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Annual Report **2009**

DTU Chemical Engineering
Department of Chemical and Biochemical Engineering

Annual Report 2009
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Photo on front page: Students from the new Elite Masters Program in Chemical and Biochemical Engineering which started in September 2009.

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"Energy can be neither created nor destroyed"
First Law of Thermodynamics

DTU Chemical Engineering has been a leader in the field of emission control since the 1980's, cooperating with power companies on both basic and applied technical research aimed at greener and cleaner production of electricity and heat.

ANNUAL REVIEW

Head of Department

HEAD OF DEPARTMENT

RENEWED ENERGY
FOR RESEARCH THAT MATTERS

Kim Dam-Johansen
Professor, Head of Department

2009 was a remarkable and highly successful year for DTU Chemical Engineering. The department engaged in promising collaborations in a number of emerging research fields and also launched new, ambitious courses and education programs. Additionally, we organized workshops and conferences as our contribution to the topical public debate around global climate issues and energy supply. Furthermore, we have strengthened the profile of our core technical areas of competence by founding new disciplinary and cross disciplinary groups. With these measures we have implemented the organizational adjustments we saw necessary to ensure that DTU Chemical Engineering remains attractive to both students and research partners.

In recent years, the chemical engineering field has started to face several exciting and challenging developments: The borders between chemistry and biochemistry fade, technological advancements and increased awareness of environmental issues spawn new markets and potential products, while industry demand for innovation and optimized production processes increases. Research at DTU Chemical Engineering has the ability to adapt with these developments and has always been firmly based on a long tradition of close collaboration with diverse academic and industrial partners from fields like the energy and oil sector, the pharmaceutical industry, bio-technology, the cement industry and the food sector.

Succesful chemical engineering requires flexibility and team spirit, and our vibrant interface with all our collaborators has the benefit that the route from laboratory to production is often relatively short. This, in turn, is a motivational factor for students and faculty alike, and keeps us focused on our ambition of being an attractive partner for industry and research organizations.

A stronger focus on energy and biotech

Currently, the demands for improvement and innovation are especially prominent in the energy sector. This is reflected in DTU Chemical Engineering, where our long-standing research in the combustion field was enforced when Peter Glarborg took seat as a Professor in January 2009. The professorship – The DTU Clean

Power Chair – is part of a cooperation between DTU Chemical Engineering, DONG, and Vattenfall, focusing on clean and green production of electricity and heat.

In 2009, DTU management decided to put more attention on the oil and gas sector, thereby forming a new cross-departmental research center on the basis of IVC-SEP and expanding with disciplines at other DTU departments. CERE, the Center for Energy Resources Engineering, launched on September 1, 2009, with petroleum engineering as its main focus and Professor Erling H. Stenby as Director.

Since the department changed its name to embrace the word 'Biochemical' in 2008, our activities in this field have expanded rapidly and resulted in a series of new cooperative research projects. In response to a growing need for technological research that bridges biotechnology, process engineering, and traditional chemistry, a new research center, The Center for Process Engineering and Technology (PROCESS), has been established at DTU Chemical Engineering with Professor John Woodley as head of the center.

Prominent people and good prospects

In September, the first batch of especially qualified students entered our new Elite Masters Program in chemical and biochemical engineering. The program has a sharp focus on the interplay between academic research and development within industry. The students will be equipped to hold the best positions within industrial research, innovation, process design, operation, and management. Our summer school program for international students was a great success again in 2009 with 48 students from other parts of the world spending five weeks in Denmark. Additionally, in 2009, we increased and broadened our range of external courses, including PAT-related courses for employees in the health and pharmaceutical sectors.

2009 was remarkable also for the many marks of recognition received from the world around us. Professor Ole Hassager received the prestigious Weissenberg prize; Assistant Professor Anne Ladegaard Skov was awarded the Elastyren Prize; and PhD student Peter Dybdahl Hede received the prize for the 'PhD Project of the year 2009.' Furthermore, our professors Jan E. Johnsson and Michael L. Michelsen shared the honor of being elected 'Teachers of the Year' by DTU students, and a rare mark of honor was bestowed on Professor John Woodley when he was elected 'Fellow of the Royal Academy of Engineering' in October.

The current technological challenges of society and industry place very high expectations on the chemical engineers of the future. With the many new initiatives and structural enhancements we undertook in 2009, I am confident that DTU Chemical Engineering is ready to meet the challenges ahead to the benefit of both our students and research partners.

I wish you a pleasant read.

Kim Dam-Johansen
Professor, Head of Department

HIGHLIGHTS 2009

At the Combustion, Carbon Capture and Storage Workshop held by DTU Chemical Engineering on May 28, 2009, combustion and CCS-technologies were presented as seen from both technical, economic, political and environmental perspectives.

In the storage session of the workshop, titled 'Geological Storage and Enhanced Oil Recovery, EOS', Deputy Director General of the Danish Energy Agency, Anne Højer Simonsen, talked about the prospects for CO_2 storage on Danish ground.

HIGHLIGHTS 2009

JANUARY

DTU Chemical Engineering joins research alliance for healthier food
Professor Anne Meyer from DTU Chemical Engineering joins a new Transatlantic Foods for Health Consortium, established by leading food scientists from Denmark and the University of California, Davis.

Peter Szabo member of the DTU board
Associate Professor Peter Szabo is elected as a member of the DTU board for a 4 year period.

Rafiqul Gani appointed new editor-in-chief of the Elsevier journal 'Computers and Chemical Engineering'
Professor Rafiqul is appointed as Editor-in-Chief of the Elsevier journal Computers & Chemical Engineering (CACE)

JANUARY 1

Peter Glarborg appointed professor at DTU Chemical Engineering
Peter Glarborg is appointed as professor at DTU Chemical Engineering. Professor Glarborg will hold the "DTU Clean Power Chair", which is part of a cooperation between DTU Chemical Engineering and the power companies DONG A/S and Vattenfall A/S working for cleaner and more efficient production of power and heat.

JANUARY 19

Catalysis Day I
More than 80 researchers from both academia and industry participate in the first Catalysis Day held at DTU Chemical Engineering.

JANUARY 20-21

In-service course for the Danish Medicine Agency
20 pharmaceutical inspectors from the Danish Medicine Agency (Lægemiddelstyrelsen) participated in a two day course arranged by DTU Chemical Engineering. The course covered aspects of the changes which are currently underway in pharmaceutical production.

JANUARY 28

Departmental seminar by Professor James Clark
A departmental seminar was given by Professor James Clark, The University of York, UK, entitled, "Green Chemistry and the Biorefinery."

FEBRUARY

FEBRUARY 5

Visit by 35 chemistry teachers
Thirty-five members of the Society of Chemistry Teachers in Copenhagen Chemistry visited DTU Chemical Engineering for a course on polymer packaging in the food industry.

One of the world's leading experts in the field, Professor Klaus Hein from the University of Stuttgart, took stock of the global CO_2 emissions and showed examples of CCS solutions in Europe, China, Japan and Australia.

Emily Rochon, Head of Section in Greenpeace International, suggested that Western countries should set an example for the rest of the world and retain a clear focus on 100 pct. sustainable technologies like solar, wind and geothermal power.

FEBRUARY 20

Celebration of Docent Jan E. Johnsson's 40 years at DTU

DTU Chemical Engineering celebrated professor (Docent) Jan Erik Johnsson's 40 years of employment at DTU in an honorary seminar.

MARCH

MARCH 25

Departmental seminar by Per Bagge Angelo

A departmental seminar was given by Per Bagge Angelo, Vice President in the department of Service, Integrity & Maintenance at Mærsk Olie og Gas A/S, entitled, "Risk Based Process Safety Management."

APRIL

APRIL 15

Professor Ole Hassager receives the Weissenberg award 2009

Professor Ole Hassager received the prestigious Weissenberg Award 2009 at a ceremony in Cardiff as part of the fifth "Annual European Rheology Conference"(AERC).

APRIL 20

Assistant Professor Anne Ladegaard Skov receives the 2009 Elastyren prize

Assistant Professor Anne Ladegaard Skov receives the 2009 ATV/Elastyren Prize for her research in synthetic elastomers.

APRIL 23

Departmental seminar by Professor Andrzej Górak

A departmental seminar was given by Professor Andrzej Górak, Universität Dortmund, Germany, entitled, "Downstream processing of biopharmaceuticals – Monoclonal antibody purification."

2G from Ordrup Gymnasium visits DPC

The 2G class from Ordrup Gymnasium visited the Danish Polymer Center (DPC).

APRIL 24

Michael Locht Michelsen and Jan Erik Johnsson receive "Teacher of the Year" award

During the DTU Annual Party on April 24th, two teachers from the Department of Chemical and Biochemical Engineering, Michael Locht Michelsen and Jan Erik Johnsson, received the honorable award, "Teacher of the Year."

APRIL 28

Ole Hassager holds Bird/Stewart/Lightfoot lecture

Professor Ole Hassager is invited to give the annual Bird/Stewart/Lightfoot lecture at the University of Wisconsin. Hassager's lecture is entitled "Filament stretching Rheometry: A Probe for Polymer Dynamics."

Forty-eight students spent five summer weeks participating in the Summer School at DTU Chemical Engineering.

HIGHLIGHTS 2009

MAY

MAY 14

Departmental seminar by Professor Costas Kipparissides

A departmental seminar was given by Professor Costas Kipparissides, CPERI, Greece, entitled, "New issues on population balance modeling and optimization of particulate polymerization and biochemical systems."

MAY 25

Professor Peter Glarborg holds inauguration lecture about cleaner energy

Peter Glarborg, who was appointed professor in January, holds his inauguration lecture about cleaner and more efficient production of power and heat.

MAY 28

CCCS Workshop

A workshop entitled "Combustion, Carbon Capture and Storage", took place at DTU. Organized by DTU Chemical Engineering for specially invited experts from academia, governmental organizations and related industries, the workshop was part of a series of thematic workshops held by DTU in preparation for DTU's climate conference on September 17 and the UN climate conference – COP15 – held in Copenhagen in December 2009. The workshop formed the basis for a recommendation concerning combustion technologies in future power plants, industrial plants and ships.

MAY 31

Søren Hvilsted co-organizes the EUPOC2009

Professor Søren Hvilsted was a co-organizer of the EUPOC2009 (EPF Europolymer Conference: "Click" – Methods in Polymer and Materials Science), 31 May to 4 June 2009 in Gargnano, Lago di Garda, Italy.

JUNE

JUNE 2-4

CAPEC Annual Meeting 2009

The CAPEC Annual Meeting 2009 had 72 participants, out of which 21 were member company representatives, 7 were invited guests and the rest were from CAPEC and the Department of Chemical Engineering.

JUNE 10-12

IVC-SEP Discussion Meeting 2009

IVC-SEP held its annual Discussion Meeting at Hotel Comwell in Holte. 75 people attended the conference which offered four sessions with the headlines: CO_2 Capture, Complex Fluids, Enhanced Oil Recovery and Petroleum Fluids.

