar and H₂O over a pressure range from high vacuum to 100 atm and temperatures from 77K to 673K. **Automated Breakthrough unit for sorbent evaluation.** A two column breakthrough unit operating at temperatures up to 800°C and pressures up to 30 atm with bed volume between 5 and 10 ml. Effluent gas analyses are done by IR or MS.

Four-column Pressure-swing adsorption (PSA) unit. The fully automated four-column PSA reactor can be used from ambient temperature to 200C and at pressures from vacuum up to 70 atm. Also rapid cycle PSA can be conducted. Analyses can be conducted by IR, MS and GC. The unit also include a gas feeding system comprising CH₄, CO₂, CO, H₂, N₂, Ar, misc. CLC rig. The 3 kW circulating fluidized bed CLC rig, handling about 1-2 kg of solid, is been in operation since 2012. This is a unit design attrition testing of (CLC) materials. The rig has relatively small cyclones to increase the attrition part both after the fuel reactor and air reactor.

Description of the facility (CHLab area):

Solid and liquid state NMR For solid state NMR analyses a Bruker Avance III 500 MHz wide bore spectrometer equipped with four probes for different applications is available: Two MAS probes for solid samples, 3.2 and 4 mm.

In-situ powder X-Ray diffraction A PANalytical Empyrean instrument equipped with an in situ cell can be used to get mechanistic information on sorbent function and possible degradation during operation. A variety of gas composition can be mixed by an automated gas feeding and mixing system (H₂, CO₂, CO, CH₄, N₂, H₂O, misc.). Effluent gas analyses can be done by IR or MS.

INFRASTRUCTURE NAME:	SINTEF PPLAB
LOCATION:	NORWAY, OSLO AND TRONDHEIM
WEB SITE ADDRESS:	WWW.SINTEF.NO
INFRASTRUCTURE'S OPERATOR:	SINTEF AS
CATEGORY:	CAPTURE

Description of the facility: Powders can be further processed to suitable morphologies and sizes by different methods. Mechanical sizing by crushing and sieving into the wanted particle size fraction. Freeze granulation, spray granulation, agglomeration, spray coating and spray drying (2015) are available techniques at different throughputs resulting in significant different powder morphologies and particle size fractions. Equipment for calcination and heat treatment in different atmospheres are available.

INFRASTRUCTURE NAME:	SINTEF MLAB
LOCATION:	NORWAY, OSLO AND TRONDHEIM
WEB SITE ADDRESS:	WWW.SINTEF.NO
INFRASTRUCTURE'S OPERATOR:	SINTEF AS
CATEGORY:	CAPTURE

Description of the facility: Fabrication facilities for inorganic membranes. The manufacturing laboratory enables to produce a final product starting from raw powders. Final products may be flat sheet membranes of maximum 6 cm x 6 cm dimensions, symmetric or thin film coated tubular membranes of up to 20 cm long dimension. It comprises ventilated benches and hoods for synthesis of powder and its conditioning via various milling processes (planetary milling, ball milling). Particles size and shape are characterised by using Morphology G3 particle size analyser directly on dry powder or in suspension. The powders are then shaped as tubular membranes (dense or porous) by water-based extrusion using 40 tons Loomis piston extruder located in a clean room facility (class 7). Testing units for inorganic and organic membranes.

Automated atmospheric and pressurised Thermal Gravimetric (TG) equipment.

Sulphur laboratory for material and component testing.

The laboratory includes a well-equipped membrane permeation characterisation setup, a sorbent test station, and a high-pressure TG (thermo-gravimetric analysis). The laboratory is very flexible, and is equipped with separate ventilation system and alarms to have a safe operation condition.



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INFRASTRUCTURE NAME:	SINTEF SDR- SOLVENT DEGRADATION RIG
LOCATION:	NORWAY, OSLO AND TRONDHEIM
WEB SITE ADDRESS:	WWW.SINTEF.NO
INFRASTRUCTURE'S OPERATOR:	SINTEF AS
CATEGORY:	CAPTURE

Description of the facility: The SDR rig is a laboratory test rig built to study the degradation of amine solvents over time under simulated CO₂ capture conditions. Execution of a process protocol should give a qualitative picture of what degradation products are formed for a given solvent system. The experimental results would provide input on what degradation products to look for in emissions from a plant running on the specified solvent. These experiments should also give a relatively good picture of the risks presented by the different solvents. Process protocols that can be run in the SDR rig consist of Standard, High Oxygen, High NO_x and High Temperature Protocols. Each protocol has different process condition as well as different gas composition resulting in different degradation products. In this rig, both oxidative and thermal degradations occur simultaneously. The rig operates 24 hours for 14 weeks (4 process protocols).

