DTU OIL AND GAS COMPETENCES

RESEARCH COMPETENCE, EQUIPMENT AND EDUCATIONAL ACTIVITIES AT DTU AVAILABLE FOR SUPPORT OF THE DANISH HYDROCARBON RESEARCH AND TECHNOLOGY CENTRE (DHRTC)

DTU is recognized internationally as a leading university in the areas of the technical and natural sciences with a business-oriented approach and a long history of collaboration with Danish and international industry. In terms of Oil and Gas research much of the research takes place in the interdisciplinary research center:

- CERE DTU – Center for Energy Resources Engineering.

CERE is a collaboration between faculty in the following academic departments:

- DTU Chemical Engineering
- DTU Chemistry
- DTU Compute
- DTU Civil Engineering
- DTU Space

Other departments where significant oil and gas research is being performed are:

- DTU Mechanical Engineering
- DTU Electrical Engineering
- DTU Nanotech
- DTU Management
- DTU Physics

This paper presents research competences located at the different DTU departments listed above where there is either active research in Oil and Gas or potential scope for such research. This document contains a general description of the relevant research in each department or center and a discussion of education initiatives in Petroleum Engineering undertaken at DTU.

EDUCATIONAL ACTIVITIES

DTU has a 2-year MSc program in Petroleum Engineering. Safe, innovative, environmentally sound, and economically viable extraction of oil and natural gas requires knowledge of geology, geophysics and rock mechanics, thermodynamic and chemical properties of oil and gases and their flow—in rocks and pipelines. The MSc programme in Petroleum Engineering covers a wide range of courses in these specific areas.

The Petroleum Engineering programme allows specialization in one of the two following focus areas:

Reservoir Engineering (oil production and engineering)

Reservoir Geophysics (oil production and geology)

The choice of courses in each individual study plan offers a high degree of flexibility. Therefore, it is possible to tailor-make a study programme and career by choosing from the wide range of courses offered at DTU.

The Petroleum Engineering programme enables one to contribute to solving the global challenge of meeting the increased demand for oil and gas. The student acquires the competencies to head the development and implementation of new technologies for efficient and sustainable production, or engage in international high-level research in the field.

Courses offered include:

Rock Physics and Rock Mechanics, Petroleum Engineering, Petrophysics and borehole logging, Oil and gas production, Enhanced Oil Recovery, Technology and Economy in Oil and Gas Production, Advanced Modelling - Applied Mathematics, Introduction to Partial Differential Equations, Multivariate Statistics, Statistical Design and Analysis of Experiments, Time Series Analysis, Large-scale Modelling, Scientific Computing for differential equations, Continuum Physics, Advanced engineering geology: soil and porous rocks, Basic Drilling Engineering, Petrophysical Engineering - Laboratory course, Mineral resources in the Arctic: Environmental impacts and technologies, Hydrology, Field Course in Applied Geophysics, Contaminated Sites, Applied Colloid and Surface Chemistry, Laboratory Course in Colloid and Surface Chemistry, Chemical Engineering Model Analysis, Phase Equilibria for non-ideal mixtures, Membrane Technology, Transport Processes, Rheology of complex fluids, Data Analysis and Modeling in Geoscience and Astrophysics, Computational Fluid Dynamics, Advanced Fluid Mechanics.

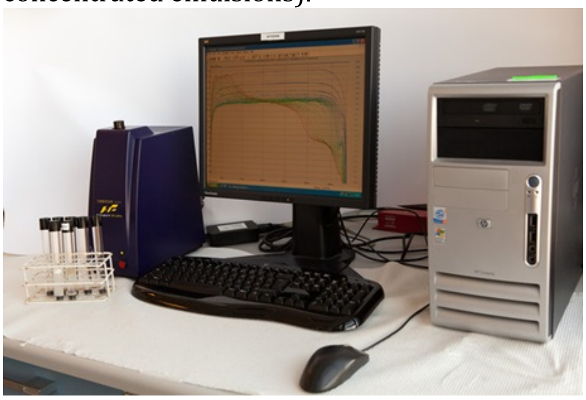
http://www.dtu.dk/english/Education/msc/Programmes/petroleum_engineering

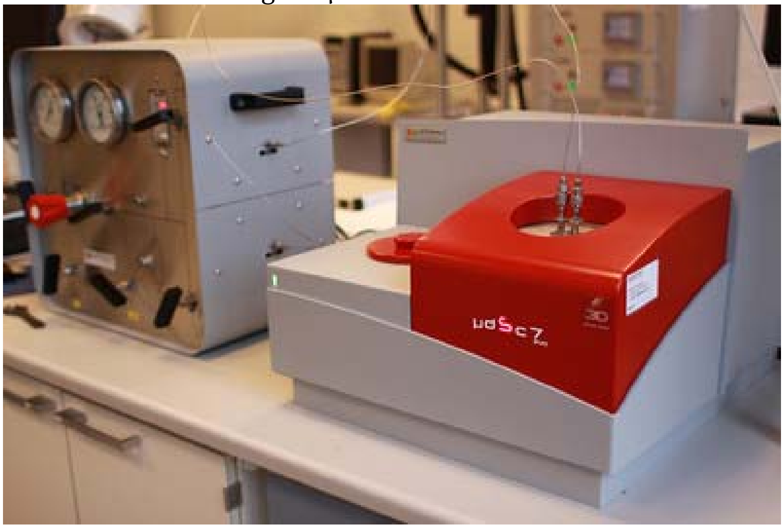
Research Competences and Laboratory Facilities

