STORAGE RESEARCH INFRASTRUCTURE ECO-SYSTEM

RI Information sheet 2022

SINTEF Energy Research, ECCSEL Energy Fluid Lab

Energy storage, transfer, or conversion technologies involving fluids are relevant for this lab within a temperature and pressure range of -60 to 200 and up to 1000 bar respectively. E.g. chemical, thermal, mechanical, cross-cutting,…

Contact person 1:

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Project Acronym	StoRIES
Call	H2020-LC-GD-2020
Grant Agreement No.	101036910
Project Start Date	01-11-2021
Project End Date	31-10-2025
Duration	48 months

1. Photo

Figure 1: Snippets of the installations of the fluid energy lab

2. Geographical coordinates

63˚, 25“,7.968N, 10˚, 24“,14.9004E

3. Description of the research infrastructure for the webpage

The ECCSEL Energy Fluid Lab includes multiple installations, all located in the Thermal Laboratory Building of SINTEF ER, involving measurement of equilibrium fluid properties, low-temperature fluid separation, and investigation of steady state and transient effects during fluid transport:

CO_2Mix and HPC-PE are two accurate static analytical phase equilibrium facilities both covering the temperature range between -60 and 200 °C, designed for toxic, flammable, and corrosive components. They differ in that CO_2Mix is designed for up to 200 bar pressure, whereas HPC-PE is rated for 1000 bar and is more suited for more complex phase and chemical equilibria.

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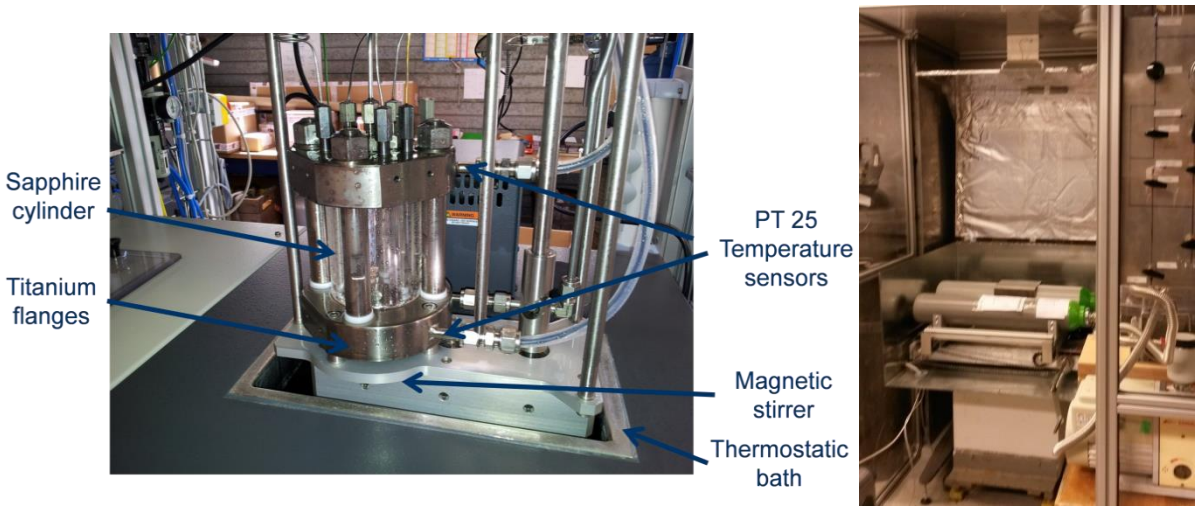

Left: Test cell of CO_2Mix phase equilibrium facility. Right: RefGasMix to prepare highly accurate calibration mixtures.

RefGasMix is an installation for very accurate (ppm-range) gravimetric preparation of fluid mixtures (gases and condensable gases)

VISC-DENS is an installation for accurate density and viscosity measurements. The setup is utilizing a two-capillary design, with a design range between -60 and 150 °C in temperature and up to 800 bar in pressure. Except for near critical conditions, the setup is designed for an accuracy of the order of 0.1 % in viscosity and pressure, and 10 mK in temperature. Thermal stability and uniformity are achieved using highly accurate thermostatic baths. A commercial densimeter is integrated with the viscometer.

SEPPIL is a small pilot for low-temperature separation which is particularly suitable to investigate separation between hydrogen and CO_2 at low temperatures, important in e.g. large- scale decarbonized H_2 production. Huge H_2 recovery potential from separation technologies such pressure swing adsorption and Pd-alloy membranes.

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Left: Interior view of SEPPIL. Right: Sketch of the DeFACTO facility

DeFACTO is a vertical flow installation that enables the circulation of fluids through a 90 m deep loop. The facility could be used to study injection and flow chemical energy carrier fluids or underground thermal or mechanical storage. The loop is instrumented with over 100 high precision-fast response pressure and temperature sensors, allowing to measure pressure waves with a high degree of accuracy. The vertical flow loop is connected to a 139 meters long horizontal flow loop, located on top of the facility. The horizontal flow loop enables circulation of fluid with precisely controlled parameters (contaminants, temperature, pressure, gas to liquid ratio). The data collected help understanding of depressurisation, cavitation phenomena, two-phase and transient flow behaviour, and ultimately assist engineers in the design of safer and more efficient fluid transport and storage systems.