Analysis. Some degradation products can be analyzed with LC-MS-MS-QQQ with an instrumental detection limit of about 5 µg/L. Typical degradation products of MEA consist of OZD, HEA, HeGly, HEPO etc. NDELA is one of the nitrosamines produced during the campaign



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State of the art The major part of this infrastructure contains various experimental techniques used to evaluate the performance of sorbents and membranes. All techniques offered are modern and the results obtained are expected to be of high scientific quality. The experiments can be conducted under realistic conditions at high temperatures, pressures, and under high partial pressures of steam. Various gases are available. Also, tests in a sulphur environment (or other special gases) can be carried out in a separate laboratory with dedicated setups. The equipment are monitored and used only by skilled technicians/scientists. The facility is very flexible with easily access to all parts of the plant. Most modifications of the plant may be done inexpensively and also additional instrumentation for special purposes. The SDR rig is designed to study degradation products formed for a given solvent system at certain process condition. The experimental results would provide input on what degradation products to look for in emissions from a plant running on the specified solvent. The laboratory has a close co-operation with analytical laboratory (SITNEF Biotechnology), which makes it possible to analyse liquid samples for degradation products and amines.

Services offered: Skilled scientists and technicians are available to assist visiting researchers. Beside the infrastructure itself, more standard laboratories are available where sample preparation and other tasks can be performed. A number of GC, MS and IR gas analysers are available, if needed. A desk with internet access will be available during the stay.

INFRASTRUCTURE NAME:	SINTEF TILLER PILOT (PLANT)
LOCATION:	NORWAY, OSLO AND TRONDHEIM
WEB SITE ADDRESS:	WWW.SINTEF.NO
INFRASTRUCTURE'S OPERATOR:	SINTEF AS
CATEGORY:	CAPTURE

Description of the facility: The pilot plant was commissioned in 2010 and is located in a new building (Figure1a) at the SINTEF site at Tiller. A propane burner (380 kW) is providing heat to the buildings and flue gas to the plant. The columns diameters in the plant have been dimensioned according to the amount of flue gas available and are quite small. However, the design philosophy has been to otherwise design the plant as similar as possible to a full scale post combustion plant.

State of the art: The Tiller plant is excellent to test new solvent systems. The total liquid holdup is about 600 litres, thus more expensive solvent systems is possible to test without giving high costs. The results are easily scaled up to industrial sizes since the gas-liquid conditions in the towers are very similar. Modifications and additional instrumentation of the plant may be done inexpensively.

Services offered: We offer the access to the pilot plant for performing solvent test campaigns. CO₂ concentrations up to 30 % CO₂ have been tested. Solvent emission tests with various contaminate may be performed including test with mist particles by using our mist generator. Skilled scientists and technicians are available to assist visiting partners.



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INFRASTRUCTURE NAME:	GISKÅS - PIPELINE CRACK ARREST TEST
LOCATION:	NORWAY, OSLO AND TRONDHEIM
WEB SITE ADDRESS:	WWW.SINTEF.NO
INFRASTRUCTURE'S OPERATOR:	SINTEF AS
CATEGORY:	TRANSPORT

Description of the facility: Test site for fracture propagation control – in combination dispersion data analysis – from running fractures in off-shore CO₂ -pipelines. This is a pilot facility for assessment and validation of models for Fracture Propagation Control in combination with CO₂ dispersion from ruptures in off-shore CO₂ pipelines. To describe the fate and risk associated with the released gas it is important to estimate the mass transfer to the water, this can be done more efficiently if two release depths are available for comparison. The greater depths translate into longer residence time for the gas and thus reducing the accuracy needed to estimate the mass transfer. This will be an offshore test-site for subsea FPC experiments on pipelines and measurements of dispersion of CO₂ following such events will be established in the mid-Norway region. Several candidate fields have previously been mapped by SINTEF. To the authors knowledge this will be the only subsea test site for such events in the world.

State of the art: Only one test site for on-shore fracture propagation control (FPC) in Norway has previously been used. This is an army test site at Giskås (100 km east of Steinkjer). Data from the experiments done on this site has been crucial for the verification in the FPC model development work being done in FME BIGCCS, as well as satisfied the immediate needs of national (DNV-GL) and international (e.g. Nippon Steel, JP) customers of the tests. Significant interest on the FPC issue from operators of national and international subsea pipelines (e.g. Gassco and other gas transporting companies as well as operators) exist.

INFRASTRUCTURE NAME:	SINTEF SCAL - CORE FLOOD LABORATORY
LOCATION:	NORWAY, TRONDHEIM
WEB SITE ADDRESS:	WWW.SINTEF.NO
INFRASTRUCTURE'S OPERATOR:	SINTEF AS
CATEGORY:	STORAGE

Description of the facility: The special core analysis laboratory consists of several high-pressure flooding rigs. The flooding rigs are equipped to perform 2- and 3-phase floods on core samples up to a pressure of 700 bars and temperature of 160 °C with a maximum core length of 120 cm. Studies may include compositional analysis of produced fluids as well as additional chemical analysis of fluids and characterization of the core material.

