PhD programme
Process, Energy and Automation Engineering

Annual Report 2013

Telemark University College,
Faculty of Technology
Process, Energy, and Automation Engineering

Telemark University College (TUC) has approximately 6 500 students. Faculty of Technology, with approximately 700 students, is located at the campus in Porsgrunn.

The faculty has run a PhD programme in Process, Energy and Automation Engineering since 2009, and currently 30 PhD students are enrolled in the programme. In 2013, three candidates were awarded the PhD degree after finishing their dissertation.

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The PhD committee at the faculty 2013:

Prof. Klaus-Joachim Jens (chairman)
Prof. Britt Halvorsen
Prof. Svein Thore Hagen
Elin Fjeld¹ / Joachim Lundberg² (PhD students)
Inger Kristiansen (secretary)
Assoc. Prof. Lars-André Tokheim (PhD programme coordinator)

This report was edited by:

Lars-André Tokheim,
PhD programme coordinator
Email: Lars.A.Tokheim@hit.no

¹ January-August 2013
² August-December 2013
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Titration analysis in the CO₂ lab.
Personnel affiliated with the PhD programme

**Academic staff**

Rune Bakke (Professor)  
Dag Bjerketvedt (Professor)  
David Di Ruscio (Assoc. Professor)  
Carlos Dinamarca (Assoc. Professor)  
Dag Eimer (Adj. Professor)  
Kim Esbensen (Adj. Professor)  
Bjørn Glemmestad (Professor)  
Svein Thore Hagen (Professor)  
Maths Halstensen (Assoc. Professor)  
Britt Halvorsen (Professor)  
Klaus-Joachim Jens (Professor)  
Bernt Lie (Professor)  
Svein Linge (Professor)  
Marius Lysaker (Assoc. Professor)  
Morten C. Melaan (Professor)  
Ole-Morten Midtgård (Adj. Professor)  
Saba Mylvaganam (Professor)  
Carlos Pfeiffer (Assoc. Professor)  
Chandana Ratnayake (Adj. Professor)  
Wilhelm Rondeel (Adj. Professor)  
Nils-Olav Skeie (Assoc. Professor)  
Lars-André Tokheim (Assoc. Professor)  
Knut Vågsæther (Assoc. Professor)  
Magne Waskaas (Professor)  
Lars Erik Øi (Assoc. Professor)  

**PhD students**

Mirnes Alic  
Ronnie Anseth  
Udara Arachchige  
Sanoja Ariyaratna  
Hiromi Ariyaratne  
Wenche Bergland  
Elin Fjeld  
Jingyi Han  
André Gaathaug  
Finn Haugen  
Chameera Jayaratna  
Bo Li  
Lu Li  
Helge Lorenzen  
Joachim Lundberg  
Anushka Perera  
Wathsala Perera  
Chaminda Pradeep  
Kanchan Rai  
Yan Ru  
Gamunu Samarakoon  
Roshan Sharma  
Vladyslav Shchuchenko  
Wang Shuai  
Ole Kristian Sommersel  
Rajan Kumar Thapa  
Sindre Tøsse  
Zhimin Xi  
Zhou Wenjing  
Haavard Aakre  

**Post doc fellows**

Christina Perianu (PhD)
Technical and administrative staff (shared with other TUC units)

Eivind Fjelddalen (Senior Engineer)
Per Morten Hansen (Senior Engineer)
Hildegunn Hegna Haugen (Senior Engineer)
Randi T. Holta (Department Head Electrical Eng., Information Tech. and Cybernetics)
Klaus-Joachim Jens (Department Head Process, Energy and Environment)
Inger Kristiansen (Higher Executive Officer)
Jan Gunnar Lode (Senior Engineer)
Morten C. Melaaen (Dean)
Research areas

CO₂ Capture

The overall goal of our work on CO₂ capture is to find innovative solutions to the climate challenge. This means finding new solutions as well as improving existing ones with regard to optimization of the CO₂ capture process and related environmental challenges. It furthermore comprises collection and transportation solutions for captured CO₂. The research is carried out in close cooperation with the Tel-Tek research institute.

Environmental biotechnology

The environmental biotechnology research focus is on resource recovery, organic waste and water treatment, combined with biofilm research. The work includes fundamental research as well as applied activities.

Industrial Flow Processes

Different flow systems are studied using experimental measurement techniques and computational fluid dynamics (CFD). Most of the experimental studies are performed using laser-based techniques such as Laser Doppler Anemometry (LDA), Phase Doppler Anemometry (PDA) and Particle Image Velocimetry (PIV), and other measurement techniques are applied as well.

Gas explosions and Technical Safety

The focus is on experimental and numerical investigation of pre-mixed combustion, dispersion, ignition, explosions and shock waves in various types of processes, equipment and systems.