JUNE 19

DTU-seminar honoring Professor Sten Bay Jørgensen

Professor Sten Bay Jørgensen's retirement from DTU was marked by an honorary seminar where colleagues, industrial partners, peers, friends and current and former students paid homage to a highly esteemed scientist and teacher.

JUNE 27

Best Poster Award at 24th ESAT goes to PhD. student Jose Fonseca

During the 24th European Symposium on Applied Thermodynamics, ESAT, held in Sanitago de Compostela, Spain, from June 27th to July 1st, PhD. student Jose Fonseca was honored as the winner of the "Best Poster Award" for his poster entitled, "Design, construction and testing of a new high-pressure, low-temperature apparatus for measuring three-phase equilibria in hydrocarbon-water-hydrate inhibitor systems."

JULY

JULY 30-31

PhD Summer Course on "Advanced Computer Aided Modelling"

Prof. Gani gave a PhD Summer Course on "Advanced Computer Aided Modelling" from 20-31 July.

JULY-AUGUST

Forty-eight students participate in the Summer School at DTU Chemical Engineering

Thirty-eight american students participated in DTU Chemical Engineering's Summer University for non-european students and 10 students participated in the european summer school.

AUGUST

AUGUST 12

Professor Rafiqul Gani holds keynote lecture at the ICOSSE 2009

At the successful 1st International Conference on Sustainability Science and Engineering event (ICOSSE 2009) that took place in Cincinnati between 9-12 August 2009, Professor Rafiqul Gani gave an invited keynote lecture on "Sustainable design of chemical and biochemical processes: The role of models and modelling."

AUGUST 16-20

Plenary lecture at PSE-2009, Salvador, Bahia, Brasil

Professor Rafiqul Gani gave a plenary lecture on "Modelling for PSE and Product-Process Design" at the 10th International Symposium of Process Engineering (PSE-2009) at Salvador, Bahia, Brasil.

AUGUST 20

Ellen Fredenslund celebrates 40 years of employment in the Danish State

A reception was held in celebration of System Manager Ellen Fredenslund's 40 years of employment in the Danish State. On the occasion, Ellen Fredenslund received a medal of honor from Her Majesty Queen Margrethe II of Denmark.

Docent Michael Locht Michelsen received the award "Teacher of the Year" at the DTU Annual Party on April 24.

On April 20 2009, Assistant Professor Anne Ladegaard Skov received the 2009 ATV/Elastyren Prize for her research in synthetic elastomers.

Docent Jan E. Johnsson received the award "Teacher of the Year" at the DTU Annual Party on April 24.

HIGHLIGHTS 2009

AUGUST 28

Departmental seminar by Dr. Michael Frenkel

A departmental seminar was given by Dr. Michael Frenkel, Director, Thermodynamic Research Center, NIST, Boulder, Colorado, USA, entitled, "Global information systems in science and engineering: Applications to the field of thermodynamics."

AUGUST 27-28

Two-day course for 50 physics and chemistry teachers

Fifty physics and chemistry teachers from Danish public schools took part in a course arranged by CHEC and the company Haldor Topsøe A/S. The participants spent one day with each of the arrangers.

SEPTEMBER

SEPTEMBER 1

The first batch of especially qualified students entered the new Elite Masters Program in Chemical and Biochemical Engineering.

SEPTEMBER 10

Thirty public school teachers visit DTU Chemical Engineering for polymer course

DTU Chemical Engineering held a polymer course in cooperation with the Danish Plastics Federation (Plastindustrien). Thirty chemistry and physics teachers from public schools participated and were presented with lectures and experiments concerning polymers to use in their classrooms.

SEPTEMBER 23

Departmental seminar by Professor Wolfgang Arlt

A departmental seminar was given by Professor Wolfgang Arlt, Univ. Erlangen, Germany, entitled, "Global information systems in science and engineering: Applications to the field of thermodynamics."

OCTOBER

OCTOBER 1

Chec Annual Meeting 2009

The Annual CHEC seminar was attended by 110 participants – 45 from within CHEC and 65 guests from industry and academia. The 29 presentations given at the seminar were categorized under the headlines "Combustion and CO_2 reduction", "Ashes, Deposits and Corrosion", "Flue Gas Cleansing" and "Catalysis".

OCTOBER 2

Farewell reception for Docent Jan E. Johnsson

A reception was held in connection with docent Jan E. Johnssons retirement. Jan E. Johnsson will continue his connection with the department as Professor Emeritus.

OCTOBER 9

John Woodley elected 'Fellow of the Royal Academy of Engineering'

John Woodley, Professor at KT since 2007, was elected a Fellow of the Royal Academy of Engineering. The Royal Academy of Engineering is the UK's National Academy of Engineering and brings together the UK's most distinguished engineers from all disciplines.

Head of Department, Professor Kim Dam-Johansen, gave a guided tour of the pilot plant facilities at DTU Chemical Engineering to the DTU Board of Representatives who held their annual meetting at the department on May 18, 2009.

Professor Ole Hassager received the prestigious Weissenberg price 2009 on April 15 in Cardiff as part of the 5th "Annual European Rheology Conference" (AERC).

OCTOBER 30

PhD student Peter Dybdahl Hede wins prize for "PhD-Project of the Year" award

Peter Dybdahl Hede, who conducted his PhD project at DTU Chemical Engineering, was awarded the 2009 prize for 'PhD Project of the year'. Hede's PhD research dealt with encapsulation of cells containing enzymes and is used in industry today.

NOVEMBER

NOVEMBER 9-10

SNCI Cop 09 Combustion Conference

The two-day Combustion Conference SNCI Cop 09 was organized by DTU Chemical Engineering. The meeting was very successful, with 74 participants from 11 countries over the two days of meeting.

NOVEMBER 13

Annual Polymer day and reception for NMR Instrument

The Graduate School of Polymer Science at DTU (DPC) held the 5th Annual Polymer Day. The day began with a reception in connection with the NMR instrument donated to DPC by Novo Nordisk A/S. Fifty-one people participated in the Annual Polymer Day, 28 of these were guests from industry.

NOVEMBER 26

Departmental seminar by Professor Rafal Dunin-Borkowski

A departmental seminar was given by Professor Rafal Dunin-Borkowski DTU Center for Nanotechnology, DK, entitled, "Advanced transmission electron microscopy of nanoscale materials and devices."

DECEMBER

DECEMBER 9

Departmental seminar by Professor Emeritus John Villadsen

A departmental seminar was given by Professor Emeritus John Villadsen, DTU Chemical Engineering, DK, entitled, "The use of Thermodynamics in the analysis of Bio-reaction networks."

DECEMBER 11

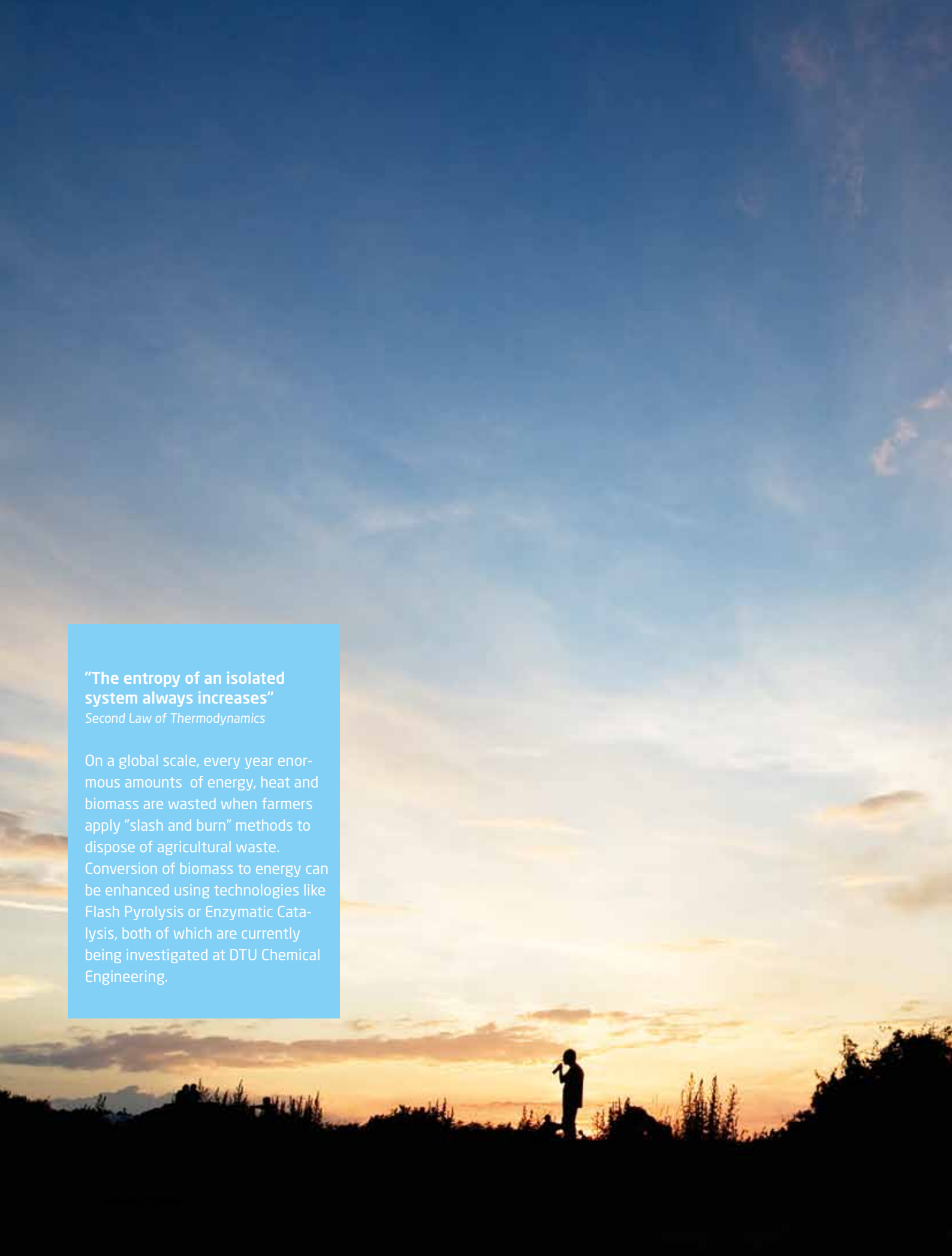
DTU Chemical Engineering Christmas seminar

Head of Department, Professor Kim Dam-Johansen, reported on the status of 2009, and prospects of the department's future were discussed at the departmental Christmas Seminar.

DECEMBER 14

Agreement of cooperation between DTU Chemical Engineering and TU Dortmund University

DTU Chemical Engineering signs an agreement of cooperation with TU Dortmund University promoting academic exchange in education and research. The agreement covers exchange of staff and students, cooperation in research, shared organisation in seminars, and cooperation on curriculum development.



"The entropy of an isolated system always increases"
Second Law of Thermodynamics

On a global scale, every year enormous amounts of energy, heat and biomass are wasted when farmers apply "slash and burn" methods to dispose of agricultural waste. Conversion of biomass to energy can be enhanced using technologies like Flash Pyrolysis or Enzymatic Catalysis, both of which are currently being investigated at DTU Chemical Engineering.