State of the art: The flexible set-ups of flooding rigs may easily be adapted according to specific needs related to the porous medium (consolidated rock or sand packs, different core sizes, etc.) and flooding conditions (volume rates, type of fluids, fluid phases, pressure and temperature). The laboratory may also offer support for rock characterization and in-situ fluid saturation measurements. The laboratory is conducting research within multiphase flow processes in porous media. This work is mostly related to enhanced oil recovery (EOR) processes including CO₂ injection for EOR as well as studies of CO₂ flow and transport processes. The core laboratory is working in close connection with the fluid laboratory (SINTEF pVT), and most core flooding projects will need fluid analysis to be included. The SCAL laboratory is also working in close cooperation with other SINTEF laboratories within rock characterization and rock mechanics. The laboratory is currently being upgraded with a new facility for X-ray computed tomography to allow detailed measurement of fluid distribution during flooding experiments.

Services offered: The laboratory offers a wide range of services and special research type of experiments.



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INFRASTRUCTURE NAME:	SINTEF PVT - FLUID LABORATORY
LOCATION:	NORWAY, OSLO AND TRONDHEIM
WEB SITE ADDRESS:	WWW.SINTEF.NO
INFRASTRUCTURE'S OPERATOR:	SINTEF AS
CATEGORY:	STORAGE

Description of the facility: The fluid laboratory consists of various cells and apparatus for fluid studies:

- Automated visual pVT-cell with working conditions up to 700 bars and 150 °C
- Special HPHT cells with working conditions up to 1400 bars and 210 °C
- Automated slim tube apparatus (700 bars, 150 °C)
- IFT cells using either the pendant drop or the interface laser light scattering principle
- Diffusion cell (temperature- and compositional gradients)
- Viscometers for HTHP conditions
- Measurement of additional fluid properties such as density and rheology at process conditions

State of art for: The fluid laboratory is well equipped to perform a wide range of fluid studies under realistic reservoir conditions, including HPHT conditions up to 1400 bar and 210°C. All basic fluid properties necessary for interpretation of core flooding studies may be measured in the laboratory.

The laboratory is conducting research in behaviour and properties of reservoir fluids (oil, gas, brine), including miscibility studies (oil/gas).



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Services offered: The laboratory offers a wide range of services and special research type of experiments.

INFRASTRUCTURE NAME:	SINTEF RESLAB - SINTEF-NTNU RESERVOIR LABORATORY, INCLUDING μ -CT
LOCATION:	NORWAY, OSLO AND TRONDHEIM
WEB SITE ADDRESS:	WWW.SINTEF.NO
INFRASTRUCTURE'S OPERATOR:	SINTEF AS
CATEGORY:	TRANSPORT

Description of the facility: A wide range of applications within flow processes in porous media and measurements of fluid properties at relevant conditions for CO₂ storage. Equipped with two installations that also are very relevant to enhanced oil recovery (CO₂-EOR) processes:

- The core flooding lab doing research within multiphase flow processes in porous media
- The fluid (pVT) lab doing research within fluid behavior and fluid properties

State of art: Features:

- Data-collection automatization (data collection and interpretation)
- Quick turn-over of experiments and results: standardized equipment, shorter training time, easy alignment with other lab facilities, e.g. the rock mechanics lab; rigs and other equipment
- Computer aided optimisation of lab experiment design and interpretation.

INFRASTRUCTURE NAME:	SINTEF WILAB - SINTEF-NTNU WELL INTEGRITY LABORATORY
LOCATION:	NORWAY, OSLO AND TRONDHEIM
WEB SITE ADDRESS:	WWW.SINTEF.NO
INFRASTRUCTURE'S OPERATOR:	SINTEF AS
CATEGORY:	STORAGE

Description of the facility: Sealing ability of cement and plugging material throughout the life-cycle of the well, including after well abandonment:

- Cement sheath integrity
- Cement plug integrity
- Temperature and pressure cycling
- X-ray computed tomography for 3D characterization of voids and leak paths
- Long-term exposure; impact from crude, brine, CO₂ and H₂S

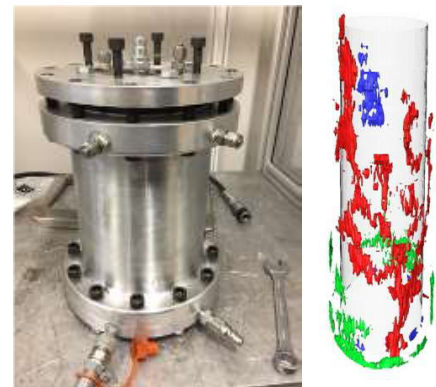


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INFRASTRUCTURE NAME:	SINTEF FPLAB (FORMATION PHYSICS LABORATORY)
LOCATION:	NORWAY, TRONDHEIM
WEB SITE ADDRESS:	WWW.SINTEF.NO
INFRASTRUCTURE'S OPERATOR:	SINTEF AS
CATEGORY:	STORAGE

Description of the facility: The SINTEF Formation physics laboratory is a well-equipped and highly specialized laboratory where rock physical parameters and processes can be studied under near in-situ conditions. It provides a link between geomechanics and rock physics. The laboratory works in cooperation with the SINTEF Core flood laboratory to also cover laboratory facility needs in studies related to CO₂-related well integrity, such as near-well dry-out and salt precipitation.