Industrial Applications of Electromagnetics

Research in this group is dedicated to modern industrial applications of electromagnetism. Basic approach is based on solving Maxwell’s equations for static, quasi-static, and dynamic phenomena. The different applications currently under study are induction heating, quasi-static analysis of sensors exploiting electromagnetic phenomena, estimating parameters of complex cable structures. Sub groups are doing research on electric drive modelling, energy loss reduction, gas insulated switchgears, induction heating and tomography.

Industrial Automation Applications

Industrial Automation Applications include the use of sensor technology, industrial IT, modelling and simulation, estimation and monitoring, and control and optimization. Different groups are doing research on applied chemometrics, hydropower control and process control.
**Industrial Automation Methods**

Industrial Automation Methods include studies in methods within the areas of sensor technology, industrial IT, modelling and simulation, estimation and monitoring, and control and optimization. There are groups doing research on model predictive control, sensor technology, state estimation and system identification.

**Powder Science and Technology**

Our research and development work includes all aspects of handling, storage, processing, separation, and characterization of particulate materials. The research is carried out in cooperation with the Tel-Tek research institute.

**Alternative Fuels**

Alternative fuels can be utilized in the industry to reduce the consumption of fossil fuels. Net emissions of pollutants such as CO$_2$ and NO$_x$ may be reduced, and in many cases the replacement of coal or other fossil fuels is also economically sound for the industry. Moreover, since many alternative fuels are based on waste streams, increased use of such waste-based fuels contributes in solving a waste problem in the society.

*Water treatment experiments in the biolab.*
Journal papers, conference papers and books 2013

Aakre, Haavard; Halvorsen, Britt Margrete; Werswick, Bjørnar; Mathiesen, Vidar. Increased oil recovery of an old well, recompleted with Autonomous Inflow Control Valve (AICV). ADIPEC 2013; 2013-11-10 - 2013-11-13


Anseth, Ronnie; Waskaas, Magn. Monitoring of charges wall growth inside pipes with impedance spectroscopy. ECS 23rd Meeting; 2013-05-12 - 2013-05-16

Arachchige, Gumunu L. Samarakoon; Andersen, Niels Højmark; Perinu, Cristina; Jens, Klaus-Joachim. Equilibria of MEA, DEA and AMP with Bicarbonate and Carbamate: a Raman Study. Energy Procedia 2013; Volume 37. p. 2002-2010

Arachchige, Udara Sampath P.; Aryal, Neelakantha; Eimer, Dag Arne; Melaaen, Morten Christian. Viscosities of pure and aqueous solutions of monoethanolamine (MEA), Diethanolamine (DEA) and N-Methyl diethanolamine (MDEA). Annual Transactions - The Nordic Rheology Society 2013; Volume 21


Arachchige, Udara Sampath P.; Kawan, Dinsesh; Tokheim, Lars Andre; Melaaen, Morten Christian. Model development for CO2 capture in the cement industry. International Journal of Modeling and Optimization 2013; Volume 3 (6)


Arachchige, Udara Sampath P.; Nair, Jishnu U.; Mohsin, Muhammad; Halstensen, Maths; Melaaen, Morten Christian. Multivariate data analysis for identification of important parameters on re-boiler duty in a post combustion chemical absorption process. European Journal of Scientific Research 2013; Volume 95 (2) p. 289-302
Ariyaratne, Hiromi Wijesinghe; Melaaen, Morten Christian; Tokheim, Lars Andre. Increased coal replacement in a cement kiln burner by feeding a mixture of solid hazardous waste and shredded plastic waste. European Journal of Scientific Research 2013; Volume 106 (1) p. 111-123


Ariyaratne, Hiromi Wijesinghe; Melaaen, Morten Christian; Tokheim, Lars Andre. The effect of alternative fuel combustion in the cement kiln main burner on production capacity and improvement with oxygen enrichment. World Academy of Science, Engineering and Technology: An International Journal of Science, Engineering and Technology 2013; Volume 76. p. 557-563


Bekken, Svein G.; Schöffel, Klaus; Aakenes, Ståle; Hatlen, Tore; Slagtern, Åse; Øi, Lars Erik. The CLIMIT Program and its Strategy for Norwegian Research, Development and Demonstration of CCS Technology. Energy Procedia 2013; Volume 37. p. 6508-6519

Botheju, Deshai; Glarborg, Peter; Tokheim, Lars Andre. The use of amine reclamer wastes as a NOx reduction agent. Energy Procedia 2013; Volume 37. p. 691-700

Ding, Songxiang; Rotter, J.M.; Ooi, J.Y; Enstad, Gisle Gotfred; Xu, D. Normal pressures and frictional tractions on shallow conical hopper walls after concentric filling: predictions and experiments. Chemical Engineering Science 2013; Volume 89. p. 264-272