RESEARCH & INNOVATION & EDUCATION

Self-sustaining biomass conversion with flash pyrolysis

Finding technological cures for pharmaceutical production headaches

Enzymatic production of biodiesel

Fighting gas hydrates with anti-freeze proteins

Intelligent polymer design for the 21st century

Gürkan Sin new profile in systems engineering

Peter Glarborg new professor at DTU Chemical Engineering

SELF-SUSTAINING BIOMASS CONVERSION WITH FLASH PYROLYSIS

In recent years, conversion of biomass to fuel has become one of the main technological routes for reduction of CO_2 emission. Flash Pyrolysis is a emerging technology offering a 'two flies with one stone' approach by not only converting biomass to bio-oil and gas but at the same time yielding high quality biochar – a porous, powdery byproduct which can be used as a soil fertilizer and possibly a vehicle for carbon capture. In a joint research project DTU Chemical Engineering and DTU Risø are currently looking for ways to harvest the full potential of this versatile and promising technology.

Pyrolysis is basically heating of biomass without oxygen, a technology applied in production of charcoal for centuries. In Flash Pyrolysis, the biomass is heated at a high heating rate at moderate temperatures, typically 400 to 600 degrees °C. This process requires a very short residence time, typically less than a second. The output of the process is bio-oil, biochar, and non-condensable gases, with the yield of bio-oil at about 50-75 percent.

50-60% yield of bio-oil from straw

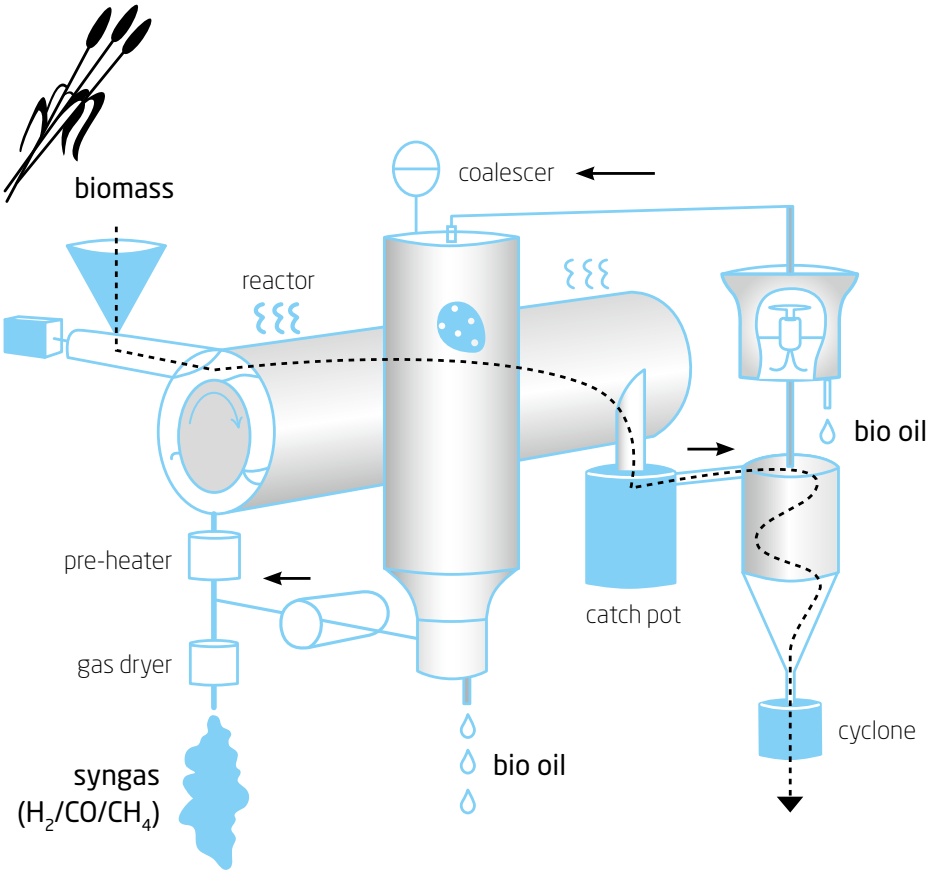
An important goal of the joint research venture is to determine the exact process parameters for maximum yield and quality of bio-oil while at the same time delivering the highest quality of biochar. DTU Risø covers the biochar research while DTU Chemical Engineering is in charge of running the pyrolysis reactor and assessing the bio-oil properties. While the principles behind Flash Pyrolysis are fairly simple, the process itself is highly complex.

"During the initial research phases an important goal has been to better understand the process behavior at a basic level," says PhD student Norazana Ibrahim who has been working with flash pyrolysis since 2007. Norazana's PhD project is titled 'Flash Pyrolysis of Agricultural Residue for Bio-oil' and her practical experiments with the Pyrolysis Centrifuge Reactor (PCR) have so far unveiled a series of key facts about the process and its properties when applied to different types of biomass.

"Different feedstocks give different qualities of bio-oil and temperature control is crucial. For wheat straw we found that the optimal temperature is 525 °C, giving a 50-60% yield of bio-oil," says Norazana who also found that bio-oils from soft and hard wood are different from agriculture residue, "Compared to straw, bio-oil from pinewood is more acidic and has a lower viscosity."

Norazana is currently studying the storage stability of the bio-oil when exposed to the elevated temperatures over extended periods of time.

PhD student Norazana Ibrahim is keenly interested in sustainable energy and hopes to one day see Flash Pyrolysis applied in her home country, Malaysia.



The Pyrolysis Centrifuge Reactor (PCR) used in Norazana Ibrahim's research converts biomass into bio-oil, gas and bio-char. Straw is introduced by the screw feeder into the centrifuge reactor. A cyclone is used for char collection, and a condenser and a coalescer is used for bio-oil collection. A pump re-circulates a part of the formed gas.

"Bio-oil has a high oxygen and high water content compared to petroleum fuel. This affects the combustion properties of the oil - you can use it directly in a turbine or boiler, but we need to thoroughly understand the bio-oil composition and find out how we can upgrade it for use in small engines such as a diesel engine," says Norazana.

A fertilizer with carbon capture potential

Once the basic pyrolysis process properties for different kinds of feedstock are mapped the data will be used for modeling. The next step will be to adjust and upgrade the pilot plant reactor for large scale production and prepare it for commercial applications.

Biochar produced by the PCR at DTU Chemical Engineering is passed on to DTU RISØ where the biochar's fertilizer and carbon capture properties are examined. Biochar contains some levels of nutrients vital for plant growth. It's high porosity helps soil retain water and provides a good growth environment for various microbes beneficial to the ecosystem. As an extra bonus biochar stores carbon in the soil, potentially keeping CO_2 out of the atmosphere for thousands of years. More research is needed, however, to validate biochar's long term carbon storage properties.

A self-sustaining system

A possible further development of the PCR unit is to make it mobile so it can operate directly on a straw field. The produced bio-oil has a large energy density compared to straw bales. A 'Mobile Flash Pyrolysis Unit' would, in principle, be a harvester which collects bio-oil and returns biochar directly to the soil,

Associate Professor Peter Arendt Jensen and PhD Student Niels Bech working with a flash pyrolysis reactor.

all the while being fueled by the syn-gas from the pyrolysis process.

"It is a very attractive feature that the system is self-sustaining, complete with cooling system and everything," says Norazana. "Flash Pyrolysis can be applied everywhere as long as we have the biomass to convert. Gas and bio-oil can be used for heating and power generation and on top of that you get the biochar which will improve future crops."

Norazana Ibrahim conducted her master's studies in Malaysia where she worked with hydrogen production for fuel cells before moving to Denmark in 2007 to start work on her PhD project. She is keenly interested in sustainable energy and she hopes to one day see Flash Pyrolysis applied in her home country.

"Usually after the rice harvest season the farmers just burn the straw. By applying Flash Pyrolysis we could reduce the pollution while getting the benefits from the other by-products. But a lot of research is still needed in order to apply that," Norazana Ibrahim says.

Flash pyrolysis can be applied to many types of biomass – even waste water sludge can be converted to bio-oil. A possible future development of the PCR is to make it mobile so it can operate directly on a straw field, fueled by gas from the pyrolysis process while producing bio-oil and recycling biochar to the the soil.

In recent years, manufacturing processes in the pharmaceutical industry have started to undergo fundamental changes and the driver is Process Analytical Technology – PAT. DTU Chemical Engineering is in the front line in the development of PAT-applications in close cooperation with major pharmaceutical companies.

FINDING TECHNOLOGICAL CURES FOR PHARMACEUTICAL PRODUCTION HEADACHES

As early as 1888, aspirin was the first drug to be manufactured industrially at large scale. Since then, pharmaceutical production has largely been based on batch production, a flexible but time-consuming step-by-step production principle necessary to meet the high quality demands of the regulatory health authorities. When, in 2004, the American Food and Drug Administration (FDA) issued a set of guidelines for a radically different approach called Process Analytical Technology (PAT) the pharmaceutical industry saw an opportunity for a technological upgrade. These upgrades consisted of existing processes with advanced on-line monitoring and control, combined with converting traditional batch processes into continuous production, potentially saving time and money and reducing the size of production facilities without compromising product quality.

PAT changes the fundamental rules for pharmaceutical production. If companies can demonstrate that they can keep critical production system variables within a specified, well-documented range (the so-called design space), then the regulatory authorities will allow production changes without requiring a new approval for each change. This new regulatory approach gives the pharmaceutical industry a green light for continuous production and production process optimization while paving the way for a multitude of fascinating chemical engineering challenges. At DTU Chemical Engineering PAT is an important and growing research field. The department is in the front line of PAT-application development in cooperation with leading pharmaceutical companies.

Online measurement with spectroscopy

"The central thing in PAT is that you try to understand your process in depth," explains Associate Professor Krist Gernaey, a key figure in PAT research at DTU Chemical Engineering. "Once you understand your process, the challenge is to design and operate it in such a way that you always achieve the quality that you expect from your production system."

On-line measurements of variables like temperature, pH, and concentration of reactants are one of the central requirements for successful PAT applications.

"You need on-line information about a process in order to control it, and these measurements are increasingly performed using a variety of spectroscopic methods," says Krist Gernaey. DTU Chemical Engineering collaborates closely with DTU Systems Biology and DTU Fotonik on the development and adaptation of spectroscopic measurements in pharmaceutical production processes. Additionally, several PhD projects are currently dedicated to optimizing measurement methods.

Better tools for process control and mathematical modeling are other important focus areas. Therefore PAT competences are drawn from across all centers within DTU Chemical Engineering where regular meetings are held for exchange of PAT-related insights, ideas and experience.

The short way from lab to production

PAT related research at DTU Chemical Engineering is done in close collabo-

"Process Analytical Technology (PAT) has opened a new chapter in the pharmaceutical industry," says Associate Professor Krist Gernaey. "It accelerates production processes in the pharmaceutical industry while offering better control of systems and product quality." Go to *http://www.kt.dtu.dk/PAT* for an overview of PAT related projects at DTU Chemical Engineering.

ration with industry partners, with a strong focus on practical application. In March of 2008, DTU Chemical Engineering and the Danish pharmaceutical company, Lundbeck A/S, launched a five year collaboration project, spawning a series of PAT-related research projects where PhD students investigate PAT-approaches for continuous production of organic-synthesis based pharmaceuticals.