1. CERE DTU - Center for Energy Resources Engineering

DTU affiliation	Center for Energy Resource Engineering
	www.cere.dtu.dk
Short affiliation description with O&G in focus	Center for Energy Resources Engineering (CERE) is Denmark's leading research center in the areas of Enhanced Oil Recovery, flow assurance, Carbon Capture and Storage and petroleum geoscience. With an excellent track record and international reputation CERE uniquely combines strong competences from several academic fields. Most of our many diverse research projects are conducted in collaboration with one or more members of the CERE Consortium – a group of 29 leading companies in the field. CERE is an independent, university based, research unit with more than 30 years of expertise in the field. The CERE co-workers are a mix of internationally renowned scientists and the sharpest young talents from different scientific communities around the group. The research center unites experience with unique talent and educates tomorrow's scientists and engineers. The education and training of MSc and doctoral students are some of the most important aspects of CERE's activities.
Researcher	**Competence (Keywords)**
Philip Loldrup Fosbøl, Associate Professor, DTU Chemical Engineering plf@kt.dtu.dk	Energy Reduction; CO_2 Corrosion CCS ; CO_2 Transport ; Carbon Dioxide Capture and Storage ; Properties of Electrolytes ; Thermodynamics and Phase Equilibrium ; Flow sheet design, simulation, and optimisation ; Biogas Cleaning
Georgios Kontogeorgis, Professor, DTU Chemical Engineering gk@kt.dtu.dk	Traditional and advanced thermodynamic models for petroleum applications of relevance to enhanced oil recovery and flow assurance (gas hydrates, asphaltenes, wax, scales). Modeling of interfacial tension and multicomponent adsorption related to petroleum applications.
Xiaodong Liang, Assistant Professor, DTU Chemical Engineering xlia@kt.dtu.dk	Fundamentals of advanced association models (PC-SAFT); Thermodynamic modelling (CPA, PC-SAFT); Surface tension modelling (DGT); Computational algorithms (phase equilibrium and optimization in general); Software development (commercial simulators, MATLAB interface, standalone tool)
Alexander Shapiro, Associate Professor, DTU Chemical Engineering ash@kt.dtu.dk	Enhanced oil recovery; Flows in porous media; Core flooding; Smart water flooding; Microbial enhanced oil recovery; Transport properties; Mathematical and physical modeling of the flows in petroleum reservoirs; Thermodynamics of fluids in porous media – adsorption and capillary forces; particles in pores – deep bed filtration and formation damage; Reservoir characterization – gravity and thermal gradients; diffusion; flows in tight reservoirs.

Nicolas von Solms, Associate Professor, DTU Chemical Engineering nvs@kt.dtu.dk	Gas hydrate modelling; gas hydrate thermodynamic and kinetic inhibition, modelling and experiments; thermodynamic modelling and fluid phase equilibrium measurements (oil/water/gas) up to high pressures; polymers for offshore hydrocarbon pipeline transport; high pressure oil upgrading experimental and modelling; surfactant flooding for enhanced oil recovery
Kaj Thomsen, Associate Professor, DTU Chemical Engineering kth@kt.dtu.dk	Energy storage in rechargable flow batteries ; Fractional crystallization ; solid-liquid equilibrium ; Electrolyte thermodynamics ; Carbon dioxide capture ; Mixed solvent solutions; Smart water EOR, oilfield scale prediction, development of software algorithms for phase equilibrium in salt solutions
John Bagterp Jørgensen, Associate Professor, DTU Compute jbjo@dtu.dk	Model Predictive Control including computational aspects and applications. The applications include industrial processes, intelligent control of smart energy systems, production optimization and closed-loop reservoir management of oil fields, and an artificial pancreas for people with type 1 diabetes.
Ida Fabricius, Professor, DTU Civil Engineering ilfa@byg.dtu.dk	Reservoir geology, petrophysics, rock physics, petrography
Katrine Alling Andreassen, DTU Civil Engineering kall@byg.dtu.dk	Rock mechanics, rock physics, borehole stability.
Wei Yan, Senior Researcher, DTU Chemistry weya@kemi.dtu.dk	High pressure fluid phase behavior esp. PVT experiment and modeling for oil and gas production; phase equilibrium calculation algorithms; compositional reservoir simulation esp. streamline simulation; EOR esp. gas injection and high pressure flooding; reservoir engineering in general
Erling Halfdan Stenby, Professor, Head of Department, DTU Chemistry ehst@kemi.dtu.dk	Energy ; Oil and gas ; Petroleum Engineering ; Enhanced Oil Recovery ; Carbon Capture and Storage ; Applied Thermodynamics ; Phase Behavior
Arne Døssing Andreasen, Senior Researcher, DTU Space ards@space.dtu.dk	

Facilities/ Equipment	**X-ray Computed Tomography** scanners have been extensively used in research laboratories around the world for reservoir rock characterization and fluid flow visualization. They became a useful tool in petroleum industry. The value of a CT lies in its ability to look inside the rock to determine flow patterns, porosity, and saturation without altering the fluids or rocks.  Located at DTU Chemical Engineering
	TURBISCAN is a liquid dispersion optical characterization instrument. It is useful to monitor emulsions and dispersions in the kinetic studies of emulsion stability and it can also be used in quality control of products. It has been used for measuring the stability of Oil-Water emulsions. This technique is fast and objective (at least 4 times quicker than the naked eye in diluted emulsions and more than 20 times for concentrated emulsions).  Located at DTU Chemical Engineering
	ROP Flooding Equipment is a high-pressure displacement apparatus for measurement of unsteady-state gas-oil and water-oil relative permeability. Conditions up to 700 bar and 150°C. The ROP is equipped with a three-phase separator. Located at DTU Chemical Engineering
	Danisco steel cell for gashydrate experiments is a stainless steel cell equipped with high quality glass windows. The cell can withstand a pressure of up to 45 bar. The cell can be used for studying gas hydrate formation. The gas entering the cell is distributed in very small bubbles by passing through a sintered steel plate. Located at DTU Chemical Engineering
	HP Differential Scanning Microcalorimeter (HP µ-DSC) allow thermal analysis