Filtvedt, Werner Olav; Mongstad, Trygve; Holt, Arve; Melaaen, Morten Christian; Klette, Hallgeir. Production of Silicon from SiH4 in a Fluidized Bed, Operation and Results. International journal of Chemical Reactor Engineering 2013; Volume 11 (1) p. 1-12

Fjeld, Elin; Vågsæther, Knut; Bjortuft, Tom-Rune; Hagen, Svein Thore; Skryten, Pål; Øyvang, Thomas; Granhaug, Ole; Stangherlin, Silvio. Small scale arc fault testing of medium voltage switchgear. In: CIRED 2013 Electricity Distribution Systems for a Sustainable Future. CIRED - Congrès International des Réseaux Electriques de Distribution 2013 ISBN 9781849197328. p. paper no-0562


Fu, Chao; Gundersen, Truls; Eimer, Dag Arne. Air separation. [Patent] Patentnr./Lisensnr.: WO 2013/014252 A2 Registrert 2013-01-31

Fu, Chao; Gundersen, Truls; Eimer, Dag Arne. Air separation. [Patent] Patentnr./Lisensnr.: GB2493230A Registrert 2013-01-30

Halstensen, Maths; Ihunegbo, Felicia Nkem; Ratnayake, Chandana; Sveinsvold, Karl. On-line estimation of fish feed pellets velocity in a pneumatic conveying system based on acoustic chemometrics. 13th Scandinavian Symposium on Chemometrics; 2013-06-17 - 2013-06-20


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Han, Jingyi; Eimer, Dag Arne; Melaaen, Morten Christian. Liquid phase mass transfer coefficient of carbon dioxide absorption by water droplet. Energy Procedia 2013; Volume 37. p. 1728-1735

Haugen, Finn; Bakke, Rune; Lie, Bernt. Adapting dynamic mathematical models to a pilot anaerobic digestion reactor. Modeling, Identification and Control 2013; Volume 34 (2) p. 35-54

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Haugen, Finn; Wolden, Kjell Erik. A revised view on teaching basic process control. Elsevier IFAC Publications / IFAC Proceedings series 2013 p. 108-113

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Jayarathna, Sanoja A.; Jayarathna, Chameera Kanchana; Kottage, Deshaka Ayasm; Dayarathna, Sithara; Eimer, Dag Arne; Melaaen, Morten Christian. Density and surface tension measurements of partially carbonated aqueous monoethanolamine solutions. Journal of Chemical and Engineering Data 2013; Volume 58 (2) p. 343-348


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Jayarathna, Sanoja B.; Lie, Bernt; Melaaen, Morten Christian. State Estimation in a CO₂ Capture Plant. 54rd SIMS Conference On Simulation and Modeling; 2013-10-16 - 2013-10-18

Li, Bo; Jens, Klaus-Joachim. Liquid-phase low-temperature and low-pressure methanol synthesis catalyzed by a raney copper-alkoxide system. Topics in catalysis 2013; Volume 56 (9-10) p. 725-729

Li, Bo; Jens, Klaus-Joachim. Low-temperature and low-pressure methanol synthesis in liquid phase catalyzed by a Copper alkoxide system. Industrial & Engineering Chemistry Research 2013

Li, Lu; Palcheva, Radostina Dimitrova; Jens, Klaus-Joachim. Conversion of ethene to propene by a dual function NiSO4/Re2O7/y-Al2O3 catalyst. Topics in catalysis 2013; Volume 56 (9-10) p. 783-788

Lie, Bernt. Street heating : Modeling for control. 18th Nordic Process Control Workshop; 2013-08-22 - 2013-08-23


Lie, Bernt; Ruan, Yiyang; Andreassen, Ingvar. Modeling for control of run-of-river power plant. SIMS 54 th conference Bergen; 2013-10-16 - 2013-10-18

Lines, Glenn Terje; Lysaker, Ola Marius; Nielsen, Bjørn Fredrik. Observability of Ischemia and the Need for Patient Specific Geometrical Models in Inverse ECG. Computers in cardiology 2013; Volume 40. p. 679-682

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Liu, Ying; Zhang, Kaisong; Bakke, Rune; Li, Chunming; Liu, Haining. Membrane installation for enhanced up-flow anaerobic sludge blanket (UASB) performance. Journal of Bioscience and Bioengineering 2013; Volume 116 (3) p. 357-361


Lysaker, Ola Marius; Nielsen, Bjørn Fredrik; Wall, Samuel Thomas. Computing Ischemic regions in the heart: on the use of internal electrodes. Computers in cardiology 2013; Volume 40. p. 675-678


Mathisen, Anette; Sørensen, Henriette; Melaaen, Morten Christian; Müller, Gunn-Iren. Investigation into Optimal CO₂ Concentration for CO₂ Capture from Aluminium Production. Energy Procedia 2013; Volume 37. p. 7168-7175