"Our research and solutions are immediately tested and implemented at Lundbeck, making the route from lab to production plant very short," says Gernaey, "this makes the PAT field very attractive to our students."

Tommy Skovby, Senior Project Manager in Lundbeck A/S's Innovative Future Manufacturing Project, works with PAT-application on a daily basis and is in close collaboration with DTU Chemical Engineering.

"With PAT you could say the laboratory is integrated into the production process, giving much better process control and eliminating time-consuming offline analysis," says Tommy Skovby. "We save time and money and also space, since continuous production runs on much smaller units."

"The PAT systems we need cannot be bought, they must be developed from scratch. And our collaboration with DTU Chemical Engineering gives Lundbeck a much wider time horizon for future production planning."

"While we need to maintain a focus on day-to-day delivery, the researchers at DTU Chemical Engineering have the resources to delve into the details of production processes and come op with fantastic new equipment and innovative process designs which become part of our long-term production strategies," says Skovby before adding that the students he works with are extremely motivated.

"I guess part of the reason is that they see their ideas and designs being promptly applied."

A new chapter

While pharmaceutical companies have only recently started harvesting the benefits of PAT, the concept is also inching it's way into other sectors of industry.

"PAT has opened a new chapter in the pharmaceutical industry. Specifically for the food industry, where the high requirements for cleanliness and product stability are similar to those in the pharmaceutical field, the new on-line spectroscopic monitoring methods open up for improved well-controlled processes. Even the bulk and commodity (bio)chemical industry is beginning to pick up on PAT concepts," states Gernaey.

ENZYMATIC PRODUCTION OF BIODIESEL

Biofuels including biodiesel are essential for reduction of CO_2 emission but the traditional production method leaves room for improvement. Biodiesel production by enzymatic catalysis has long been known as a promising alternative - it is more eco-friendly and applicable to a larger range of raw materials. Technical and economical hurdles have so far barred enzymatic catalysis from adaptation to mass production in the biodiesel field but this may change: In a joint research effort by Novozymes A/S, DTU Chemical Engineering, DTU Management Engineering, Aarhus University and Emmelev A/S researchers from a range of different fields collaborate to finally bring enzymatic biodiesel to large scale production.

The sustainable biodiesel project initially focuses on traditional feedstocks such as rapeseed and soybean oil. In the long term, the goal is to be able to convert low quality and waste oils, feedstocks which are particularly difficult to refine into biodiesel with traditional methods and therefore hold great potential for commercialization. Launched in autumn 2008 and partly financed by the Danish National Advanced Technology Foundation, the biodiesel project is an umbrella for a wide span of different technical disciplines. Novozymes A/S provides the enzymes, University of Aarhus supplies research on enzyme kinetics, the Danish biodiesel company Emmelev A/S provide know-how on biodiesel and the conventional production process and DTU Chemical Engineering covers process technology, reactor technology and design as well as cost evaluation and supporting DTU Management Engineering by feeding them data used for Life Cycle Assesment (LCA) of the new technology.

Obvious advantages with enzymes
With the traditional method, homogeneous catalysis, oil is mixed with methanol and potassium hydroxide. When the reaction is complete, excess alcohol is evaporated and the potassium salt is washed away with water.

"It is a fairly simple process but it has some fundamental limitations," explains PostDoc Mathias Nordblad who is responsible for development and evaluation of the basic process designs for the enzyme-based reactor within the biodiesel project at DTU Chemical Engineering.

In a process that uses the traditional method, low quality and waste oils result in soap formation in the reactors. This problem is eliminated with enzymatic processes, leading the way for catalysis with a range of oils we couldn't use before."

"We also believe that we can reduce the release of toxins and use less energy with the enzymatic approach. Our process will use ethanol instead of the much more toxic methanol. Another advantage is that by using enzymes we can produce glycerol which is more pure than the one produced by traditional chemical catalysis," says Mathias Nordblad.

Collaborative project
Mathias Nordblad and his co-workers are conducting laboratory and pilot-scale work covering different aspects of the enzymatic process from a chemical engineering point of view.

"My focus is to develop computer based models for calculating the cost and eventually also simulating the processes, based on experimental data generated at KT and Aarhus University," says Mathias Nordblad whose role in the project goes beyond the chemical engineering part:

"I actually work almost as much with organization as I do with engineering, and I have come to enjoy the management aspect," says Mathias. "With so many people covering different bits and pieces of the research, a lot of meetings are required and the focus on close co-operation and communication between groups is a key to success."

PostDoc Mathias Nordblad at work in the laboratory.

Total environmental evaluation
Mathias Nordblad is assisting DTU Management Engineering on assessments of the broader environmental implications of the biodiesel project:

"We feed information about our process designs to DTU Management Engineering which they then use to assess the environmental impact of each design, using tools for life cycle assessment (LCA)," says Mathias.

LCA is based on an inventory of the environmental emissions from a full production chain from raw material to waste disposal. With the constantly growing focus on sustainability and CO_2 reduction, LCA concepts are becoming key ideas in corporate planning and marketing strategies.

Mathias Nordblad elaborates:

"With LCA you evaluate all the environmental impacts of a production chain or process. Carbon dioxide equivalence is presently the most frequently mentioned measure of environmental impact, addressing the global warming contributions, but the complete LCA also gives an idea of the human and ecotoxicity potential, degree of acidification of the earth, release of nutrients into water streams etc. caused by the process."

From cooking oils to algae
So far the biodiesel project has been based on available commercial enzymes and ordinary rape seed oil is used for testing, but enzymatic catalysis in the biodiesel field has barely rounded its initial phases and there is a vast and diverse potential for future development.

"The enzymes we use were developed for the pharmaceutical industry, but in the future we are likely to see enzymes modified and produced specifically for biodiesel production," says Mathias Nordblad. "In the first phase of the project we worked with vegetable oils such as rapeseed oil and soybean oil. However, we hope to be able to apply the current methods to used cooking oils and low quality oils such as oil from algae. The latter is a possible and interesting candidate for enzymatic processing – but a lot of research lies ahead before we may see mass production in this field."

Working with immobilized enzymes
Enzymes normally appear in aqueous solutions, but these are difficult to use in a biodiesel process since water and oil do not mix well. Novozymes' solution is to put the enzymes on a carrier material, a process known as immobilization. This produces a catalyst in particle form, which can be readily mixed with the oil. A further advantage of this method is that the catalyst can easily be removed and reused after each reaction, which is essential to the economy of the process.

FIGHTING GAS HYDRATES WITH ANTIFREEZE PROTEINS

Formation of gas hydrates in undersea oil pipes is a major challenge to the oil industry. Gas hydrates are ice-like crystals that form under high pressure and moderate temperature, potentially halting production flow and causing a security hazard by clogging the pipes running between oil wells and platforms. To ensure a continuous flow of reservoir-fluids, oil companies add antifreeze agents like methanol or kinetic inhibitors to the fluids. With their eco-toxicity and low biodegradability, these agents are not the ultimate answer, but research done by PhD student Lars Jensen at DTU Chemical Engineering has shown that certain arctic animals provide an eco-friendly alternative.

Fish, insects and plants living in cold environments are at risk of fatal ice formation in their cells. Some species have developed antifreeze proteins as a natural defense, and Lars Jensen was doing initial research based on proteins from the arctic eelpout when he became aware of research done by Professor Anders Løbner-Olesen and Professor Hans Ramløv at Roskilde University. Lars Jensen contacted Ramløv, an expert in extreme biology, freezing and polar exploration whose research group had isolated antifreeze proteins that allow the larvae of the longhorn beetle (Rhagium mordax) to be exposed to temperatures as cold as -15 degrees Celsius without their bodily fluids freezing.

"A moderately active protein is interesting but this one is really interesting – it is super active," says Lars Jensen. A research collaboration was soon established and in 2009 Lars Jensen's research produced results that showed that the beetle protein is indeed as efficient as the commercially available antifreeze agents while having one major advantage: Biodegradability.

Better biodegradability

Environmental concern is the driver for investigating these proteins. The two categories of anti-freeze agents available to oil companies today each pose a problem. Methanol, a chemical used for anti-freeze in cars, is soluble in water, and therefore not accumulated in fatty tissues in fish due to minimal exposure, but the enormous amounts used in oil production is a concern. As a reference, a case study from a large wet gas production field reported typical usage in the range of 200 cubic meters of methanol per day to prevent hydrate formation. Other hazards are that methanol is poisonous and corrodes pipes. In some cases it can be recovered by distillation, but this requires a large amount of energy. The other alternative, kinetic inhibitors (usually water soluble polymers) are efficient in much smaller quantities, however, with their low biodegradability – 6 % in 28 days – they cannot be used in the Danish and Norwegian sector of the North Sea where authorities demand a biodegradability of at least 20 % in 28 days.

Lars Jensen started work on his project in March 2007, initially testing the properties of proteins from the arctic eelpout. Tests on the more promising proteins from the longhorn beetle took place at the Colorado School of Mines in the USA where Lars was a guest student from January to May 2009.

A different experimental approach was used for the classification of each protein's antifreeze potential.

"In the eelpout experiments, I placed an aqueous solution containing the active protein in a cell – simulating the conditions in an oil pipe. By using an electronic pressure regulator and measuring the amount of gas entering the cell over

PhD Student Lars Jensen with a handful of gas hydrates, also known as 'burning ice'.

time, I got a clear picture of the anti-freeze effect of the protein," Lars Jensen explains.

"The beetle protein was tested using High Pressure Differential Scanning Calorimetry (DSC). I compared the results from the beetle protein with a commercial inhibitor used in oil and gas pipes, and it turned out to have the same efficiency. No one has found a protein which works as well while also having a high degree of biodegradability."

Ahead lies the engineering challenge of producing these proteins in the enormous amounts required by the oil industry – and at competitive prices.

Mass production by fermentation

"The isolation of and synthetic production of the active groups in the molecule have been considered, but this remains a hypothetical method, partly because it is still a mystery exactly how the molecules obtain their anti-freeze properties," says Lars Jensen.

"Production of the molecules by fermentation seems a much more viable solution. This implies getting a bacteria culture to produce the protein by gene modulation. A large amount of research and experimental work is needed before we can bring this process up to a full-scale production level."

Though the longhorn beetle is so far the unchallenged champion in terms of anti-freeze properties, Lars Jensen is still working with the eelpout protein.

"I have the fish protein available in greater amounts than the insect protein and we are planning further experiments to get a more exact idea of how efficient the two proteins are when compared to each other, and to probe whether the beetle protein keeps the advantage even in large scale experiments," says Lars Jensen.