State of art: The test systems can be divided into three groups:

- Triaxial tests with high stress and pressure capacity (140 MPa) for samples either of 1" or 1.5" diameter samples
- Triaxial tests at low pressure (20 MPa) with 20 kN axial force capacity for 15 mm diameter samples
- Hollow cylinder tests under isotropic pressure for specimen sizes of 50 mm, 100 mm or 200 mm outside diameter, with pore pressure and radial fluid flow capacity. Sample length to outside diameter ratio = 1

The laboratory also has access to extensive modelling capabilities for interpretation of laboratory tests.

INFRASTRUCTURE NAME:	IFE GEOCHEMISTRY LABS
LOCATION:	NORWAY, OSLO
WEB SITE ADDRESS:	WWW.IFE.NO
INFRASTRUCTURE'S OPERATOR:	IFE INSTITUTT FOR ENERGITEKNIKK
CATEGORY:	STORAGE

Description of the facility: The SINTEF Formation physics laboratory is a well-equipped and highly specialized laboratory where rock physical parameters and processes can be studied under near in-situ conditions. It provides a link between geomechanics and rock physics. The laboratory works in cooperation with the SINTEF Core flood laboratory to also cover laboratory facility needs in studies related to CO₂-related well integrity, such as near-well dry-out and salt precipitation.

State of art: The test systems can be divided into three groups:

- Triaxial tests with high stress and pressure capacity (140 MPa) for samples either of 1" or 1.5" diameter samples
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- Hollow cylinder tests under isotropic pressure for specimen sizes of 50 mm, 100 mm or 200 mm outside diameter, with pore pressure and radial fluid flow capacity. Sample length to outside diameter ratio = 1

The laboratory also has access to extensive modelling capabilities for interpretation of laboratory tests.

INFRASTRUCTURE NAME:	TPRL - TRANSPORT PROPERTIES RESEARCH LABORATORY
LOCATION:	KEYWORTH, NOTTINGHAM, UK
WEB SITE ADDRESS:	WWW.BGS.AC.UK
INFRASTRUCTURE'S OPERATOR:	NATURAL ENVIRONMENT RESEARCH COUNCIL (NERC) REPRESENTED BY THE BRITISH GEOLOGICAL SURVEY
CATEGORY:	STORAGE

Description of the facility: Focus is on multi-phase flow in natural and engineered, low and ultra-low permeability geomaterials (e.g. caprocks, well bore cements, halite and engineered clays), and their associated deformation behaviour. Measurements include: saturation and consolidation properties; intrinsic permeability (or transmissivity); anisotropy; specific storage; coupled flow parameters (e.g. osmotic permeability); capillary entry, breakthrough and threshold pressures; gas permeability function; drained and undrained compressibilities; and rheological (creep) properties.

State of the art for TPRL: The TPRL is one of the leading centres in Europe for the study of fluid movement in ultra-low permeability media. The facility is well known within the radioactive waste disposal and carbon capture and storage sectors for high quality experimental work and process-based interpretation. Unique BGS-manufactured equipment and experimental systems provide high-resolution and high accuracy data. Data is collected using a state-of-the-art National Instrument logging system and tests can be monitored and operated by remote control online.

Services offered: Complimentary services available to the laboratory include sample preparation, geotechnical characterisation, thin section preparation and petrological/microstructural analysis.



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INFRASTRUCTURE NAME:	RMPL - ROCK MECHANICS AND PHYSICS LABORATORY
LOCATION:	KEYWORTH, NOTTINGHAM, UK
WEB SITE ADDRESS:	WWW.BGS.AC.UK
INFRASTRUCTURE'S OPERATOR:	NATURAL ENVIRONMENT RESEARCH COUNCIL (NERC) REPRESENTED BY THE BRITISH GEOLOGICAL SURVEY
CATEGORY:	STORAGE

Description of the facility: The Rock Mechanics and Physics Laboratory (RMPL) undertakes research on the physical properties and behaviour of rock specifically for: planning, design and construction within the civil engineering sector; extraction and storage within the energy sector; developing our understanding of near-surface to shallow crustal earth processes in order to help predict and mitigate the effects of small and large scale geohazards.

State of the art for RMPL: RMPL is the home of BGS's large scale rock deformation apparatus which is used to measure the physical properties and behaviour of rock when subjected to changes in pressure and temperature associated with near surface to shallow crustal conditions (~6 km).

Services offered: Research in this laboratory has been used to improve the understanding of material behaviour and processes related to the mechanical and physical properties of rocks, and hence contribute to process models and performance assessment related to CO₂ storage, underground gas storage and other underground construction applications.