Services currently offered by the infrastructure:

The ECCSEL Energy Fluid Lab 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. The facilities are continuously used in a number of national and international research projects sponsored by industry and the public. In addition to SINTEF's own staff, the installations of the Lab is annually used by a number of visiting researchers and students. Data quality of the installations is controlled in accordance with the SINTEF's accreditation to standards ISO 9001, ISO 14001 and ISO 45001:

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http://www.sintef.no/en/a-certified-institute. A brief summary of the services offered by the installations is summarized below.

Brief descriptions of the facilities are provided below. Further details are provided on the ECCSEL web pages:

- CO_2Mix/ RefGasMix: https://eccsel.org/catalogue/112
- VISC-DENS: https://eccsel.org/catalogue/116
- SEPPIL: https://eccsel.org/catalogue/90
- DeFACTO: https://eccsel.org/catalogue/115

CO_2Mix and HPC-PE

The main service of these installations are highly accurate measurements of highly accurate phase equilibria using the analytical method. In addition, both facilities offer the possibility of visual access to the cell content during experiments, and it is also possible to perform synthetic measurements through various means. The main method for analysis is GC with different detectors, but for HPC-PE also other analytical techniques could be supported. The facilities are prepared for toxic, flammable, and corrosive fluids, but additional safety measures following a specific review could be required depending on the desired measurement to be undertaken. HPC-PE is prepared for testing of in-situ measurement principles. While the HPC-PE facility is new, CO_2Mix has had on average 1-2 international users per year. Selected publications:

- S. Ottøy, T. Neumann, H.G.J. Stang, J.P. Jakobsen, A. Austegard, S.W. Løvseth, Thermodynamics of the carbon dioxide plus nitrogen plus methane (CO_2 + N_2 + CH_4) system: Measurements of vapor-liquid equilibrium data at temperatures from 223 to 298 K and verification of EOS-CG-2019 equation of state, Fluid Phase Equilib., 509 (2020) 112444. doi: 10.1016/j.fluid.2019.112444
- S.W. Løvseth, Austegard, Westman, Stang, Herrig, Neumann, Span, Thermodynamics of the carbon dioxide plus argon (CO_2 + Ar) system: An improved reference mixture model and measurements of vapor-liquid, vapor-solid, liquid-solid and vapor-liquid-solid phase equilibrium data at the temperatures 213–299 K and pressures up to 16 MPa, Fluid Phase Equilib., vol 466, pp. 48-78, 2018. doi: 10.1016/j.fluid.2018.02.009
- S.F. Westman, A. Austegard, H.G.J. Stang, S.W. Løvseth, Vapor-liquid equilibrium data for the carbon dioxide and carbon monoxide (CO_2 + CO) system at the temperatures 253, 273, 283 and 298 K and pressures up to 13

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MPa, Fluid Phase Equilib., vol 473, pp. 37-49, 2018. doi: 10.1016/j.fluid.2018.05.006

- E. Petropoulou, E. Voutsas, S.F. Westman, A. Austegard, H.G.J. Stang, S.W. Løvseth, Vapor - liquid equilibrium of the carbon dioxide/methane mixture at three isotherms, Fluid Phase Equilib., vol. 462, pp. 44-58, 2018. doi: 10.1016/j.fluid.2018.01.011
- S. F. Westman, H. G. J. Stang, S. W. Løvseth, A. Austegard, Snustad, Ertesvåg, Vapor-liquid equilibrium data for the carbon dioxide and oxygen (CO_2 + O_2) system at the temperatures 218, 233, 253, 273, 288 and 298 K and pressures up to 14 MPa, Fluid Phase Equilib., vol 421, pp. 67-87, 2016. doi: 10.1016/j.fluid.2016.04.002
- S. F. Westman, H. G. J. Stang, S. W. Løvseth, A. Austegard, S.Ø. Størset, Ertesvåg, Vapor-liquid equilibrium data for the carbon dioxide and nitrogen (CO_2+N_2) system at the temperatures 223, 270, 298 and 303 K and pressures up to 18 MPa, Fluid Phase Equilibria, vol 409, pp 207–241, 2016. doi: 10.1016/j.fluid.2015.09.034
- H.G. J. Stang, S. W. Løvseth, S. Ø. Størset, B. Malvik, H. Rekstad, "Accurate measurements of CO2-rich mixture phase equilibria relevant for CCS transport and conditioning," Energy Procedia, vol 37, pp 2897-2903, 2013. doi: 10.1016/j.egypro.2013.06.175

RefGasMix:

The main service of this installation is to produce mixtures with very accurate composition for the other ECCSEL Energy Fluid Lab installations, but it could also be used independently to prepare mixtures for other facilities and/or types of measurements outside the ECCSEL Energy Fluid Lab. A heated gas cylinder roller is also available to ensure uniform composition. Mixtures are prepared in 10 l gas cylinders. See the publications listed above for a further description.