Mazzetti, Marit Jagtoyen; Eldrup, Nils Henrik; Anthonsen, Karen L; Haugen, Hans Aksel; Onarheim, Kristin; Bergmo, Per Eirik Strand; Kjarstad, Jan; Johnson, Filip; Stigson, Peter; Gislason, Sigurdur R.; Røkke, Nils Anders. NORDICCS CCS Roadmap. 7th Trondheim CCS Conference on CO₂ Capture, Transport and Storage; 2013-06-05 - 2013-06-06

Minkkinen, Pentti; Esbensen, Kim H. Multivariate variographic versus bilinear data modeling. Journal of Chemometrics 2013

Nielsen, Bjørn Fredrik; Lysaker, Ola Marius; Grøttum, Per. Computing Ischemic Regions in the Heart With the Bidomain Model—First Steps Towards Validation. IEEE Transactions on Medical Imaging 2013; Volume 32 (6) p. 1085-1096

Pant, Rabin Bilas; Halvorsen, Hans-Petter; Skulbru, Frode; Mylvaganam, Saba. Intermediate measurement node for extension of WSN coverage. Journal of Cyber Security and Mobility, 2013; Volume 2 (1) p. 29-61

Perinu, Cristina; Arstad, Bjørnar; Bouzga, Aud Mjærum; Jens, Klaus-Joachim. A Chemical Study of Aqueous Amine Solvents for Post Combustion Capture by NMR Spectroscopy.. 2nd Post Combustion Capture conference (PCCC-2); 2013-09-17 - 2013-09-20

Perinu, Cristina; Arstad, Bjørnar; Bouzga, Aud Mjærum; Jens, Klaus-Joachim. Basic research for chemical absorption of carbon dioxide using NMR spectroscopy.. XXXVIII Colloquium Spectroscopicum Internationale conference (CSI); 2013-06-16 - 2013-06-20

Perinu, Cristina; Arstad, Bjørnar; Bouzga, Aud Mjærum; Jens, Klaus-Joachim. NMR Investigation on Carbamate Formation from Alkanolamines for CO₂ Capture. 7th Trondheim CCS conference (TCCS-7); 2013-06-04


Perinu, Cristina; Arstad, Bjørnar; Jens, Klaus-Joachim. 13CNMR experiments and methods used to investigate amine -CO₂-H₂O systems. Energy Procedia 2013; Volume 37. p. 7310-7317

Plausinaitis, Deivis; Pulmanas, Arunas; Waskaas, Magne; Raudonis, Rimantas. Piezoelectric resonator and drag force study of the properties of an interfacial hexafluorophosphate solution layer at gold electrode surface. Electrochimica Acta 2013; Volume 109. p. 756-765


Sahari Moghaddam, Farzan; Aryal, Raju; Aakre, Haavard; Halvorsen, Britt Margrethe. Near well simulations of heavy oil production with ICD completion. WIT Transactions on Engineering Series 2013; Volume 79.

Shafiee, Sobhan; Furenes, Beate; Lie, Bernt. Prediction of daily runoff from hydrological catchment area. 54rd SIMS Conference On Simulation and Modeling; 2013-10-16 - 2013-10-18


Singh, Bhawna; Ramirez, Andrea; Eldrup, Nils Henrik; Hertwich, Edgar G.; Strømman, Anders Hammer. EDDiCCUT – Environmental Due Diligence of CO₂ Capture and Utilization Technologies. 7th Trondheim CCS Conference; 2013-06-04 - 2013-06-06

Skeie, Nils-Olav; Arvoh, Benjamin Kaku; Halstensen, Maths. Adaptive online level estimation in oil/water separators based on pressure measurement and regression modeling. 13th Scandinavian Symposium on Chemometrics; 2013-06-17 - 2013-06-20


Thapa, Rajan Kumar; Pfeifer, C; Halvorsen, Britt Margrethe. Scaling of biomass gasification reactor using CFD simulation. ICPS 13, International Conference on Polugeneration Strategies; 2013-09-03 - 2013-09-05

Tøsse, Sindre; Vågsæther, Knut; Lundberg, Joachim; Gaathaug, Andre Vagner; Bjerketvedt, Dag; Nilsen, S.; Jayarathna, Chameera Kanchana. Experimental study of CO₂ releases from saturated liquid reservoir. Energy Procedia 2013; Volume 37. p. 4818-4824

Viumdal, Håkon; Mylvaganam, Saba. Enhancing signal to noise ratio by fine-tuning tapers of cladded/uncladded buffer rods in ultrasonic time domain reflectometry in smelters. Ultrasonics 2013; Volume 54 (3)


Wang, Shuai; Hovland, Jon; Bakke, Rune. Efficiency of the anaerobic digestion of amine wastes. Biotechnology letters 2013


Wang, Shuai; Hovland, Jon; Brooks, Steven; Bakke, Rune. Detoxifying CO2 capture reclaimer waste by anaerobic digestion. Applied Biochemistry and Biotechnology 2013; Volume 172.(2) s.776-783