The anti-freeze proteins have a number of exciting potential uses outside the oil industry. For example, they could be added to dough, allowing it to go straight from the freezer to the oven without the yeast cultures being destroyed. Or for production of ice cream that would still keep its creamy consistency, even with a very high water content. Another idea is for anti-freeze paint used on airplane wings to limit the need for deicing. Even an anti-freeze agent for humans based on these proteins has been suggested. At DTU Chemical Engineering, however, the research focus remains 'frozen' on eliminating gas hydrate formation in oil and gas pipelines.

"And with the enormous amounts of methanol kinetic inhibitors used every day as anti freeze agents in oil production, the market potential of the biodegradable alternative is considerable," says Lars Jensen.

Assistant Professor Anne Ladegaard Skov received the 2009 Elastyren Prize for her outstanding polymer research

INTELLIGENT POLYMER
DESIGN FOR THE 21ST CENTURY

Polymer-based products left their distinctive marks in all areas of life in during 20th century – from vinyl records and nylon stockings to plastic bottles, acrylic paint and rubber tires. While each of these products were innovative milestones in their time, they appear antique when compared to the prospects of 21st century polymer technology: fabric that intelligently adapts to the weather, paint that changes structure when exposed to light, polymer 'muscles' that draw energy from ocean waves, and much more. "The possibilities are endless and one of the biggest challenges right now is to come up with the right ideas," says Anne Ladegaard Skov, Assistant Professor at DTU Chemical Engineering and supervisor for a range of polymer-related projects within the Danish Polymer Center (DPC).

When Anne Ladegaard Skov received the Elastyren prize in 2009 the prize committee of the Danish Academy of Technical Sciences based it on her 'outstanding contribution to research in the synthetic elastomer field.' In her current work as a researcher and project supervisor at DPC, Ladegaard Skov takes these tracks even further by combining deep theoretical grounding and high mathematical skills with the creative playfulness which is often key to success in science.

"Getting the right ideas is the hardest part but it is also where the fun and enthusiasm begin – when you get that feeling of 'Yes! Why didn't we think of that before?'" says Anne Ladegaard Skov who admits that sheer luck also plays a part.

"An idea is followed by an intuitive guess about how it may work. This is where mathematics is essential – when we deal with these materials we have maybe 10^8 possible combinations. So we start out by making a model based on simplifications – if we're lucky we hit right on the nail, and if it seems hopeless we start all over again by adjusting the simplifications."

Plastic with memory

"Nature is the great inspirator. You look at a plant and see how it grows towards the light, and right there you may have an idea for a project," says Anne Ladegaard Skov and mentions a project inspired by sea cucumbers:

"I read an article about how these animals are able to change skin structure from soft to hard by emitting a nerve impulse. I thought it would be interesting to copy this principle and we pursued the idea in a project where we aim at changing from a gel-like to a rubber band-like structure by applying light. You can imagine how effective this could be in a protective suit, but the technology could be useful in lots of other areas," she says.

In a related project, researchers from DPC collaborated with industrial designers from the Copenhagen Academy of Fine Arts School of Architecture who were looking for ways to make interior walls 'come alive.'

"They wanted to apply polymer paint or create a wall structure that changes structure and even color depending on the light," says Ladegaard Skov. "In this case we can transfer results from ongoing research in the medicine field to interior design: When a polymer strip is exposed to light it 'remembers' the shape it had before and coils up, and researchers are working to apply this when two veins are sewn together after an operation."

"There are many more potential applications for this technology and it has been very inspiring to exchange ideas with the industrial designers," says Ladegaard Skov. The initial contact has resulted in further collaboration where

Assistant Professor Anne Ladegaard Skov specializes in cross-linked polymers, ranging from jelly-like, sticky substances to hard rubber materials. For a list of projects supervised by Anne Ladegaard Skov in 2009 go to *http://www.kt.dtu.dk/ALS*

DPC will deliver a greater quantity of material to the designers.

Wave energy from polymer muscles

Having finished her PhD project at DTU Chemical Engineering in 2004, Anne spent a year at Coloplast A/S where she worked with skin adhesives. A year as a PostDoc in Cambridge University followed before she returned to DTU Chemical Engineering, first as a PostDoc and since 2008 as Assistant Professor. Her PhD focused on cross-linked polymers used for muscles in robots. This technology has today reached a point where an intelligent mechanism can lift fragile objects. In industry, the technology is mostly used for valves, however, some very exciting new uses have come into play.

"In principle an artificial muscle is a polymer film with electrodes applied," Anne explains. "The muscle contracts when a strong electrical current is applied. In the research field, the main focus right now is on reversing the sequence. For example, when a polymer muscle is deformed by an ocean wave it generates electricity."

Approximately twenty students are currently engaged in a joint DTU project targeting this kind of polymer-based, sustainable energy production. Other current polymer projects are looking at artificial skin, mimicking human body expression and electronic paper with the potential of displaying animated ads. There is also research in bio-medicine with artificial hearts and aorta valves, as well as touch-screen technology.

"Some of these things may sound like science fiction but we are not far from making them work," says Anne. "Converting desktop experiments to full production scale remains a major challenge, but I would say we are well on our way."

When asked about what consumers can expect in the near future, Anne places her bet on self-regulating fabrics.

"Shirts that change color when you add voltage from a small battery in your pocket, jackets which react to weather conditions and change isolation properties accordingly. If it rains it becomes waterproof. Those items will be available to consumers in the not-so-far future. And I will definitely go buy that jacket myself!" says Anne Ladegaard Skov.

GÜRKAN SIN
NEW PROFILE IN SYSTEMS ENGINEERING

When Professor Sten Bay Jørgensen retired in the summer of 2009 Assistant Professor Gürkan Sin was employed to carry the banner and further develop DTU Chemical Engineering's activities on Process Dynamics and Control in research and education areas. Gürkan Sin is based in the CAPEC center where his main research field is process systems engineering which focuses on management of complexity in chemical/biochemical engineering. Specifically, his research looks at integrated process design and control, process design under uncertainty, process modeling & simulation for technology evaluation, among others.

"The excellent collaboration environment at DTU Chemical Engineering is immensely important for young researchers starting out a career in academic world," says Gürkan Sin who joined the faculty at DTU Chemical Engineering in November 2008.

"Collaboration helps us unlock the potential within and create synergy across different research disciplines and centers. This strategy makes research a fun environment with tangible results at hand such as high quality research with visibility and recognition on international levels in our respective fields," says Gürkan Sin.

PETER GLARBORG
NEW PROFESSOR AT DTU CHEMICAL ENGINEERING

In January 2009, Peter Glarborg took seat as Professor in The DTU Clean Power Chair, a new professorship sponsored by DONG and Vattenfall focusing on clean and efficient production of heat and electricity.

Peter Glarborg is internationally recognized for his research in high temperature chemistry and has been working closely with Danish and international universities and companies on this issue for years.

The professorship is a result of collaboration between DTU Chemical Engineering and two major power companies dedicated to development of clean and efficent thermic processes for production of heat and electricity: DONG Energy and Vattenfall. Glarborg's work involves theoretical and experimental studies combined with semi-industrial and full-scale tests. The primary aim of this work is to enhance utilization of alternative fuels in the production of power to facilitate CO_2 reduction targets in the power industry.

Professor Glarborg has been a member of the faculty at DTU Chemical Engineering since 1996 and is also a competent and popular teacher.

The leader team at DTU Chemical Engineering.
From left: Professor Georgios Kontogeorgis, Senior Adviser Jytte Boll Illerup, Head of Administration May Brandt, Professor Anker D. Jensen, Professor Anne Meyer, Professor and Head of Department Kim Dam-Johansen, Secretary Lisbeth Degn and Technical Manager Lars G. Kiørboe.

ORGANIZATION

DPC

CHEC

CAPEC

BIOENG

PROCESS

CERE

Administration & Technical Support

Professor and Head of DPC
Ole Hassager gets to work by train.

At the Danish Polymer Center we are devoted to the application of molecular design, synthesis and processing of polymers to create materials and products with unlimited ranges of properties and applications. We strive towards this goal in a balanced environment of education, research and industrial cooperation.

Ole Hassager, Head of DPC

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DPC

THE DANISH POLYMER CENTER

The Danish Polymer Center is devoted to fundamental research in polymers, soft materials, and complex fluids. The aim is to utilize polymer research in education, technological innovation and industrial collaboration. Organized within the Department of Chemical and Biochemical Engineering, the center is located in close proximity to polymer activities at the Department of Mechanical Engineering and the Department of Micro and Nanotechnology. The research is interdisciplinary ranging from chemical synthesis, chemical and physical characterization of polymers and soft materials to fluid mechanics of complex fluids.

Equipped with state of the art instrumentation for polymer characterization, the laboratories at the DPC provide a common ground for polymer chemists, polymer physicists and chemical engineers. Current techniques include the synthesis of polymers with controlled molar mass, branching structure and functional groups, application of scattering methods for study of complex polymer systems, rheological characterization and the design of multi-phase systems.

MSc in Polymer Engineering
Students in the DTU Master's Program in Advanced and Applied Chemistry may specialize in Polymer Engineering. This will allow master students to be trained in our laboratories and to engage in research at DPC.

Research Consortium in Polymers at DTU
The basic purpose of this consortium, established in 2006, is to ensure both stability and continuity of contact and communication between the Polymer Center at DTU and the parts of Danish industry that commercially use polymers. The consortium will run a number of smaller research projects and will serve as a greenhouse for conceiving ideas and innovating plans for future research and educational initiatives.

Graduate School Program in Polymer Science
Initiated in 2003, the Graduate School of Polymer Science is a research education network between the Department of Chemical and Biochemical Engineering at DTU, the Department of Chemistry at Aarhus University, Risø National Laboratory, and other associated industrial companies.

Financial support
Financial support to the DPC is provided by the Danish National Research Council, the European Union, the members of the Research Consortium in Polymers, and the members of the Graduate School in Polymer Science.

Members of the Graduate School Program of Polymer Science are as follows

- Coloplast A/S
- Elektro-Isola A/S
- Grundfos A/S
- Novo Nordisk A/S
- Radiometer Medical ApS
- Teijin Twaron

Members of the Research Consortium in Polymers are as follows

- Alfa Laval Nakskov A/S
- Aquaporin A/S
- Coloplast A/S
- Dana Lim A/S
- Dyrup A/S
- Elektro-Isola A/S
- Grundfos Management A/S
- Hempel A/S
- Novo Nordisk A/S
- Radiometer Medical ApS
- Rockwool International A/S

Søren Kiil, Associate Professor and CHEC group member, arriving at DTU Chemical Engineering on his bike.

A vital part of our research is conducted in very close collaboration with industrial enterprises and international research organizations. The industrial relations cover close joint projects with a mutual exchange of staff and cooperation on experimental research ranging from microscale over pilot plants to full-scale industrial production plants. This approach ensures high relevance of our research and efficient exchange of technology, know-how and know-why.

Kim Dam-Johansen, Head of CHEC

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CHEC

COMBUSTION AND HARMFUL EMISSION CONTROL – THE CHEC RESEARCH CENTER

CHEC is a research center mainly in the field of Chemical Reaction Engineering and Combustion, emphasizing high-temperature processes, formation and control of harmful emissions, particle technology, and product design.