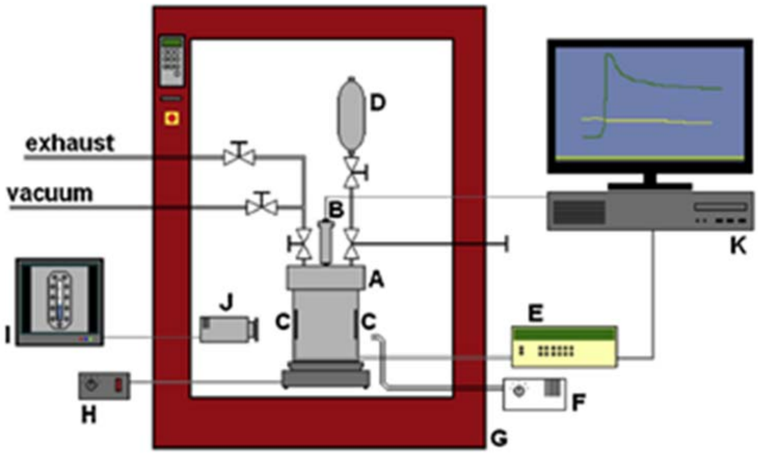
	of phase transition processes i.e. the phase transition temperature as well as the energy needed or created during the phase transition. The main advantage of the HP μ-DSC compared to other DSC's is that it can be used at pressures up to 200 bar. This makes it in particular suitable for studying the thermal behaviour of systems of relevance to the petroleum industry. Below you see some examples of systems which could be studied using the μ-DSC.  Located at DTU Chemical Engineering
	 The **Rocking Cell** (RC-5; has five test cells, PSL Systemtechnik, Germany) is used to test kinetic inhibitors for natural gas hydrate nucleation, growth and decomposition. Each of the five stainless steel test (AISI 316L) cells has a volume of 40.13 cm3 and can operate up to 200 bar working pressure (Fig. 1B). The working temperature range of the cells is between -10 °C and 60 °C. A stainless steel ball (Dia: 17 mm) is placed inside and rolls back and forth along the length of the cell to agitate the solution inside it. The mixing in the cells is controlled by rocking the cells back and forth between angles of -45° and +45°. Once the cells are loaded with the desired

	solution, they are placed in a cooling bath controlled by an external refrigerator, which can be operated between 10 °C and 60 °C. The pressure and temperature of cells are monitored by a data acquisition system throughout the experiment. Located at DTU Chemical Engineering
	Shell hydrate cell is a cylindrical semi-batch cell for studying natural gas hydrates based on visual and pressure decline detection. Maximum pressure 50 bar and temperature range -20 - 40°C. Located at DTU Chemical Engineering
	The **2-D diffusion and permeation cell** is indigenously designed and developed to measure the diffusivity and permeability of gases in polymer samples. The cell is designed to perform the measurements at pressures up to 700 bar and 150°C.  Located at DTU Chemical Engineering
	A **Magnetic Suspension Balance** (MSB) is a gravimetric device which makes possible to weigh samples contactlessly under nearly all environments. An electromagnet, which is attached to the underfloor weighing hook of a balance, maintains a freely suspended state of the suspension magnet via an electronic control unit. Using this magnetic suspension coupling the measuring force is transmitted contactlessly from the measuring chamber to the microbalance, which is located outside the chamber under ambient atmospheric conditions. A controlled suspended state is achieved by means of a direct analogous control circle (PID controller and position transducer). This modulates the voltage on the electromagnet in such a way that the suspension magnet is held constantly in a vertical position. A microcontroller driven digital set point controller superimposed to the direct PID controller allows various positions of the suspension magnet to be set up. The microbalance can be tared and calibrated during measurements and this zero-point correction and calibration of sensitivity of the microbalance is important for measuring the gas solubilities accurately, because long sorption times are generally needed. The MSB offers the possibility of lowering the suspension magnet in a controlled way to a second stationary position, a few millimeters below the measuring position. At this position, a sample basket is set down on a support by the suspension magnet's descent, and the sample is decoupled from the balance. This so-called 'zero-