Øi, Lars Erik; Lundberg, Joachim; Pedersen, Morten; Hansen, Per Morten; Melaaen, Morten Christian. Laboratory rig for atmospheric CO2 absorption and desorption under pressure. Energy Procedia 2013; Volume 37. p. 1933-1940


Doctoral dissertations 2013

2013-1: Tielin Wang: "Degradation of aqueous 2-amino-2-methyl-1-propanol for carbon dioxide capture" (TUC supervisor: Klaus-Joachim Jens)

2013-2: Jiru Ying: "Mass Transfer Kinetics of Carbon Dioxide into Concentrated Aqueous Solution of Monoethanolamine" (TUC supervisor: Dag Eimer)

2013-3: Werner O. Filtvedt: "Production of polysilicon from silane pyrolysis in fluidized bed" (TUC supervisor: Morten C. Melaaen)
Ongoing PhD projects

Arc Faults in Metal Enclosed Medium Voltage Switchgears (PhD student: Elin Fjeld; main supervisor: Svein Thore Hagen)

Better and more intelligently formulated CO₂ absorbents (PhD student: Gamunu Samarakoon; main supervisor: Klaus-Joachim Jens)

Biological CCS waste treatment (PhD student: Wang Shuai; main supervisor: Rune Bakke)

CO₂ capture post combustion, experimental and simulation studies (PhD student: Uda Arachchige; main supervisor: Morten Chr. Melaaen)

Control and optimization of hydropower plant (PhD student: Zhou Wenjing; main supervisor: Bjørn Glemmestad)

Dispersion and ignition of hydrogen leaks (PhD student: Ole Kristian Sommersel; main supervisor: Dag Bjerketvedt)

Energy modelling and simulation for optimal energy design of hospitals (PhD student: Vladyslav Shchuchenko; main supervisor: Bernt Lie)

Engineering Particulate Solids by Comminution to Manufacture Powders with Desired Flow Properties by Controlling Particle Size and Shape (PhD student: Zhimin Xi; main supervisor: Chandana Ratnayake)

Fully integrated regenerative calcium cycling (PhD student: Chameera Jayarathna; main supervisor: Lars-André Tokheim)

Hydrogen gas explosions - experimental investigations of deflagrations and detonations (PhD student: André Gaathaug; main supervisor: Dag Bjerketvedt)

Hydrogen safety (PhD student: Kanchan Rai; main supervisor: Dag Bjerketvedt)

Image-based sizing techniques for fire water droplets (PhD student: Joachim Lundberg; main supervisor: Dag Bjerketvedt)

Kinetics of CO₂ absorption into aqueous MEA solution droplets (PhD student: Jingyi Han; main supervisor: Morten Chr. Melaaen)

Model based control in the metallurgical industry (PhD student: Anushka Perera; main supervisor: Bernt Lie)

Model studies of natural gas conversion catalysts (PhD student: Bo Li; main supervisor: Klaus-Joachim Jens)

Modeling, simulation and control of a metallurgical plant (PhD student: Mirnes Alic; main supervisor: Bernt Lie)

Modelling of increased oil production with AICD (PhD student: Haavard Aakre; main supervisor: Britt Halvorsen)

Olefin transformation catalysts (PhD student: Lu Li; main supervisor: Klaus-Joachim Jens)
Optimal operation of biogas reactors (PhD student: Finn Haugen; main supervisor: Bernt Lie)

Optimization of energy consumption in buildings based on information from sensor networks (PhD student: Wathsala Perera; main supervisor: Nils-Olav Skeie)

Optimization of flow behaviour in gasification reactors (PhD student: Rajan Kumar Thapa; main supervisor: Britt Halvorsen)

Optimum utilization of oil reserves with improved operation (PhD student: Roshan Sharma; main supervisor: Bjørn Glemmestad)

Rapid boiling of carbon dioxide (PhD student: Sindre Tøsse; main supervisor: Knut Vågsæther)

Rate based modeling of a post combustion CO₂ capture plant (PhD student: Sanoja Ariyarithna; main supervisor: Morten Chr. Melaaen)

Real time observation and analysis of GRID signals for optimal control of GRID performance (PhD student: Helge Lorenzen; main supervisor: Saba Mylvaganam)

Sensor network for online monitoring and control of energy loss in pipeworks (PhD student: Ronnie Anseth; main supervisor: Magne Waskaas)

Tomographic approach to automatic and non-intrusive flow regime identification (PhD student: Chaminda Pradeep; main supervisor: Saba Mylvaganam)

Two-stage, high rate biogas process analysis (PhD student: Wenche Bergland; main supervisor: Rune Bakke)

Usage of process tomographic techniques in the study of flow dynamics in fluid and particulate flow (PhD student: Yan Ru; main supervisor: Saba Mylvaganam)

Utilization of CO₂ neutral fuels in cement kilns (PhD student: Hiromi Ariyaratne; main supervisor: Lars-André Tokheim)
**Ongoing research projects**

*CO₂ capture - Grenland leads the way (2008-2013)*

The project is supported by the Telemark Province Municipality (Telemark fylkeskommune). The resources are mainly used for funding two part-time professorships at TUC, dedicated to CO₂ capture research, the two professors are Dag Eimer and Wilhelm Rondeel.