The research approach involves a combination of modelling and experimental work. Experiments are conducted over scales ranging from small laboratory reactors to full-scale industrial units.

The models typically combine a generic description of the chemical reaction system with a process-specific flow description. They are used to analyze and extrapolate the experimental data as well as providing input for design and optimization.

The work is conducted in collaboration with enterprises and a range of national and international research organizations.

The field of Product Design covers quantitative formulation engineering using traditional chemical engineering methods in the design of products such as granular enzymatic products, and controlled release systems, in many different fields like advanced coatings.

Waste fuel utilization, methods to reduce CO_2 emissions, and production of liquid fuel from biomass have received increasing attention in the CHEC Research Center over the last years. The work conducted there is directed towards pyrolysis of biomass, oxyfuel combustion, gasification, methanol and bio-ethanol production, as well as fuel cell technology.

The CHEC Research Center collaborates mostly with the following industrial partners

- Babcock & Wilcox Vølund ApS
- B&W Energy A/S
- Danish Gas Technology Center A/S
- Dong Energy A/S
- Energinet.dk
- F.L. Smidth A/S
- H. Lundbeck A/S
- Haldor Topsøe A/S
- Hempel A/S
- Hwam A/S
- MAN Diesel A/S
- Novozymes A/S
- Topsøe Fuel Cell
- Vattenfall A/S

The industrial support is supplemented with funding from these organizations

- DTU
- Nordic Energy Research
- The Danish Council for Technology and Innovation
- The Danish Research Training Council
- The European Union
- The Public Service Obligation Programme
- Danish National Advanced Technology Foundation

Professor and Head of CAPEC Rafiqul Gani gets to work by car. In the background Associate Professor and member of the CAPEC group Gürkan Sin.

Briefly, the research objective of CAPEC is to develop computer-aided systems for process simulation, process/product synthesis, design, analysis, and control/ operation that is principally suitable for the chemical, petrochemical/oil, pharmaceutical, and bio-chemical industries.
Our computer-aided systems are developed on the basis of fundamental modelling studies that incorporate correlation and estimation of thermophysical and phase equilibrium properties as well as model the underlying phenomena and behavior of the processes and operations. We manage the complexity related to the solution of a wide range of problems in product and process engineering.

Rafiqul Gani, Head of CAPEC

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CAPEC

COMPUTER AIDED PROCESS-PRODUCT ENGINEERING CENTER (CAPEC)

The CAPEC research center applies a systems approach to develop comprehensive solutions to various industrial problems based on a thorough analysis of scientific issues and actual product/process requirements. The developed systematic methods are generic in character and therefore applicable to a wide range of problems in process and product engineering.

Additionally, the systems approach enables CAPEC to convert the developed methods into software tools for problem analysis and solution. Thus, the research at CAPEC has resulted in the development of a range of generic model-based techniques and their conversion into state of the art computer-aided tools for modelling, synthesis, design, operation, control, and analysis – each method dedicated to systematic and efficient process-product engineering.

The research at CAPEC is organized into six research programs within a logical framework ranging from fundamental to applied research. Based on the fundamental modelling at the generic levels, computer-aided methods and tools are developed at the next (intermediate) levels for synthesis, design, analysis, and control of process/product/operation. Again, these models, methods and tools are integrated in the final research levels, where end-user solutions are generated for the development of cleaner, safer, and sustainable technologies.

Headed by Professor Rafiqul Gani, the CAPEC research center constitutes a very distinct group of professors and associate professors, researchers, post-docs, and PhD students that contribute to the joint activities of DTU Chemical Engineering. Members of two research groups (Systems Engineering and Process within DTU Chemical Engineering) now contribute to the products and services offered by CAPEC. Additionally, CAPEC usually hosts around ten MSc and BSc students plus a varying number of visiting students and international visitors.

In 2009 CAPEC was supported by the following industrial consortium

- Akzo-Nobel (NL)
- Alfa Laval A/S (DK)
- AstraZeneca (S)
- BASF (D)
- Bayer AG (D)
- Borealis Polymers Oy (SF)
- ChemProcessTechnologies (USA)
- Cognis (D)
- ConocoPhilips Company (USA)
- Danisco A/S (DK)
- DSM (CH)
- DuPont (USA)
- Firmenich (CH)
- FLS-Automation A/S (DK)
- FMC Corporation (USA)
- GlaxoSmithKline (USA)
- Invensys SimSci-Esscor (USA)
- Kongsberg Maritime (NO)
- Mitsubishi Chemical Corp. (JPN)
- Neste Oil (SF)
- Novozymes A/S (DK)
- Optience (USA)
- Petrobras (Brasil)
- Processium (F)
- ProSim (F)
- SCG Chemicals Co. Ltd. (TH)
- Syngenta (UK)
- Unilever (USA)
- VTT Technical Research Centre of Finland (SF)

Professor and Head of BioEng Anne Meyer takes her bicycle to work.

The goal of the Center for BioProcess Engineering is to create a strong link between generic chemical engineering research and the industrial application of biotechnology.

The vision of the Center is to provide new knowledge led principles for designing new biobased production processes and procucts. At the same time the objective is to hatch top-qualified M.Sc. and Ph.D. cadidates through research based teaching and supervision. We hope that this twofold strategy will contribute to fullfilling the potential of biotechnology to substantially impact indutrial production and hereby contribute to development of new, ingenious, and sustainable processes and products.

Anne S. Meyer, Head of BioProcess Engineering

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BIOENG

CENTER FOR BIOPROCESS ENGINEERING

Center for BioProcess Engineering is a multidisciplinary research center established at the Department of Chemical and Biochemical Engineering, DTU. The purpose of the Center is to strengthen the integration of chemical engineering research with biotechnology via a focused research effort linking generic chemical engineering science with industrial applications of biotechnology. BioProcess Engineering is thus an interdisciplinary research field that employs chemical engineering principles in the industrial application of biologically based reactions and processes. The Center operates at the interface between biotechnology and chemical product and process engineering. Particular focus areas include enzyme catalysed conversions and application of biochemical reaction engineering principles for analysing, modelling, developing, improving, controlling, and scaling-up of industrial biocatalyctic processes. The Center for BioProcess Engineering hosts three larger research structures:

The Novozymes BioProcess Academy was established in 2002 with substantial support from Novozymes A/S. The overall mission of the Academy is to strenghten the integration of chemical engineering, processing technology, and biotechnology. The particular objective is to ensure the education of candidates being highly competent within product and process engineering acquired both in the laboratory and in the pilot plant scale to the booming Danish biotech industry. Currently, 8 full-time, post-graduate students studying for the qualification of Ph.D. as well as 4 M.Sc. students are enrolled with the academy.

The Research Consortium "Innovative BioProcess Technology" was established in 2005 as a major research collaboration between the Department of Chemical and Biochemical Engineering and Department of Systems Biology, DTU and the three major Danish biobased companies: Novozymes A/S, Danisco A/S, and Chr. Hansen A/S. In this Research Consortium generic research tools are being developed to adress three main goals with respect to bioprocess development: I. Procuring the scientific basis for the process, II. Choosing the right process scheme, and III. Quantifying the pace of the biocatalyctic events. This research effort will run for at least 5 years and educate at least 5 Ph.D., 1 post doc, and 10 M.Sc. candidates.

Center for Biological Production of Dietary Fibres and Prebiotics was established in 2007 via a grant from The Danish Council for Strategic Research. The research focus is on developing bioconversion processes for upgrading of plant polysaccharides present in industrial byproduct streams. The objective is to design high value carbohydrate products having potential health benefits.

The Center for Bioprocess Engineering particpates in the EU ITN Programme LEANGREEN FOOD and in 2010 a new effort on enzymatic design of human milk oligosaccharides will be initiated with a grant from the Danish Council for Strategic Research.

Center for BioProcess Engineering cooperates with the following industrial partners

- Arla Foods amba
- Chr. Hansen A/S
- Danisco A/S
- Foss Analytical A/S
- Grundfos A/S
- Lyckeby Stärkelsen Amba (Sverige)
- Novo Nordisk A/S
- Novozymes A/S
- Vallø Saft A/S

Professor and Head of PROCESS John Woodley takes his right side steering car to work.

"The vision of the Center for Process Engineering and Technology is to provide the necessary support to enable the next generation of processes to be implemented in industry. In this way the new developments in biotechnology, catalysis and separation science alongside process engineering can be translated into industrial practice. New processes with reduced waste, high efficiency and based on all the principles of sustainability can be developed which will help develop the European industrial sector in the production of chemicals, bio-based materials and chemicals, as well as pharmaceuticals"

John M. Woodley, Head of PROCESS

Head of PROCESS, Professor John M. Woodley
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PROCESS

CENTER FOR PROCESS ENGINEERING AND TECHNOLOGY

The Center for Process Engineering and Technology is focused on the development of new and innovative processes for industry. PROCESS works at the interface of a number of disciplines, including biotechnology, process engineering and chemistry. The objective is to provide the necessary infrastructure and support to evaluate and implement the next generation of processes in the chemical, bio-based and pharmaceutical sectors in particular. The research is carried out in close collaboration with industry and work is carried out at three levels, namely: laboratory scale experimental process evaluation; model based evaluation of process technology and pilot-scale process validation. Two demonstration units operate in the pilot facilities (one for immobilized enzyme reactions and the other for organic synthesis). Using the results from work at the three levels enables new technology and processes to be evaluated both experimentally and also from the perspective of implementation.

The Center is involved in the following large collaborative projects in Denmark and in Europe:

Bio-petrochemicals is a project established in 2007 with the Danish National Advanced Technology Foundation, DTU Chemistry and Novozymes A/S. It is focused on providing a new route to monomer building blocks from sugars such as glucose to enable an alternative route to chemicals from fossil fuels.

Sustainable Biodiesel is a project established in 2008 with the Danish National Advanced Technology Foundation, DTU Management, Novozymes A/S, Aarhus University and Emmelev A/S. It is focused on developing a new enzymatic route to biodiesel.

Towards Robust Fermentation Processes by Targeting Population Heterogeneity at Microscale is a project established in 2009 with the Danish Council for Strategic Research, DTU Systems Biology, DTU Fotonik, Department of Biology (University of Copenhagen), Department of Biotechnology, Chemistry and Environmental Engineering (Aalborg University), Crystal Fibre A/S, Fermenco ApS and Foss A/S. It is focused on characterization and control of the heterogeneity of a population of microorganisms in a fermentation.

In the pharmaceutical sector several projects sustain the development of the next generation of enzyme based methods for the synthesis of optically pure molecules. The Center is also involved in a 5-year project with Lundbeck aiming at moving from batch towards continuous production, and is a partner in the F3 European consortium established in 2009. The main focus of F3's activities is the development of early stage pharmaceutical leads in collaboration with AstraZeneca Ltd.