	point position' allows a taring and calibration of the balance at any time, even while recording measurements.  Located at DTU Chemical Engineering
	DBR-JEFRI Cell for supercritical extraction, VLLE and VLS and conventional PVT analysis of gas condensates and black oils. The apparatus for measuring solubilities and phase equilibrium consist of a phase equilibrium view cell with a piston, an air bath, a displacement pump, high-pressure pycnometers, rocking mechanism and filling, cleaning and sampling lines. For separation of the sample in the pycnometer a gasometer is used. Maximum pressure 700 bar and maximum temperature 180°C. Located at DTU Chemical Engineering
	ROP fiber optic detection is designed to accurately measure the fluid saturation pressures, i.e., dew and bubble points at pressures up to 700 bar and temperatures from –5 to 150°C. The currently available operational pressure conditions can also be extended to, for e.g., fluid studies at subatmospheric conditions by changing the pressure transducer. The 80 ml equilibrium cell is housed in a thermostatic enclosure, in which a high-speed fan provides efficient circulation of air in order to achieve stable isothermal conditions. A mechanically driven piston varies the internal volume of the cell. Viton 'O' rings placed on Teflon seats mounted in the grooves of the piston maintain the pressure integrity of the equilibrium cell. A small magnetic stirrer placed on the piston is used to enhance the sample homogeneity. Moreover, the housing of the entire apparatus in a rocking cage permits additional equilibration of the sample. A high-precision Pt-100 thermocouple and a SEDEME pressure transducer measure the cell temperature and pressure respectively. The accurate detection of phase boundaries is achieved via the extrinsic fiber optic sensors mounted in the cell cover. A beam of light (red light 660 nm wavelength), launched through a bunch of optical fibers is incident upon a 45° sapphire roof prism surrounded by the fluid in the cell. The returned signal of the red light, which is a function of the fiber geometry. Located at DTU Chemical Engineering
	ROP Mercury free cell for bubble and dew point has two PVT cells: the primary cell of 500 cm^3 and the secondary cell of 50 cm^3. Both cells are equipped with mechanic pistons to vary the cell volumes. The piston movement in the two cells are computer

	controlled so as to realize a series of operations such as constant pressure, constant flow rate, and sychronization. Both cells have sapphire windows allowing observation of phase transition inside the cells. The apparatus is also equipped with a gas meter for accurate gas-oil-ratio measurement or recombination. It is also possible to attach on-line meters to measure high-pressure density and viscosity. The apparatus can be operated up to 150 °C and 700 bar. The large volume of primary cell makes it ideal for PVT study of gas condensate or gas. Located at DTU Chemical Engineering
	Simulated distillation: FISCHER® LABODEST® HMS 500 AC is a compact, versatile, the fully automated unit with high separation efficiency (up to 90 theoretical plates). It can handle samples from 10 to 500 ml. The maximum operation temperature is 350 °C. It can operate at atmospheric pressure or vacuum (down to 0.1 mbar). The distillation procedure can be programmed and automatically controlled. The major application of this unit is to perform a distillation analysis of crude oil composition. The True Boiling Point (TBP) distillation (ASTM D2892) using a 15-theoretical plate column and 5:1 flux ratio is a classical method to obtain the distillation curve for a crude oil sample. The distillation fractionates the crude oil into a number of narrow fractions up to 400°C Atmospheric Equivalent Temperature (AET). Compared to Simulated Distillation, TBP distillation provides physical narrow fractions which can be further analyzed for their molecular weights, densities, viscosities and other properties. With higher separation efficiency and smaller sample volume, FISCHER® LABODEST® HMS 500 AC is particularly suitable to samples from the oil fields. The unit can also be designed to perform other distillation studies according to specific requirements. Located at DTU Chemical Engineering
	The **PVT apparatus 240/1500 from Sanchez Technologies** has a volume of 240 cm^3 and can perform measurements up to 200°C and 150 MPa with full visibility. It has a magnetic stirrer with retractable blades mounted on top of the cell piston to homogenize the sample. Moreover the cell has a rocking system that allows experiments to be performed in four different positions. It also comprises an infrared dew point detector. The whole apparatus is computer controlled through Falcon software. Different types of studies can be performed such as oil studies, i.e. constant mass expansion (CME), differential vaporization (DV) and separator test, as well as gas condensate studies such as constant mass depletion (CMD) or constant volume depletion (CVD).

	 Located at DTU Chemical Engineering
	AnT Cell is an Analytical isothermal cell and is used for the purpose of measurement of multi-phase equilibria in hydrocarbon-water-hydrate inhibitor systems, but can be applied to other similar systems. The main part of the apparatus is the variable-volume high-pressure equilibrium cell, specially designed for this application and equipped with a 360° sapphire window. The volume of the cell can be varied manually and automatically by means of a high pressure syringe pump. The temperature, measured in different points of the cell by platinum resistance thermometers, is monitored and recorded over time through a computer. Connected to the cell are three automatic ROLSI™ (Rapid On-Line Sampler-Injector) sampler-injectors, which allow for the withdrawing of very small samples from the different phases directly to the carrier gas stream of a gas chromatograph (GC), where the samples are then analysed. The current analysis is done using an Agilent 6890 GC system, equipped with an Agilent 7683B automatic injector, a HP-PLOT Q capillary column, and a thermal conductivity detector (TCD) coupled in series with a flame ionisation detector (FID). For acquisition and treatment of the GC data, a computer installed with the software GC ChemStation (Agilent Technologies, Inc., USA) is used. Located at DTU Chemical Engineering
	SynVis Cell (Synthetic Visual Cell) is a high pressure cell, equipped with two sapphire windows, with a volume of 580 cm^3 + volume of the gas cylinder attached to it, which can be varied between 150 cm^3 and 1000 cm^3 (by changing the cylinder). The cell is inside a temperature chamber, with an available volume of 720 dm^3 and an operating temperature range from -40 °C to 150 °C. The temperature of the cell is monitored through two platinum resistance thermometers PT100 class 1/10 DIN and the pressure inside the cell is monitored by a temperature compensated pressure transmitter for measurements up to 200 barg. All the sensors are connected to a computer. Located at DTU Chemical Engineering