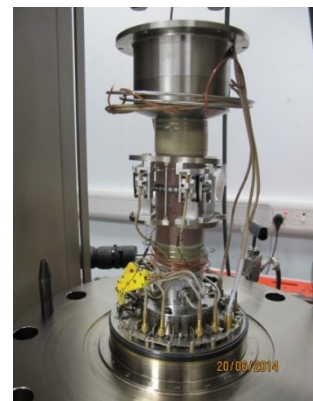


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INFRASTRUCTURE NAME:	HTL - HYDROTHERMAL LABORATORY
LOCATION:	KEYWORTH, NOTTINGHAM, UK
WEB SITE ADDRESS:	WWW.BGS.AC.UK
INFRASTRUCTURE'S OPERATOR:	NATURAL ENVIRONMENT RESEARCH COUNCIL (NERC) REPRESENTED BY THE BRITISH GEOLOGICAL SURVEY
CATEGORY:	STORAGE

Description of the facility: The BGS Hydrothermal Laboratory enables the study of chemical reactions between fluids and rocks under conditions found in the top few kilometres of the Earth's crust. The lab contains a variety of equipment capable of maintaining controlled conditions for timescales of up to many years. Reactions are followed by various means, including: visual observations, monitoring fluid chemical changes over time, and detailed mineralogical analysis of the reaction products. The experimental reaction products are characterised using a wide range of fluid chemical and mineralogical analytical techniques that are available within other dedicated laboratories at the BGS.

State of the art for HTL: The hydrothermal laboratory is the leading laboratory within Europe for the study of the chemical and mineralogical changes caused by stored CO₂, (including other acidic impurities in the CO₂), on reservoir rocks (e.g. sandstones and limestones) and caprocks (e.g. clays and evaporites), the impact of stored CO₂ on borehole infrastructure (i.e. borehole steel and cement), and how these contribute to long-term safe storage.

Static (batch) and flow-through equipment are available in the laboratory, with useable volumes ranging from less than one ml to over ten litres, although they have variable pressure and temperature limitations up to 600°C and 1500 bar.

Services offered: The laboratory offers a wide range of experimental geochemistry equipment and expertise, with a long track record in CCS

INFRASTRUCTURE NAME:	GAS MON - NEAR SURFACE GAS MONITORING FACILITY
LOCATION:	KEYWORTH, NOTTINGHAM, UK
WEB SITE ADDRESS:	WWW.BGS.AC.UK
INFRASTRUCTURE'S OPERATOR:	NATURAL ENVIRONMENT RESEARCH COUNCIL (NERC) REPRESENTED BY THE BRITISH GEOLOGICAL SURVEY
CATEGORY:	STORAGE

Description of the facility: BGS facilities for the collection and measurement of gases in the near surface environment. This includes field and laboratory capability for measuring gases in the shallow subsurface (e.g. soils), fluxes from the soil into the atmosphere and determinations in the atmosphere just above the ground surface. The scope of research has been extended to include work on baselines in areas prospective for shale gas and geothermal exploration.

State of the art for Gas Mon: Monitoring of near surface gases for CCS onshore needs to include a range of capabilities including: wide area coverage to detect potential surface seepage of CO₂ over the large surface footprint of a large scale (Mt/year) storage site, continuous monitoring of possible leakage pathways (e.g. wells and faults), discrimination of gas source (is the CO₂ coming from storage at depth or natural CO₂ produced by near surface processes?) and quantification of any emissions of stored CO₂.



Continuous CO₂ and CO₂ flux measurement by eddy covariance. Click anywhere to close

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INFRASTRUCTURE NAME:	GEOMICROBIOLOGY LABORATORY - S16
LOCATION:	KEYWORTH, NOTTINGHAM, UK
WEB SITE ADDRESS:	WWW.BGS.AC.UK
INFRASTRUCTURE'S OPERATOR:	NATURAL ENVIRONMENT RESEARCH COUNCIL (NERC) REPRESENTED BY THE BRITISH GEOLOGICAL SURVEY
CATEGORY:	STORAGE

Description of the facility: A fully equipped Containment Level 2 microbiology laboratory is available with the capability of handling geological materials (core materials and groundwaters). The Facility specialises in evaluating the impacts of CO₂ injection on deep subsurface indigenous microbial populations and the effects of those organisms on the movement of CO₂, solutes and contaminants.

State of the art: The Facility has a proven track record investigating the effects of CO₂ leakage on ecosystems. For over 5 years it has conducted extensive research in both the UK and overseas and currently involved in projects assessing the ecosystem response to CO₂ leakage and in understanding microbial activity in the reservoir.

Services offered: The Facility can examine the impacts of CO₂ injection on deep subsurface microbial populations and the impacts of those organisms on CO₂ movement in the deep subsurface.