The PROCESS Research Center collaborates primarily with the following industrial partners

- AstraZeneca Ltd (UK)
- BioSilta Oy (SF)
- Bioingenium SL (ES)
- Britest Ltd (UK)
- CLEA Technologies BV(NL)
- c-Lecta GmbH (D)
- Crystal Fibre A/S (DK)
- Emmelev A/S (DK)
- Evonik Industries AG (D)
- Fermenco ApS (DK)
- Foss A/S (DK)
- Haldor Topsøe A/S (DK)
- Ingenza Ltd (UK)
- Novozymes A/S (DK)
- Royal DSM NV (NL)

Georgios Kontogeorgis, professor and leader of the disciplinary group of Engineering Thermodynamics, walks to work.

For 30 years the IVC-SEP has been a leading research group in the area of applied thermodynamics. In close collaboration with industry, relevant authorities and international research organizations, the scientific results from IVC-SEP are implemented in industrial products and processes. September 1, 2009 DTU decided to create a new Center for Energy Resources Engineering (CERE) on the basis of IVC-SEP and expanding with disciplines at other DTU departments. The creation of CERE will be a great opportunity for further development and expansion of the current activities.

Erling H. Stenby, Director of CERE

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CERE

CENTER FOR ENERGY RESOURCES ENGINEERING (FORMERLY IVC-SEP)

For 30 years the IVC-SEP has been a dynamic research group with an excellent track record and international reputation in the areas of applied thermodynamics, transport processes, and mathematical modeling. With six tenured faculty members the center covers several topics with both experimental and theoretical research.

The main activities of the center are in the areas of complex solutions (including polymers, electrolytes, peptides, and associating chemicals), non-equilibrium thermodynamics (diffusion and thermo diffusion), petroleum chemistry at the molecular level, and finally simulation of petroleum recovery processes (from the pore to reservoir scale). Furthermore, the center is active in several research projects of strategic importance such as CO_2 capture and storage and Enhanced Oil Recovery (EOR).

The Industrial Consortium of the center has existed for 30 years and continues to be a valuable asset for research and education at DTU. Many companies financially support research projects as well as hold the membership. For instance the Chemicals in Gas Processing project (CHIGP) which is extensively sponsored by industrial partners (Total, Statoilhydro, BP, Gassco, and Maersk Oil).

Furthermore, the center participates in a new major effort on the use of CO_2 for EOR in the Danish North Sea. This is a collaboration with DONG Energy, supported by The Danish National Advanced Technology Foundation. A rapidly growing activity is the research concerning post-combustion CO_2 capture. Within this area the center has recently initiated several projects in collaboration with DONG Energy and Vattenfall.

The focus is the high energy penalty associated with the established technologies for CO_2 capture. New solvents such as chilled ammonia, amino acid solutions, and ionic liquids are among the potential solutions under investigation.

September 1, 2009 DTU decided to create a new Center for Energy Resources Engineering (CERE) on the basis of IVC-SEP and expanding with disciplines at other DTU departments. The research topics formerly covered by IVC-SEP will continue in CERE with an increased staff.

Over the years many students have benefitted from the close contact with Danish and international industry through a project in IVC-SEP and we will continue to create these links in the new CERE.

In 2009 the Consortium of IVC-SEP consisted of the following members:

- Akzo Nobel (NL)
- BP (UK)
- Chevron (USA)
- Conocophillips
- DONG Energy A/S (DK)
- Eni (I)
- Exxon Mobil (USA)
- Gassco (N)
- Gaz de France (F)
- Haldor Topsøe (DK)
- INEOS (UK)
- Institut Français du Pétrole (F)
- Kommune Kemi (DK)
- Linde (D)
- Mærsk Olie og Gas A/S (DK)
- OMV (AUT)
- Petrobras (BRA)
- RWE Dea (D)
- Sasol (South Africa)
- Saudi Aramco (Saudi Arabia)
- Schlumberger (USA)
- Shell Global Solutions (NL)
- Sinopec (China)
- SQM (Chile)
- Statoilhydro (N)
- Total (F)
- Vattenfall A/S (S)
- Welltec (DK)
- ØDS (DK)

Head of the Workshop Ivan Horst Pedersen takes his car to work.

Our support units provide important services for students, teachers and researchers and are responsible for the full array of technical and administrative functions at the department.

You will find some remarkable people working as support staff at the Department of Chemical and Biochemical Engineering. Our team enjoys its work and benefits from relationships marked by trust and team spirit, both within our department and with our colleagues throughout the Technical University of Denmark.

May Brandt, Head of Administration

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Phone: +45 4525 2807

ADMINISTRATION & TECHNICAL SUPPORT

SUPPORT STAFF

Innovative teaching, research and consulting require the support of professional services. Our high-quality services enable us to deliver excellent education and project work. Working in our support units means being a strong partner for our students, teachers and research teams, and accompanying them throughout all phases of their work.

ADMINISTRATION

Efficient support from our people in the administrative functions plays an important role within our department. We provide services in many different areas, including project administration, contracts, facility management, education, personnel and general administration.

CORPORATE COMMUNICATION

Our webeditor ensures that our website meets our high standards with respect to design and business communication, and writes up the latest company news in our corporate website and annual reports.

SERVICE AND PLANNING

The secretaries are the first point of contact for students, partners and colleagues alike. They handle a multitude of inquiries, information, and tasks and they play a major role in ensuring that a wide range of internal processes run smoothly.

INFORMATION TECHNOLOGY SERVICES

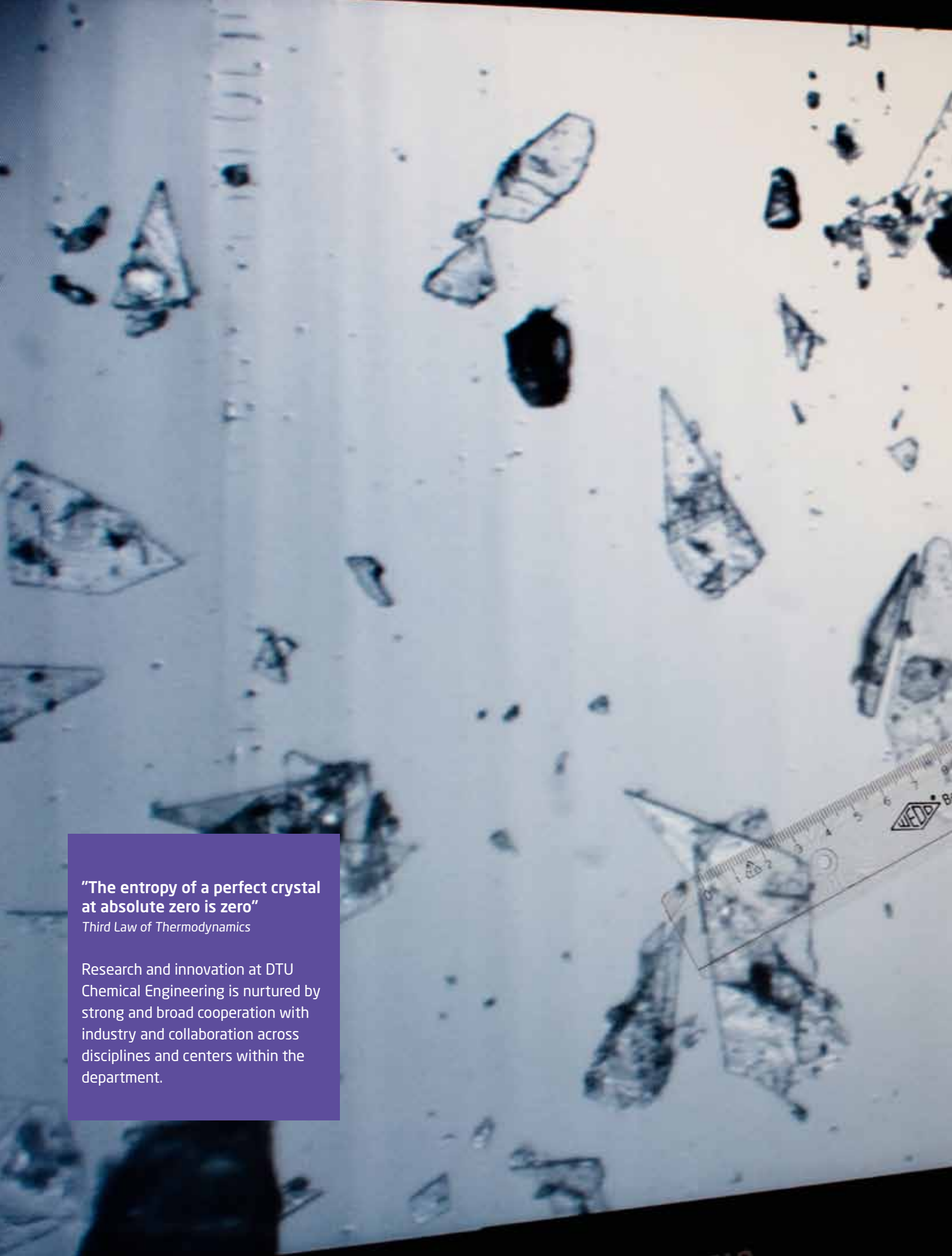
The focus of this unit is knowledge management (databases), IT consulting, IT solutions and support which include ordering, installing, and configuring hardware and software, as well as maintaining the IT back office.

WORKSHOP

Craftsmanship and innovation go hand in hand when the workshop at the Department provides our small and large scale laboratories with custom made, high quality equipment.