VISC-DENS:

The facility provides accurate viscosity measurements for a wide range of fluid conditions. In order to get full benefit of the viscosity measurements, it is important to measure density of the same mixtures under identical conditions such that both kinematic and dynamic viscosities are found. Hence, an Anton Paar oscillating tube densimeter is connected to the viscometer. Viscosity is particularly important in order to calculate pressure drop or heat transfer for applications where there are laminar flow, e.g. in reservoirs used for energy storage.

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- B. Khosravi, S. W. Løvseth, et al., "A New Facility on Accurate Viscosity and Density Measurements," in 11th International Trondheim CCS Conference, Trondheim, Norway. https://hdl.handle.net/11250/2786924
- S. W. Løvseth, ImpreCCS: Lower CCS cost and risk through better CO2 viscosity and thermal conductivity knowledge, 2019. https://blog.sintef.com/sintefenergy/impreccs-lower-ccs-cost-risk-co2-viscosity-thermal-conductivity/
- SEPPIL:

SEPPIL is a lab-pilot experimental facility suitable for CO_2 separation, purification and liquefaction 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. It is liquid CO_2 storage experiments can also be conducted, with different setups possible. The facility is highly relevant for separation processes in the blue and carbon negative hydrogen production, i.e. from reforming with carbon capture of natural gas and biogas, respectively.

Some of the capabilities of the rig is to demonstrate the capture efficiency (CO_2 capture ratio) and CO_2 purification (from low-pressure liquid flash) from various types of above-mentioned relevant gas mixtures by cooling and condensation. This will be demonstrated in operational modes (finite separator retention time) and in a scale sufficiently large for industrial interest. The throughput capacity is approximately 340 Sm3/h, which gives a CO_2 throughput rate in the rough interval 5–15 ton per day, depending on the exact gas composition in consideration.

CO_2-rich liquid is separated from CO_2-depleted gas in two separator tanks in series. The bulk separation takes place at high pressure in the first of the two vessels. At the inlet of the second vessel the liquid is throttled to lower pressure, which increases the purity of the liquid CO_2.

The test rig is instrumented to monitor the operation of heat exchangers, separators, compressors and other auxiliary systems: 15–20 temperature sensors (excluding compressor instrumentation); 6 pressure transmitters (excluding compressor instrumentation); 2 level meters for separation tanks; 3 mass flow meters; 5 extraction points for composition measurement by gas chromatography. Maximum operation pressure is 120 bar on the high-pressure side. All interior equipment and ventilation are Ex Zone-2 classified. Available chemical components are currently: CO_2, N_2, H_2, CO, CH_4. The infrastructure includes auxiliary refrigeration with CO_2 as refrigerant.

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Selected publications:

- CEMCAP D11.2 Experimental investigation of CO2 liquefaction for CO_2 capture from cement plants (https://zenodo.org/record/2605080/files/d11.2-experimental-co2-liquefaction.pdf?download=1)
- Experimental investigation of low temperature CO2 liquefaction and phase-separation for carbon capture (https://doi.org/10.18462/iir.cryo.2019.0044)

DEFACTO:

Areas of research normally supported by the facility include fluid transport and injection, characterization of phase behavior of fluids with impurities in a vertical well, fluid flow and expansion.

Experiments conducted by the facility include:

- Accurate estimation of heat transfer coefficient under controlled conditions.
- Both single- and two-phase flow.
- Steady state flow at different T/P conditions and gas to liquid ratios.
- Transient,
    - Shut in and first fill.
    - Depressurizations.
    - Blowouts.
    - Fluid hammers.
- Reservoir backflow.

https://blog.sintef.com/sintefenergy/ccs/defacto-underground-testing-of-co2-transport-and-injection/

4. Availability of the research infrastructure

(Please indicate time periods in which infrastructure will not be available for StoRIES in the next 2 years – if already known)

In general, all services are expected to have some spare capacity during the StoRIES project period. Applicants are encouraged to present their measurement needs to SINTEF Energy Research and find a mutually suitable time for the experiments using the contact information provided above.

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5. Special considerations (confidentiality / NDA agreements, insurance requirement, special training, HSE training)

Access to the labs of the SINTEF Energy Research (SER) is dependent on compliance to all its relevant procedures and policies relating to HSE and protection of the intellectual property of SER and its partners, including signing a confidentiality agreement. Independent use of facilities will be dependent on individual approval as an operator by SER following training.

6. Energy storage technology that can be analysed/studied by using the research infrastructure

- Electrochemical ☐
- Chemical ☒
- Thermal ☒
- Mechanical ☒
- Superconducting Magnetic ☐
- Cross-cutting ☒ (Specifically: transfer of different forms of energy using fluids)

7. Key words for the webpage

Fluids, fluid dynamics, thermodynamics, fluid properties, transport properties, phase equilibria, density, viscosity, CO_2, hydrogen, ammonia, working fluids, refrigerants, well injection, liquefaction

8. TRL level (if applicable):

- 1-3 ☒
- 4-6 ☒
- Above ☒

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