	
	Thermo Optical Analysis by Microscopy (Toam) is a powerful and versatile tool for determination of Cloud-point/melting curves for polymer/hydrocarbon solutions. The Temperature operating conditions are from -60 °C to +375 °C. The Thermo Optical Analysis by Microscopy (Toam) is connected to the following components with different functions: FP90: The FP90 Central processor (control and evaluation unit) and several measuring cells for the determination of a wide range of thermal data. The temperature of the attached cell is measured by a precision sensor, the Pt 100 sensor. FP81: The FP81 measuring cell can be used to determine melting points and melting ranges of samples in glass capillary tubes. The measuring cell is also suitable to determine the boiling point of a liquid or the cloud point. FP82: The FP82 Hot Stage is used to observe the thermal behavior of a sample under a microscope. FP83: This measuring cell serves to determine the dropping and softening points of fats and pasty products in accordance with various national and international industrial standards. FP85: With the FP85 measuring Cell, the sample is placed in a small aluminum crucible/ glass capillary tubes and subjected to a temperature program. The temperature difference between sample and inert reference crucible (DTA signal) caused by physical or chemical changes of the sample is measured and recorded. Based on the DTA signal which is proportional to the heat flow to the sample, the DSC signal in milliwatts is calculated by the Mettler computer program FP99. Located at DTU Chemical Engineering
	The Wetted Wall cell is used with the purpose to compare the rate of absorption of gaseous carbon dioxide by MEA and ammonia aqueous solvents. The gas comes from N_2 and CO_2 bottles. The flow and the pressure of the gases sent to the chamber are controlled by the mass flow controllers. The gas is then saturated with water, and reaches the reaction chamber that consists of a glass tube that can resist a pressure up to 10 bars. The gas outlet, on the top of the chamber, comprises a needle valve to reduce the pressure to atmospheric. The gas passes through an acid wash section in order to remove the ammonia present in the gas phase and through a condenser in order to remove the water. The concentration of carbon dioxide is then

	measured with a gas analyzer and sent to the fume hood. An alternative would be to measure the gas before it is condensed and washed and by correcting the actual value of the CO_2 pressure by evaluating the pressure of ammonia and water using the thermodynamic model. When MEA is used, it can be assumed that the amount of MEA in the gas phase is negligible. The liquid is pumped from a stainless steel tank to the chamber, after it passes through the oil tank to control its temperature. It flows though the stainless steel tube and on its surface as a homogeneous film where it can react with the gas. The liquid leaves the chamber by its bottom, and is transferred back to the liquid tank. Therefore, the liquid is used in a closed loop. It is assumed that the CO2 loading of the solvent does not significantly change during an experiment. A water cooling bath is used to control the temperature. The water is circulated around the chamber to maintain a constant temperature. The experiments will be conducted in the temperature range of 0-80 °C.  Located at DTU Chemical Engineering
	The **Virtual Reality room** is equipped with stereo 3D solution provided by Cyviz. In combination with 3D visualization software such as Petrel and Avizao, it can be used for high definition 3D virtual reality realizations in various situations, ranging from experimental to simulation, from microscopic scale to macroscopic scale, from subsurface to outer space, and from static processes to dynamic processes. The typical applications of the VR facility include visualization of seismic results, reservoir simulations, CFD simulations, CT scanning of core flooding, rock core analysis, and molecular simulations. Located at DTU Chemical Engineering
	High Temperature Equilibrium Cell.

	 The experimental set-up is designed for measuring the solubility of sparingly soluble salts. The system mainly consists of 3 key parts, an equilibrium cell (2), transport of sample at constant temperature (4) and filtration at constant temperature (5). The set-up is equipped with 2 thermocouples installed in the equilibrium cell (2) and in the glass body that keeps the sampling hose at constant temperature (4). The set-up runs at constant temperature by means of a thermostatic bath using glycerin as heat-transfer fluid. The filter chamber (5) is a double walled chamber that contains a porous body (6) made of fritted glass of porosity (10-16 µm). Temperatures up to 95 °C are possible. Located at DTU Chemical Engineering
	High Temperature/High Pressure Titanium Cell.

The experimental set-up is designed for measuring the solubility of sparingly soluble salts. The HP/HT Titanium Cell consists of 2 vessels: TK3 and TK4. TK3 is the equilibrium cell and TK4 is the dilution cell. Each cell is equipped with a stirrer, pressure and temperature probes. In order to pressurize the system, each cell is connected to an ISCO Pump. A sample can be withdrawn from TK3 and transferred to TK4 by means of the transfer line (TL). Dilution is required to avoid any precipitation of solid when sampling for analysis. The transfer line is kept a constant temperature by means of a heated coil. A stainless steel sintered filter is located in the transfer line to avoid solid particles to reach the dilution cell. The TL line is also equipped with conductivity and temperature probes. The HP/HT Titanium Cell is controlled by software specially designed to operate it. Pressures up to 60 bar and temperatures up to 200 °C are achievable.

Located at DTU Chemical Engineering

	 **Elastic wave velocity** Compressional wave velocity Vp and shear wave velocity Vs are measured by recording the travel time of a transmitted ultrasonic wave through a sample of known length. Travel time is calculated from the first break for P-wave and from the zero crossing for the S-wave. Overall accuracy of the measurement is 50 m/s for P-waves and 100 m/s for S-waves. Elastic wave velocity measurement can be performed at variable axial, radial and fluid pressure condition. It can be combined with geotechnical and flooding tests. Located at DTU Civil Engineering
	Electrical resistivity is measured by connecting a variable resistor in series with the sample in a 1 kHz AC circuit of 1 volt power supply. As current flows through the sample and the variable resistor is equal (i1=i2) The variable resistor is adjusted by looking at the oscilloscope, so that the voltage drop across the sample becomes half of the supply voltage. At this condition the resistivity set in the variable resistor gives the resistivity of the sample. Low frequency and low supply voltage are selected so that the phase angle shift remains close to zero. Precautions in the sample handling during this procedure setup are taken to avoid evaporation and consequent sample drying. Located at DTU Civil Engineering
	NMR Spectrometry Nuclear Magnetic Resonance (NMR) technique uses the response of atomic nuclei in a magnetic field. A spinning proton acts as a loop of current and therefore produces a magnetic field along the spin axis. As hydrogen nuclei have only a proton, it produces