INFRASTRUCTURE NAME:	PACT 250 KWTH PF AIR-OXY-FUEL COMBUSTION PLANT
LOCATION:	SHEFFIELD, UK
WEB SITE ADDRESS:	WWW.PACT.AC.UK
INFRASTRUCTURE'S OPERATOR:	UNIVERSITY OF SHEFFIELD
CATEGORY:	CAPTURE

Description of the facility: The 250 kWth Pulverised Fuel Combustion Plant supports advanced combustion research, CCUS and BECCS. The 4m (h) x 0.9m (ID) down-fired, cylindrical test rig is equipped with a variety of burners and fuel feeding systems for coal and biomass. The rig can be operated in conventional air-fired and oxyfuel mode including simulated oxyfuel with a dedicated gas mixing facility, and trace gas and steam injection capability. The facility is equipped with multiple analytical ports for advanced R&D: including: 2D & 3D flame visualisation and laser diagnostics; detailed profiling of in-flame gas composition, gas temperatures (suction pyrometer) and heat-flux; online analysis of gas emissions (FTIR and stack analyser); online particulate (DMS500) and metal (ICP-OES) emission; deposition and corrosion studies and multi-point ash sampling. The plant is integrated with (1) a 1tonne of CO₂/day post-combustion capture (PCC) plant; (2) a Gas Mixing Facility and steam injection system for real as well as controlled, simulated oxyfuel combustion with flexible gas concentration + steam and/or trace gas injection capability.

State of the art: In addition to conventional CCS research, the facility has been used in pioneering fundamental and applied research on BECCS with oxyfuel and post combustion capture. Its unique features include: (1) flexible operation with coal/biomass under air and oxyfuel combustion; (2) integration with PCC plant; (3) integration with gas mixing and steam injection facilities combustion conditions and flue gas control; and (4) extensive state of the art analytical capability, including analytical probes and online gas, particulate and metal emissions monitoring and analysis. Experimental operations and supported by expert advanced modelling including integrated system modelling.

Services offered: Advanced combustion research; fuel and burner development and evaluation; CCUS, BECCS R&D for Post Combustion Capture and Oxyfuel combustion; gas, particulate and metal emissions analysis; process and system modelling.

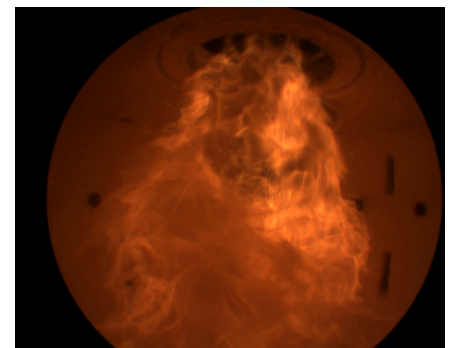


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INFRASTRUCTURE NAME:	PACT 330 KWTH CHP GAS TURBINES
LOCATION:	SHEFFIELD, UK
WEB SITE ADDRESS:	WWW.PACT.AC.UK
INFRASTRUCTURE'S OPERATOR:	UNIVERSITY OF SHEFFIELD
CATEGORY:	CAPTURE

Description of the facility: Turbec T100 series 1 and 3 microturbines support CCUS research from gaseous/ liquid fuels. The CHP units each generate up to 100kWe and 170kWth energy with an overall efficiency of 77%. Normally operated on 330kW of natural gas the units can be configured to also run on other fuels such as biogas, syngas, diesel, kerosene, methanol and LPC. Equipped with a range of analytical equipment the systems enables detailed process monitoring of system operations, temperatures, pressures and gaseous (gas analyser and FTIR) and soot particulate (DMS500) emissions. The turbine CHP units are integrated with (1) a 1 tonne of CO₂/day post-combustion capture plant; (2) a Gas Mixing Facility for flue gas composition modulation and simulated Exhaust Gas Recycling; and (3) steam injection system for Humid Air turbine Cycle operation.

State of the art: Direct integration with carbon capture plant and gas mixing and steam injection facilities, alongside comprehensive system and emissions monitoring and analysis offer a unique capability to support various aspects of CCS research and has been used extensively in projects focussing on flue gas optimisation on the turbine side as well as on the carbon capture side.

Services offered: CCUS R&D: Post combustion capture from gas turbines; Exhaust Gas Recycling (EGR) and selective EGR with membranes; Humid Air Turbine Cycle; alternative fuels research; process and integrated system modelling.

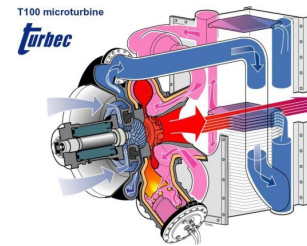


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INFRASTRUCTURE NAME:	PACT BIOMASS GRATE COMBUSTION BOILER
LOCATION:	SHEFFIELD, UK
WEB SITE ADDRESS:	WWW.PACT.AC.UK
INFRASTRUCTURE'S OPERATOR:	UNIVERSITY OF SHEFFIELD
CATEGORY:	CAPTURE