*Optimization and environmental improvement of CO₂ capture processes (2008-2012)*

This strategic research programme (SIP - "Strategisk Instituttprogram") at Tel-Tek was supported by the Norwegian Research Council. One PhD student, supervised by Klaus-Joachim Jens, defended his thesis on this topic in January 2013.

*Channel Integrated Treatment (2008-2013)*

The project is supported by the Norwegian Research Council and StatoilHydro. Tel-Tek has been awarded a contract from StatoilHydro, who operates this project. Two PhD students work on this project, supervised by TUC professors Morten C. Melaaen and Dag Eimer.

*Biogas from agriculture point sources – process optimization (2009-2013)*

This research is supported by TUC strategic funds, the Norwegian agriculture department (Statens landbruksforvaltning), and Innovation Norge. One PhD student is supervised by TUC professor Rune Bakke.

*Biogas process control (2009-2013)*

The research is supported by TUC strategic funds, the Norwegian agriculture department (Statens landbruksforvaltning) and Innovation Norge. One PhD student is supervised by TUC professors Bernt Lie and Rune Bakke.

*CO₂ capture from industrial point sources and further development of amine reclaimer waste handling by incineration and biological treatment (2010-2014)*

This research project (type KMB) is supported by the Norwegian Research Council and Gassnova through the CLIMIT research programme, and by industrial and academic partners. The project is run by Tel-Tek, but TUC personnel are managing the four work packages of the project: I) CO₂ capture and energy integration (Professor Morten C. Melaaen), II) Chemical characterisation of amines and degradation products (Professor Klaus-Joachim Jens), III) Bio-degradation of amine waste (Professor Rune Bakke), IV) Amine waste as a NOx reduction agent in incineration (Associate Professor Lars-André Tokheim). Two PhD students are educated and 1 post doc position is part of the project, which involves international cooperation with international universities (Chalmers University of Technology and Denmark Technical University) and industrial companies.
Better and more intelligently formulated CO₂ absorbents (2010-2013)

This research project is supported by the Norwegian Research Council and Gassnova through the CLIMIT research programme. The project is run by TUC professors Dag Eimer and Klaus-Joachim Jens, who supervise two PhD students.


This research project (type KMB) is supported by the Norwegian Research Council, The Norwegian Farmers Association (Norsk Bondelag) and Bioplan AS, and involves 8 academic partners in Norway, Sweden and Denmark. The total budget is MNOK 16. This research is coordinated by Bioforsk (Bioforsk Jord og miljø). One PhD student employed at NTNU is supervised by TUC professor Rune Bakke.

Fully Integrated Regenerative Calcium Cycling (2013-2016)

Alstom Norway has been granted funding from Gassnova via the Climit programme for a three-year project investigating the potential of CO₂ capture by calcium cycling applying indirect heat transfer in the calciner. The project is a cooperation between Alstom Norway, Alstom Power (Germany), Telemark University College, Tel-Tek, IFE and ETH (Switzerland). The project has four different work packages, and TUC/Tel-Tek is strongly involved in one of these. One PhD candidate will be educated at TUC as part of the project. Associate Professor Lars-André Tokheim is the sub-project manager, and he is also the main supervisor of the PhD student.

Guest researchers 2013

<table>
<thead>
<tr>
<th>Researcher (position)</th>
<th>Institution</th>
<th>Research topic</th>
<th>Period at TUC</th>
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<tbody>
<tr>
<td>Henrik Jilvero (PhD Student)</td>
<td>Chalmers University of Technology (Gothenburg, Sweden)</td>
<td>CO₂ capture</td>
<td>Feb-Dec 2013 (several periods)</td>
</tr>
<tr>
<td>Nataliia Nauchu (PhD student)</td>
<td>Kiev Polytechnic (Kiev, Ukraine)</td>
<td>Landfills energy potential and degradation products impact assessment</td>
<td>Feb-Sep 2013</td>
</tr>
<tr>
<td>Tetiana Lutchyn (PhD student)</td>
<td>Kiev Polytechnic (Kiev, Ukraine)</td>
<td>Identification of regime parameters of electrical energy consumption</td>
<td>Jan-Aug 2013</td>
</tr>
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### Guest lectures, seminars and workshops 2013