	relatively large magnetic moment when it spins. In a bulk of fluid that contains hydrogen, as water, these spinning protons are aligned randomly. By applying a strong external magnetic field, the spinning protons can be aligned in the direction of the applied magnetic field. If the field is turned off, the aligned protons begin to spin in random direction again. Located at DTU Civil Engineering
	Porosity Porosity is measured by two different methods. In uniform cylindrical core plugs porosity is measured byHelium Expansion method with a Helium porosimeter. On irregularly shaped samples, porosity is measured by Mercury Immersion method. Located at DTU Civil Engineering
	Specific surface The specific surface, SSA, of a material is measured by gas (Nitrogen) adsorption according to the method developed by Brunauer, Emmet and Teller (BET). If a solid is exposed to a gas at its condensation temperature, the solid adsorbs the gas physically. If the solid has a uniform surface the entire surface will be covered by one layer of gas molecules - a monolayer. The adsorption behaviour of a monolayer can by expressed by Langmuir's isotherm equation. By making some assumptions, Brunauer, Emmet, and Teller introduced a multilayer model on the basis of Langmuir's equation. The calculation of specific surface is done in two steps: evaluation of the adsorbed monolayer volume, and conversion of this quantity to SSA by means of the molecular area. Located at DTU Civil Engineering
Educational activities	The center participates in education at the BEng, BSc, MSc, PhD and continuing education level, both in the Petroleum Engineering MSc as well as in courses in other programs offered through the various departments, such as the MSc in Advanced and Applied Chemistry, MSc in Chemical and Biochemical Engineering, BSc in Chemistry and Technology, BEng in Chemical and Bio Engineering, BEng in Chemical Engineering and International Business

2. DTU Chemical Engineering

DTU affiliation	Department of Chemical and Biochemical Engineering
	www.kt.dtu.dk
Short affiliation description with O&G in focus	At the Department of Chemical and Biochemical Engineering our research is built on the technological core subjects and engineering scientific disciplines. Our research covers separation processes, reaction engineering, dynamics and process regulations, process and facility planning, unit operations, heat transmission, fluid mechanics and applied thermodynamics. We work closely with industry to reach research results that are

Researcher	Competence (Keywords)
	applicable to industry and society. Within our six research centres we carry out a wide range of specialized chemical and biochemical engineering research through in field experiments, experiments in lab scale, pilot facilities and in industrial scale. Our main activities are in the areas of product design, process design and production in the chemical, biotechnological, pharmaceutical, food – and energy technological industries. The centers within the department are: Danish Polymer Centre (DPC), Center for Combustion and Harmful Emission Control (CHEC), CAPEC-PROCESS Research Centre, Center for Bioprocess Engineering (BIOENG), Applied Thermodynamics - Center for Energy Resources Engineering (AT CERE) and Centre for Experimental Process and Equipment Design (PILOT PLANT).
Researcher	**Competence (Keywords)**
Philip Loldrup Fosbøl, Associate Professor, DTU Chemical Engineering plf@kt.dtu.dk	Energy Reduction; CO_2 Corrosion CCS ; CO_2 Transport ; Carbon Dioxide Capture and Storage ; Properties of Electrolytes ; Thermodynamics and Phase Equilibrium ; Flow sheet design, simulation, and optimisation ; Biogas Cleaning
Georgios Kontogeorgis, Professor, DTU Chemical Engineering gk@kt.dtu.dk	Traditional and advanced thermodynamic models for petroleum applications of relevance to enhanced oil recovery and flow assurance (gas hydrates, asphaltenes, wax, scales). Modeling of interfacial tension and multicomponent adsorption related to petroleum applications.
Xiaodong Liang, Assistant Professor, DTU Chemical Engineering xlia@kt.dtu.dk	Fundamentals of advanced association models (PC-SAFT); Thermodynamic modelling (CPA, PC-SAFT); Surface tension modelling (DGT); Computational algorithms (phase equilibrium and optimization in general); Software development (commercial simulators, MATLAB interface, standalone tool)
Alexander Shapiro, Associate Professor, DTU Chemical Engineering ash@kt.dtu.dk	Enhanced oil recovery; Flows in porous media; Core flooding; Smart water flooding; Microbial enhanced oil recovery; Transport properties; Mathematical and physical modeling of the flows in petroleum reservoirs; Thermodynamics of fluids in porous media – adsorption and capillary forces; particles in pores – deep bed filtration and formation damage; Reservoir characterization – gravity and thermal gradients; diffusion; flows in tight reservoirs.
Nicolas von Solms, Associate Professor, DTU Chemical Engineering nvs@kt.dtu.dk	Gas hydrate modelling; gas hydrate thermodynamic and kinetic inhibition, modelling and experiments; thermodynamic modelling and fluid phase equilibrium measurements (oil/water/gas) up to high pressures; polymers for offshore hydrocarbon pipeline transport; high pressure oil upgrading experimental and modelling; surfactant flooding for enhanced oil recovery
Kaj Thomsen, Associate Professor, DTU Chemical Engineering kth@kt.dtu.dk	Energy storage in rechargable flow batteries ; Fractional crystallization ; solid-liquid equilibrium ; Electrolyte thermodynamics ; Carbon dioxide capture ; Mixed solvent solutions; Smart water EOR, oilfield scale prediction, development of software