Description of the facility: The 240kWth PACT Biomass Grate Combustion Boiler supports research on Bioenergy (BE) including fuel processing and development, emissions and BECCS. The boiler can operate on virgin and recycled/waste wood and biomass chip/pellets. Moving grate provides homogeneous combustion with continual automatic removal of ash and the individually controlled and metered primary, secondary and tertiary air and the high-temperature post combustion zone ensures optimum combustion and support the utilisation of lower grade fuels. Automatic heat exchanger cleaning and cyclone filter ensure optimum efficiency and minimum emissions. The system is fully automated and utilises pressure, temperature and lambda sensors for optimum combustion control and efficiency. The combustion chamber and hot gas path are fitted with arrays of sampling ports enabling detail research of the combustion processes and emissions, including: temperature profiling; profiling of heat flux, and gas composition and temperatures (suction pyrometer); deposition and corrosion studies; thermal imaging and online monitoring and analysis of gas (FTIR and stack analyser), particulate (DMS500) and metal aerosol emissions (ICP-OES). The boiler is integrated with a 1 tonne of CO₂/day post-combustion capture plant.

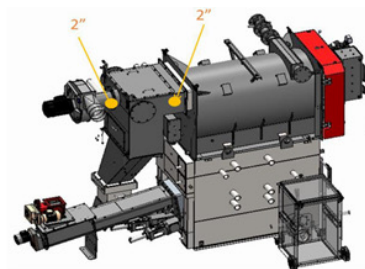
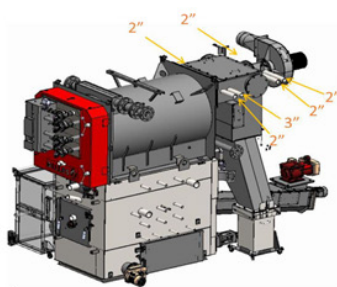
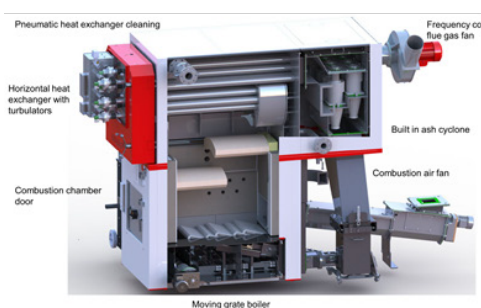


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State of the art: The boiler's (1) fuel tolerance; (2) integration with PCC plant; and (3) extensive state of the art integrated, online and supporting analytical facilities; complemented by expert process and integrated system modelling expertise create a unique capability to support advanced R&D in bioenergy and BECCS. The facility has been deployed in projects focussing on fuel processing and testing; corrosion, deposition and emissions research; and pioneering research on BECCS.

Services offered: R&D in BECCS and Waste to Energy; fuel development, blending and fuel screening research; emissions research; process and integrated system modelling.

INFRASTRUCTURE NAME:	PACT POST-COMBUSTION CAPTURE PLANT
LOCATION:	SHEFFIELD, UK
WEB SITE ADDRESS:	WWW.PACT.AC.UK
INFRASTRUCTURE'S OPERATOR:	UNIVERSITY OF SHEFFIELD
CATEGORY:	CAPTURE

Description of the facility: The PACT 1 tonne of CO₂ per day Post Combustion Capture Plant enables integrated CCUS/BECCS research in power generation and industrial applications. The plant utilises chemical solvent, typically amines, for Capture of CO₂ from combustion Flue or industrial process gasses. The plant comprises an integrated Flue Gas Disulphurisation (FGD) wash system (also a direct contact cooler), 8m absorber (possible 2x 8m columns in series), 8m desorber and a water wash column. The absorber and desorber are equipped with multiple sampling points enabling detailed temperature, pressure and gas/liquid profiling, aiding mechanistic and dynamic operations research and process/component modelling. The plant is fully automated with integrated detailed process monitoring and control to support flexible operation and research. The plant is equipped with state of the art online multipoint emissions monitoring by FTIR, column CO₂ profiling (CO₂ analyser), metal aerosols/particulates (ICP-OES), particulate and aerosol analysis (DMS500). Online capability is further agumented by lab analytical facilities, including autotitrators and ion chromatography and GCMS. The capture plant is interfaced with onsite: (1) Pulverised fuel (coal/biomass) combustion plant; (2) Biomass chip/pellet grate boiler; (3) CHP Gas turbines; and (4) Synthetic Gas Mixing Facility with trace gas injection capability for the modulation of real flue gases or the generation of simulated combustion flue gases or industrial process gases. This enables integrated CCUS/BECCS research in power generation and industrial applications.

State of the art: Flexible configurations and operating parameters, and the direct integration with onsite multi-fuel combustion rigs and the synthetic gas mixing facility for modulated/simulated gas compositions, combined with state of the art analytical capability both on the flue gas generation and capture side, offer a unique integrated-systems R&D capability. The facilities have been deployed in research on the development and evaluation of novel capture solvents for conventional CCS with gas/solid fuels, BECCS, dynamic operations research; and the development of online solvent monitoring systems.