<table>
<thead>
<tr>
<th>Date</th>
<th>Topic</th>
<th>Lecturer(s)</th>
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<tbody>
<tr>
<td>19 March</td>
<td>Renewable energy: Generation and utilization of gas from organic</td>
<td>Professor Christoph Pfeifer, Vienna University (+ several other lecturers)</td>
</tr>
<tr>
<td>(Workshop)</td>
<td>materials</td>
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<tr>
<td>9 April</td>
<td>Alarm systems</td>
<td>Tom Kjærgård, IFEA</td>
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<tr>
<td>(Seminar)</td>
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<td>Håkon Wærstad, Yara</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Jan Grønlid, Ineos</td>
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<tr>
<td></td>
<td></td>
<td>(+ several other lecturers)</td>
</tr>
<tr>
<td>29-30 April</td>
<td>Process intensification using Aspen Plus: Intensive study of a MTBE</td>
<td>Professor Marc Wijnants, Karel de Grote-Hogeschool, Antwerpen, Belgium</td>
</tr>
<tr>
<td>(Workshop)</td>
<td>reactive distillation process as case study on energy consumption</td>
<td>Professor Kristof Verhulst, Karel de Grote-Hogeschool, Antwerpen, Belgium</td>
</tr>
<tr>
<td></td>
<td>minimization</td>
<td></td>
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<tr>
<td>15-16 May</td>
<td>Entrepreneurship in education and in research &amp; development</td>
<td>Professor Slawomir W. Hermanowicz, University of California, Berkeley, USA</td>
</tr>
<tr>
<td>(Seminar)</td>
<td></td>
<td>(+ several other lecturers)</td>
</tr>
<tr>
<td>24 May</td>
<td>Fuzzy sets and fuzzy logic in thermal processes: Chosen applications</td>
<td>Professor Jacek Kucharski, University of Lodz, Poland</td>
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<tr>
<td>(Guest lecture)</td>
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<tr>
<td>3 June</td>
<td>Graph cut, convex relaxation and continuous max-flow problems for</td>
<td>Professor Xue-Cheng Tai, University of Bergen</td>
</tr>
<tr>
<td>(Guest lecture)</td>
<td>image processing and computer vision</td>
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</tr>
<tr>
<td>23 October</td>
<td>Industrial simulators for engineering courses</td>
<td>Associate Professor Tiina Komulainen, Oslo and Akershus University College</td>
</tr>
<tr>
<td>(Guest lecture)</td>
<td></td>
<td>(HiOA)</td>
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</table>
**PhD courses**

TUC offers 17 PhD courses on a regular basis; see Table 1. An overview of courses (including individual curricula) given in 2013 is presented below the table.

*Table 1: PhD courses offered by the faculty.*

<table>
<thead>
<tr>
<th>Course code</th>
<th>Course name</th>
<th>Sem.</th>
<th>Credits</th>
<th>Assessment Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Compulsory</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>D0611</td>
<td>Theory of science and Ethics</td>
<td>5</td>
<td></td>
<td>Essay</td>
</tr>
<tr>
<td><strong>Compulsory, select one of the two next data analysis courses</strong></td>
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<tr>
<td>D0110</td>
<td>Process Analytical Technology</td>
<td>5</td>
<td></td>
<td>Course assignment and oral final examination</td>
</tr>
<tr>
<td>D0308</td>
<td>Matrix methods</td>
<td>5</td>
<td></td>
<td>Written intermediate and final examinations</td>
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<tr>
<td><strong>Elective – Data analysis</strong></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D1208</td>
<td>Advanced Multivariate Data Analysis</td>
<td>10</td>
<td></td>
<td>Final examination</td>
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<tr>
<td>D1408</td>
<td>Multi Sensor Data Fusion – Using Fuzzy Logic and Neural Networks</td>
<td>10</td>
<td></td>
<td>Exercises, semester assignment, final “take home” examination</td>
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<tr>
<td>D1508</td>
<td>Linear Systems Theory</td>
<td>10</td>
<td></td>
<td>Exercises, final examination</td>
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<tr>
<td>D1608</td>
<td>System Identification</td>
<td>5</td>
<td></td>
<td>Exercises, final examination</td>
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<tr>
<td><strong>Elective – Modeling</strong></td>
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<td></td>
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<tr>
<td>D1708</td>
<td>Modeling for Control</td>
<td>10</td>
<td></td>
<td>Semester assignment, final examination</td>
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<tr>
<td><strong>Elective – Process technology</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D0408</td>
<td>Mechanics of Particulate Solids</td>
<td>10</td>
<td></td>
<td>Lab. report, final examination</td>
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<tr>
<td>D0508</td>
<td>Bioenergetics</td>
<td>10</td>
<td></td>
<td>Final examination</td>
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<tr>
<td>D0608</td>
<td>Biofilm Processes</td>
<td>10</td>
<td></td>
<td>Final examination</td>
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<tr>
<td>D0708</td>
<td>Convective Heat and Mass-Transfer</td>
<td>10</td>
<td></td>
<td>Final examination</td>
</tr>
<tr>
<td>D0908</td>
<td>Natural Gas Conversion</td>
<td>10</td>
<td></td>
<td>Final examination</td>
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<tr>
<td>D1809</td>
<td>Gas Treating</td>
<td>10</td>
<td></td>
<td>Final examination</td>
</tr>
<tr>
<td>D0410</td>
<td>Fluid-Particle Multiphase Flow</td>
<td>10</td>
<td></td>
<td>Final examination</td>
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<tr>
<td><strong>Elective – Energy technology</strong></td>
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<tr>
<td>D1108</td>
<td>Advanced Combustion</td>
<td>10</td>
<td></td>
<td>Final examination</td>
</tr>
<tr>
<td>D1308</td>
<td>Magneto Thermal Calculations</td>
<td>10</td>
<td></td>
<td>Exercises, final examination</td>
</tr>
</tbody>
</table>
D0611 Theory of Science and Ethics (5 ECTS credits)