	algorithms for phase equilibrium in salt solutions
Anne Ladegaard Skov, Associate Professor, DTU Chemical Engineering al@kt.dtu.dk	Synthesis and applications of silicone elastomers with main emphasis on dielectric elastomers.
Peter Szabo, Associate Professor, DTU Chemical Engineering ps@kt.dtu.dk	Rheology of complex fluids; Flow of non-Newtonian fluids; Simulation of multiphase flow; Finite element methods; Volume-of-fluid techniques.
Peter Glarborg, Associate Professor, DTU Chemical Engineering pgl@kt.dtu.dk	high temperature chemistry; chemical kinetic modeling; combustion; harmful emission control
Gürkan Sin, Associate Professor, DTU Chemical Engineering gsi@kt.dtu.dk	Methodological research: Process Systems Engineering, Process synthesis and design, Model-based Process design and scale-up, Process/plantwide optimisation and control, Global Uncertainty and Sensitivity analysis (GSA), Risk Assessment, Process safety and hazard analysis, Information Technology. Application domain in biotechnology, water/wastewater treatment, biopharma, food and biorefinery.
Sten Bay Jørgensen, Professor, DTU Chemical Engineering sbj@kt.dtu.dk	Biochemical and Chemical Process and Product Systems Engineering: Chemical Process and Product Modelling & Design; Process Dynamics and Identification for Control. Industries: oil, petrochemical, chemical, bio-chemical and pharmaceutical. Nonlinear process behaviour is of special relevance.
Facilities/Equipment	Most of the relevant equipment can be found under section 1. CERE DTU – Center for Energy Resources Engineering

3. DTU CHEMISTRY

DTU affiliation	Department of Chemistry
	www.kemi.dtu.dk
Short affiliation description with O&G in focus	DTU Chemistry is responsible for most of the introductory classes in chemistry at DTU. The research ranges wide in compliance with the objective of research-based teaching. The Department's areas of strength are: Sustainable Chemistry - Energy - Chemical Biology - NanoChemistry – Femtochemistry. DTU Chemistry's trademark is scientific expertise founded in fundamental research in applied chemistry. The research is wide and divided into two research areas each with underlying research groups: Organic and Inorganic Chemistry - Physical and Biophysical.
Researcher	**Competence (Keywords)**
Wei Yan, Senior Researcher,	High pressure fluid phase behavior esp. PVT experiment and

<table>
<tr><td>DTU Chemistry
weya@kemi.dtu.dk</td><td>modeling for oil and gas production; phase equilibrium calculation algorithms; compositional reservoir simulation esp. streamline simulation; EOR esp. gas injection and high pressure flooding; reservoir engineering in general</td></tr>
<tr><td>Erling Halfdan Stenby, Professor, Head of Department, DTU Chemistry
ehst@kemi.dtu.dk</td><td>Energy ; Oil and gas ; Petroleum Engineering ; Enhanced Oil Recovery ; Carbon Capture and Storage ; Applied Thermodynamics ; Phase Behavior</td></tr>
<tr><td>Esben Thormann, Associate Professor, DTU Chemistry
esth@kemi.dtu.dk</td><td>Enhanced oil recovery; Specific ion effects; Surface chemistry of calcium carbonate; molecular and surface forces between oil and mineral substrates; high pressure studies of wetting behaviour and oil adsorption & release.</td></tr>
<tr><td>René Wugt Larsen, Associate Professor, DTU Chemistry
rewl@kemi.dtu.dk</td><td></td></tr>
<tr><td>Anders Riisager, Professor, DTU Chemistry
ar@kemi.dtu.dk</td><td>Ionic liquid technology; Gas absorption; Catalysis; Inorganic material science</td></tr>
<tr><td>Jingdong Zhang, Professor, DTU Chemistry
jz@kemi.dtu.dk</td><td>Nanomaterials for removing oil from oil/water systems , Atomic Force Microscope for investigation of oil-related mineral surfaces at nanometer scale, Electrochemistry</td></tr>
<tr><td>Facilities/Equipment</td><td>QCM-D HPT (Quartz Crystal Microbalance with Dissipation High Pressure and Temperature System)


The quartz crystal microbalance with dissipation (QCM-D) has been used to study crude oil adsorption/desorption on various surfaces during the past decade. But the commercial QCM-D can only work under limited pressure and temperature. In order to carry out the study at higher pressures and temperatures closer to actual reservoir conditions, we designed a high pressure QCM-D cell which</td></tr>
</table>

	uses a non-conductive liquid on the back side of the sensor to equalize the high pressure on the sample side. This design makes it possible to work with both conductive and non-conductive samples. Verification study shows that the deviation between measurements and theory is less than 6% on both the frequency and dissipation shifts. The new setup can work at temperature from -4 to 150 °C and pressures up to 750 bar. Adsorption and desorption of crude oil on and from the mineral surfaces can be investigated with the new high pressure QCM-D.