Services offered: Example research areas: Development and energy benchmarking of capture solvents for power generation and industry; integrated carbon capture research including dynamic operations, BECCS, impact of different fuels and trace gas components on solvent performance and emissions, solvent mechanistic studies; solvent degradation and mitigation strategies; corrosion and materials testing research; plant and integrated system modelling.



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INFRASTRUCTURE NAME:	PACT- MOBILE ONLINE ICP-OES
LOCATION:	SHEFFIELD, UK
WEB SITE ADDRESS:	WWW.PACT.AC.UK
INFRASTRUCTURE'S OPERATOR:	UNIVERSITY OF SHEFFIELD
CATEGORY:	CAPTURE

Description of the facility: The mobile Inductively Coupled Plasma – Optical Emission Spectrometer (ICP-OES) Lab is used for online monitoring of metal aerosols in combustion flue /process gases and is key in CCUS and BECCS in enabling the understanding and optimisation of combustion processes under various conditions including oxyfuel combustion as well as understanding and mitigating the impact of emissions on downstream post combustion capture plant. The self-contained unit can be transported to test site and connect to the process via a 40 m heated line. The state of the art facility can perform real time simultaneous multi-elemental detection of entrained metal aerosols such as As, Ca, Cd, Hg, K, Na, Pb, Sn, V, Zn, and others with detection limits as low as 0.0004 mg m⁻³. The online facility is integrated with PACT combustion test rigs and post combustion plant.

State of the art: Simultaneously online monitor of the concentrations of over 30 elements enables the monitoring of process emissions and the understanding of their impact on downstream processes to inform the development of emissions mitigation strategies. The mobile facility has been extensively deployed in CCS and BECCS research with solid fuels.

Services offered: Example research area: Impact of metallic emissions on Post Combustion Capture process: solvent degradation, atmospheric emissions, and CO₂ purity; utilisation of biomass and waste fuels in power generation with CCS; fuel pre-treatment R&D.

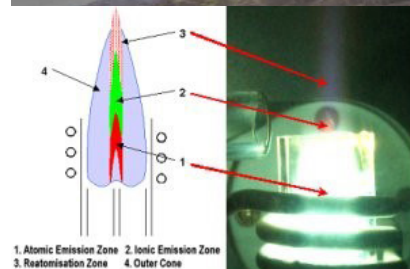


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INFRASTRUCTURE NAME:	PACT ANALYTICAL FACILITIES POOL
LOCATION:	SHEFFIELD, UK
WEB SITE ADDRESS:	WWW.PACT.AC.UK
INFRASTRUCTURE'S OPERATOR:	UNIVERSITY OF SHEFFIELD
CATEGORY:	CAPTURE

Description of the facility: PACT facilities have a wide range of state-of-the-art analytical facilities. These include: (1) online analytical instruments such as FTIR gas analysers and particle size analyser which complement and enhance dedicated analytical capabilities on a specific rig as well as (2) lab based analytical equipment which provides supporting analysis such as fuel analysis or solvent concentration, composition, or degradation analysis. Selected facilities are highlighted below;

Online

- PACT Combustion DMS500 Fast Particulate Analyser enables real-time online (via heated sampling line) analysis of particle size and distribution, for example for the analysis of soot or fly ash particulates in exhaust gases of PACT combustion plants, or to analyse aerosol on the PACT Post Combustion Capture plant.
- PACT Gasmet FTIR Gas Analysers enable online real-time analysis of 20-25 compounds including conventional combustion products, solvent emissions and solvent degradation products; they are ideal for measuring trace concentrations of pollutants in wet, corrosive gas streams and routinely deployed across all PACT pilot-scale test facilities

Lab based

- PACT Clarus® SQ 8 GC/MS enables analysis of gaseous and liquid samples covering fuel and combustion products, and solvent from PACT Post-Combustion Capture plant including solvent component concentrations and solvent degradation products
- PACT Perkin Elmer Pyris 1 Thermogravimetric Analyser enables detailed thermal decomposition studies under inert and oxidative atmospheres of samples such as fuel and ash to determine amounts of volatiles and ash content for fuel assessment or carbon in ash for combustion efficiency.
- PACT TG-MS, TG-GCMS enables characterisation of the evolved products from the thermal degrading of samples including fuels (for example treated biomass or waste fuels) and solvent.
- PACT Perkin Elmer 2400 Series II CHNS Elemental Analyser enables the determination of the carbon, hydrogen, nitrogen and sulphur content in organic and other types of samples, including solids, liquids, volatile and viscous samples with main application in fuel and ash analysis
- PACT PetroOxy Oxidation Stability Tester can be utilised for thermal and oxidative stability/degradation tests of capture solvents.

State of the art: comprehensive analytical suite to support research on the combustion and capture side of CCUS/BECCS

Services offered: Supporting online/lab facilities for PACT pilot scale rigs as well as mobile facilities (ICP-OES, FTIR, DMS500, other...) which can be deployed on customer/partner site.



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ECCSEL ERIC is registered in Norway in the Company Registry with the organisation number 919298243