Course content: a) Science in history: General outline of the historical development of science; the impact of science and technology on culture in the past and present; cases from the history of science. b) Theories, methods and problems of empirical science Induction, hypothetico-deductive method; philosophies of science: logical positivism, critical rationalism (Popper), theory of scientific revolutions (Kuhn), contemporary critiques; observation and theory: the problem of theory-dependence; different types of science/disciplines and their relationships: natural sciences, social sciences and the humanities – explanation and understanding; methodological approaches in the social sciences: collectivism and individualism, hermeneutics, phenomenology, constructivism and positivism. c) Ethics and issues of value in science and research The role of value and interest in science and research: pure and applied science and research, commissioned research; the justification of science: Aristotle vs. Bacon; ethical responsibility in science and research: professional responsibility, social and environmental responsibility, responsibility to individuals; codes of ethics: their role and justification; uncertainty and managing risk in the acceptance of scientific theory and uses of technology. d) Science, Technology and Society The impact of technology on individuals and contemporary society.

Responsible: Professor Sven Arntzen

No of students 2013: 26

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D0708 Convective Heat and Mass Transfer (10 ECTS credits)

Course content: Conservation equations for both elliptic and parabolic problems; Momentum and heat transfer for laminar and turbulent fluid flow; Mass transfer analysis; Forced and free convection; Selected multiphase topics; Numerical techniques for solving elliptic and parabolic conservation equations

Responsible: Professor Morten C. Melaaen

No of students 2013: 2

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3 Participants from several universities and university colleges; five from TUC Faculty of Technology
**D1908  Gas Treating (10 ECTS credits)**

**Course objectives:** The candidate will master advanced theory on mass transfer processes combined with chemical reactions and will know how gas treating or processing is practiced in the natgas and syngas industries. The candidate will also be able to assess and calculate complex mass transfer transfer problems applied to gas treating.

**Course description:** Overview: Natural gas treating for pipeline transport; Options for sulphur removal; Current options for post-combustion CO₂ removal; Gas separation techniques in general

Absorption with chemical reactions: Rate limited mass transfer between gas and liquid; Influence of water transfer between phases; Sensible heat transfer between gas and liquid; Reynolds analogy and Chilton-Colburn analogy; Key aspects of the CO₂ (and/or H₂S) absorption from gases; Models for absorption equilibria and mass transfer coefficients; Chemical degradation of absorbent chemicals

**Responsible:** Professor Dag Eimer

**No of students 2013:** 3

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**D0110 Process analytical technology (5 ECTS credits)**

**Course objectives:** Give candidates basic insight and knowledge related to process experimental design, representative process sampling and multivariate process data analysis

**Course description:** Process Analytical Technology is currently revolutionizing industrial production. Instead of bringing samples to the central laboratory, PAT brings the analytical instruments directly to the production process, most often in the form of multi-channel instrumentation opening up for a powerful multivariate data modeling (chemometrics). There are many benefits: increased process understanding, increased opportunities for process monitoring and control, increased profitability. Content: 1. Introduction to Process Analytical Technology, 2. Multivariate Data analysis, 3. Process sampling - Theory of sampling, 4. On-line process analytical techniques – overview, 5. Process analytical techniques: in-depth treatment: Acoustic chemometrics and Multivariate Image Analysis (MIA)

**Responsible:** Associate professor Maths Halstensen

**No of students 2013:** 1
D1108  Advanced Combustion (10 ECTS credits)

Course objectives: The course will give advanced knowledge in the topics chosen.

Course description: The course deals with fundamental aspects of combustion and combustion theory. The conservation equations and reaction kinetics are treated, as well as premixed flames, diffusion flames, droplet combustion, explosions, detonations, ignition, turbulent flow, turbulent combustion and combustion of solid fuels.

Responsible: Professor Dag Bjerketvedt

No of students 2013: 1

High-speed camera analysis
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