4. DTU Compute

DTU affiliation	Department of Applied Mathematics and Computer Science
	www.compute.dtu.dk
Short affiliation description with O&G in focus	
Researcher	**Competence (Keywords)**
John Bagterp Jørgensen, Associate Professor, DTU Compute jbjo@dtu.dk	Model Predictive Control including computational aspects and applications. The applications include industrial processes, intelligent control of smart energy systems, production optimization and closed-loop reservoir management of oil fields, and an artificial pancreas for people with type 1 diabetes.
Paul Pop, Professor, DTU Compute paupo@dtu.dk	
Sven Karlsson, Associate Professor, DTU Compute svea@dtu.dk	
Bjarne Kjær Ersbøll, Professor, DTU Compute bker@dtu.dk	
Facilities/Equipment	

5. DTU Civil Engineering

DTU affiliation	Department of Civil Engineering
	www.byg.dtu.dk
Short affiliation description with O&G in focus	The mission of the department is education, research, research-based public sector consultancy and innovation. The department contributes to the establishment of social and commercial values through the development of research-based constructional knowledge. Sections of most relevance to Oil and Gas research include: Section for Structural Engineering:

	Bridge structures, Structural design, Stability and fatigue, Safety and riskanalysis, Windtechnology, Glass and glass structures Section for Geotechnics and Geology: Oil extraction, Geothermics, Wind turbine foundations, Geotechnics, Integration of geological, rock mechanical and petrophysical data for interpretation of reservoir properties and deep excavations/tunnels
Researcher	**Competence (Keywords)**
Ida Fabricius, Professor, DTU Civil Engineering ilfa@byg.dtu.dk	Reservoir geology, petrophysics, rock physics, petrography
Katrine Alling Andreassen, Assistant Professor, DTU Civil Engineering kall@byg.dtu.dk	Rock mechanics, rock physics, borehole stability.
Rune Brincker, Professor, DTU Civil Engineering runeb@byg.dtu.dk	
Gregor Fischer, Associate Professor, DTU Civil Engineering gf@byg.dtu.dk	Mechanical characterization of cementing materials, testing, crack formation, fiber reinforcement, shrinkage cracking
Eyal Levenberg, Associate Professor, DTU Civil Engineering eylev@byg.dtu.dk	
Facilities/Equipment	

6. DTU Space

DTU affiliation	National Space Institute
	www.space.dtu.dk
Short affiliation description with O&G in focus	
Researcher	**Competence (Keywords)**
Arne Døssing Andreasen, Senior Researcher, DTU Space ards@space.dtu.dk	
Facilities/Equipment	

7. DTU Mechanical Engineering

DTU affiliation	Department of Mechanical Engineering
	www.mek.dtu.dk

Short affiliation description with O&G in focus	At DTU Mechanical Engineering we focus our research on the physical aspects in and behind the products we use every day. We strive to make constructions as strong, light and cost effective as possible by using the right materials and intelligent construction. We reduce emissions by making energy consumption as efficient as possible. DTU Mechanical Engineering covers the engineering disciplines connected to the application of basic thermodynamics, fluid and hydrodynamics, structure and solid mechanics, materials and surface engineering for the analysis, design, manufacture and maintenance of mechanical products, systems and large structures and plants.
Researcher	**Competence (Keywords)**
Rajan Ambat, Professor, DTU Mechanical Engineering ram@mek.dtu.dk	
Morten Stendahl Jellesen. Senior Researcher, DTU Mechanical Engineering msj@mek.dtu.dk	
Niels Henrik Mortensen, Professor, DTU Mechanical Engineering nhmo@mek.dtu.dk	
Christian Berggreen, Associate Professor, DTU Mechanical Engineering cbe@mek.dtu.dk	
Marcel Somers, Professor, DTU Mechanical Engineering somers@mek.dtu.dk	Materials characterization, surface engineering, materials modelling
Christian Frithiof Niordson, Professor, DTU Mechanical Engineering cn@mek.dtu.dk	Fracture mechanics and fatigue, metal plasticity, materials modeling, continuum mechanics, homogenization, material size-effects
Facilities/Equipment	

8. DTU Electrical Engineering

DTU affiliation	Department of Electrical Engineering
	www.elektro.dtu.dk
Short affiliation description with O&G in focus	The Department of Electrical Engineering is the central DTU department within Electrical Engineering and Biomedical Engineering. We conduct research within acoustics, antenna and microwave technology, audiology, biomedical engineering, power electronics, playware, robotics, electric power and energy.

	An important part of this research is carried out in close cooperation with the industry and international research institutions. It is our goal to ensure research and engineering training at the highest international level.
Researcher	**Competence (Keywords)**
Morten Lind, Professor Emeritus, DTU Electrical Engineering mli@elektro.dtu.dk	
Facilities/Equipment	

9. DTU Nanotech

DTU affiliation	Department of Micro- and Nanotechnology
	www.nanotech.dtu.dk
Short affiliation description with O&G in focus	The research at DTU Nanotech is coordinated within 4 strategic research fields. Scientists at DTU Nanotech conduct research and develop technologies based on a strong collaboration across the different fields. The strategic research fields are: Biomedical Engineering and Life Science; Sustainable Nanotechnology; Lab-on-a-Chip; Materials and Fabrication
Researcher	**Competence (Keywords)**
Facilities/Equipment	

10. DTU Management

DTU affiliation	Department of Management Engineering
	www.man.dtu.dk
Short affiliation description with O&G in focus	The research at the Department contributes to new knowledge about planning, production and management and hereby contributes to the development of innovative decision support systems and optimisation of products and production in both the public and the private sector. The research is carried out within the following four key areas: • Development and implementation of quantitative decision support systems • Product development, design and innovation • Production and organisation development/development of production and organisation • Transport

	With these four areas as the overall focus the Department carries out research activities and assists with consulting in varies fields such as: Energy and climate, food and health, transport and logistics, construction, the service sector and knowledge intensive organisations – often in close cooperation with international research environments and industrial and public partners.
Researcher	**Competence (Keywords)**
Facilities/Equipment	

11. DTU Physics

DTU affiliation	Department of Physics
	www.fysik.dtu.dk
Short affiliation description with O&G in focus	
Researcher	**Competence (Keywords)**
Facilities/Equipment	