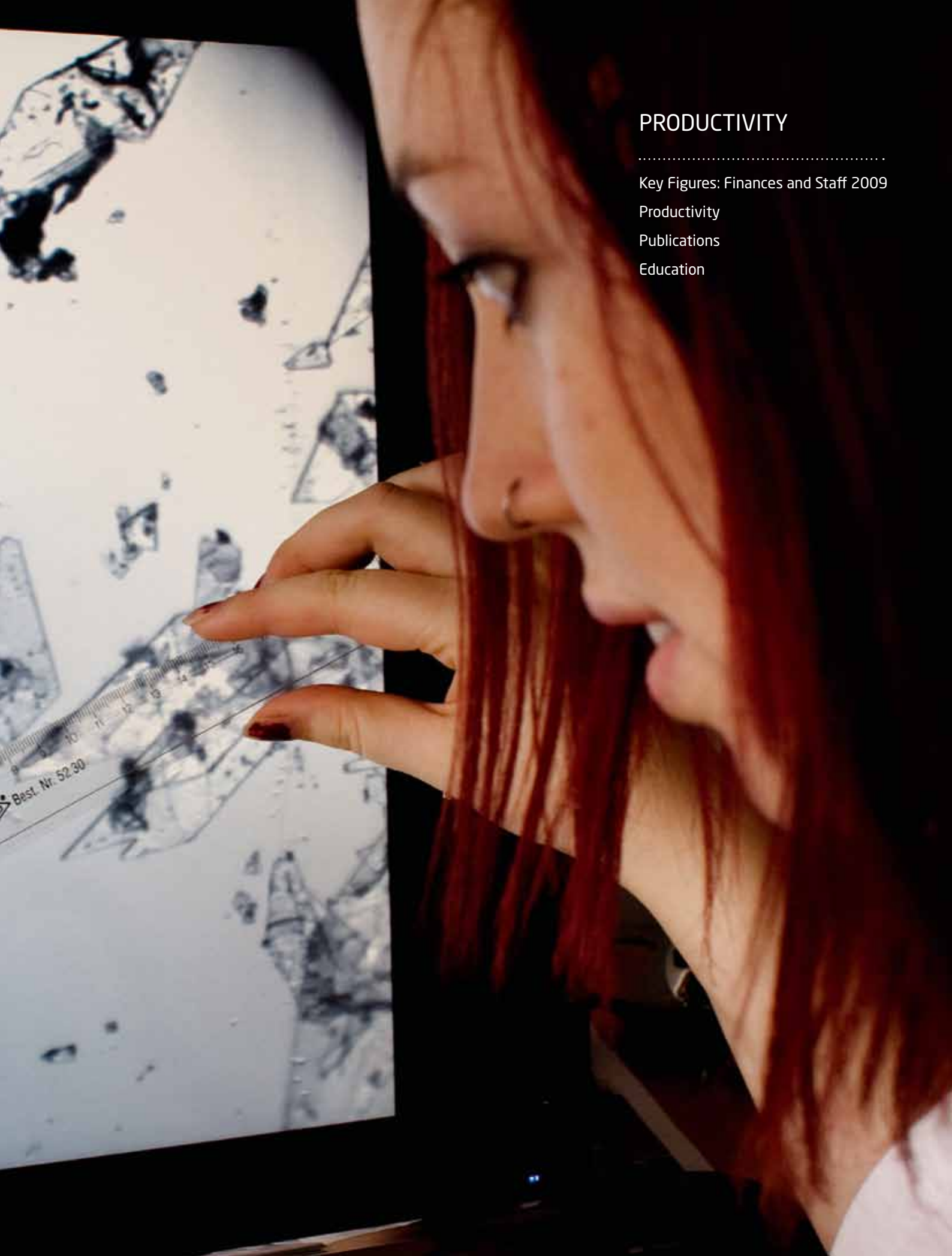
LABORATORIES

Our laboratory technicians ensure high safety standards and efficient caretaking of our laboratories, education and research facilities.



"The entropy of a perfect crystal at absolute zero is zero"
Third Law of Thermodynamics

Research and innovation at DTU Chemical Engineering is nurtured by strong and broad cooperation with industry and collaboration across disciplines and centers within the department.

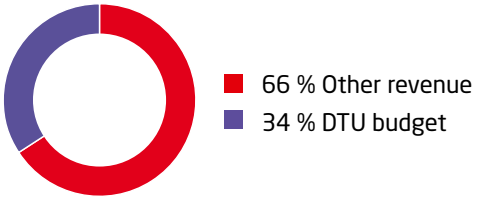


PRODUCTIVITY

KEY FIGURES: FINANCES AND STAFF 2009

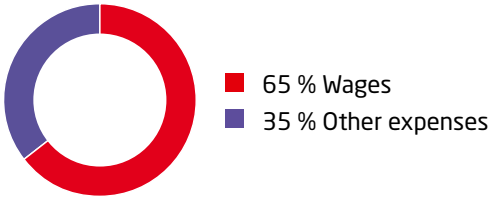
REVENUE 2009

(Total 153.175 mill. DKK)



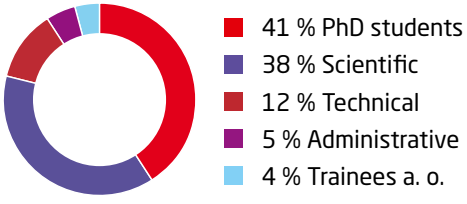
EXPENDITURES 2009

(Total 116.904 mill DKK)



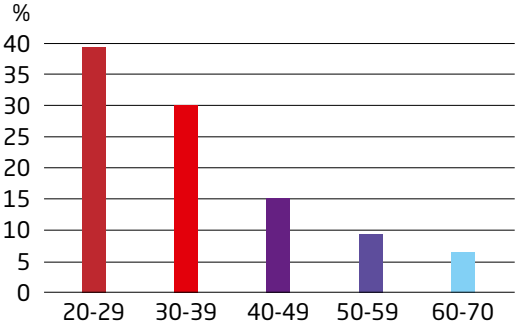
TYPE OF STAFF

(Total 215 persons)



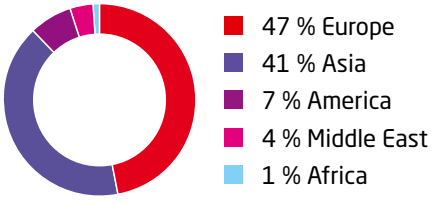
STAFF DISTRIBUTED BY AGE

(Total 215 persons)



FOREIGN SCIENTIFIC STAFF

(Total 94 persons)



PRODUCTIVITY

TEACHING & EDUCATION 2009

STUDENTS, EDUCATIONAL RESOURCES AND -IMPACT

Students in total (STÅ*)	**189**
Completed BSc projects	**29**
Completed MSc projects	**39**

* One STÅ is the equivalent of one student studying full time in a year

RESEARCH & INNOVATION 2009

Scientific publications with referee	**164**
Contributions to conference proceeding	**86**
PhD theses	**14**

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Jonsson, Gunnar Eigil. **Using membrane techniques with aspects on energy and environment**. Presented at: 12th Nordic Filtration Symposium. Gothenburg, Sweden, 26-27 August (Keynote Lecture), 2009

Jørgensen, Sten Bay. **Modelling for Process and Control Design**. Presented at: Nordic Process Control Workshop '09, NPCW09. Porsgrunn, Norway, 29-30 January, 2009

Jørgensen, Sten Bay. **Modelling Paradigms for Process Design, Identification and Control**. Presented at: MIC´09: Modelling, Identification and Control, IASTED conference. Innsbruck, Austria, 16-18 February, (Invited Keynote Lecture), 2009

Karunanithi, Arunprakash T.; Gani, Rafiqul; Achenie, Luke E.K. **Biodiesel Process Design through a Computer-aided Molecular Design Approach**. Presented at: Foundations of Computer-Aided Process Design (FOCAPD) 2009. Breckenridge, Colorado, June 7 – 12, 2009

Kiil, S. (Keynote lecture) **Design of controlled release systems for antifouling coatings**, November 2009 at the International conference New Perspectives in marine antifouling research, organized by the University of Gothenburg, Sweden.

Kratzer, Regina; Pival, S.; Woodley, John; Nidetzky, B. **Evaluation methodology and multi-level engineering approach to improve whole cell ketone reduction**. Presented at: AIChE Annual Meeting. Nashville, TN, USA, 8-13 November, 2009

Kontogeorgis, Georgios; Tsivintzelis, Ioannis; Breil, Martin Peter; Tybjerg, Peter Chr. V.; Stenby, Erling Halfdan; Michelsen, Michael Locht. **Recent Developments of the CPA equation of state for associating fluids**. Presented at: 24th ESAT European Symposium on Applied Thermodynamics, 2009 Book of Abstracts: 24th ESAT, 74

Kontogeorgis, Georgios. **Modelling the Solubility of Pharmaceuticals in Liquid and Supercritical Pure and Mixed Solvents**. Invited speaker at: DCIS2009 Danish Colloid and Interface Symposium. University of Aarhus, Denmark, 2009 DCIS 2009 Danish Colloid and Interface Symposium

Kontogeorgis, Georgios; Tihic, A.; Folas, Georgios; Tsivintzelis, Ioannis; Grenner, Andreas; von Solms, Nicolas; Constantinou, L.; Economou, Ioannis; Michelsen, Michael Locht. **Capabilities and Limitations of Association Theories**. Invited speaker at: Thermodynamics 2009. Imperial College London, UK, 2009 Book of abstracts: Thermodynamics 2009

Kontogeorgis, Georgios; von Solms, Nicolas; Tsivintzelis, Ioannis; Grenner, Andreas; Bøgh, David; Frost, Michael; Knage-Rasmussen, Anders; Economou, Ioannis; Michelsen, Michael Locht. **The Role of Monomer Fraction Data in Association Theories**. Presented at: Equifase 2009 - VIII Iberoamerican Conference on Phase Equilibria and Fluid Properties for Process Design, 2009 Book of abstracts: Equifase 2009, 32

Kontogeorgis, Georgios; Tihic, A.; Folas, Georgios; Tsivintzelis, Ioannis; Grenner, Andreas; von Solms, Nicolas; Constantinou, L.; Economou, Ioannis; Michelsen, Michael Locht. **Capabilities and Limitations of Association Theories**. Presented at: Thermodynamics 2009. Imperial College London, UK, 2009 Book of abstracts: Thermodynamics 2009

Lek-utaiwan, Pimporn; Suphanit, Bunyaphat; Mongkolsiri, Nakarin; Gani, Rafiqul. **Integrated design of solvent based extractive separation processes including experimental validation**. Presented at: 19th European Symposium on Computer Aided Process Engineering – ESCAPE19. Krakow, Poland, 14-17 June, 2009

Lerche, Benedicte Mai; Stenby, Erling Halfdan; Thomsen, Kaj. **CO_2 Capture from Flue Gas using Amino Acid Salt Solutions**. Presented at: Risø International Energy Conference, 2009 Energy solutions for CO_2 emission peak and subsequent decline.

Lundsgaard, Rasmus; Kontogeorgis, Georgios; Economou, Ioannis. **Modeling partition coefficients of additives in polymer/polymer and polymer/solvent systems by free energy calculations**. Presented at: 24th ESAT European Symposium on Applied Thermodynamics. Santiago de Compostela, Spain, 2009 Book of abstracts: 24th ESAT, 234

Lutze, Philip; Gani, Rafiqul; Woodley, John. **A Systematic Methodology to Synthesize and Design Processes, Incorporating Process Intensification**. Presented at: AIChE Annual Meeting 2009. Nashville, TN, US, 8-13 November, 2009

Maribo-Mogensen, Bjørn; Thomsen, Kaj; Breil, Martin. **Modelling Separation Processes of Mixed Solvent-Electrolyte Systems Using an Extended UNIQUAC User Model Implemented in ASPEN Plus**. Presented at: 24th ESAT - European Symposium on Applied Thermodynamics. Santiago de Compostela, Spain, 2009 Book of Abstracts: 24th ESAT; PA-5

Morales Rodriguez, Ricardo; Sin, Gürkan; Gernaey, Krist; Meyer, Anne S. **Development of An Integrated Dynamic Model for Bioethanol Production From Lignocellulosic Biomass**. Presented at: AIChE Annual Meeting 2009. Nashville, TN, US, 8-13 November, 2009

Morales Rodriguez, Ricardo; Gani, Rafiqul. **Multiscale Modelling Framework for Chemical Product-Process Design**. Presented at: 19th European Symposium on Computer Aided Process Engineering – ESCAPE19. Krakow, Poland, 14-17 June, 2009

Morales Rodriguez, Ricardo; Gani, Rafiqul. **Product-Process Design Multiscale Modelling Framework**. Presented at: AMIDIQ XXX (Academia Mexicana de Investigación y Docencia en Ingeniería Química 2009). Mazatlan, Mexico, 19-22 May, 2009

Nielsen, M. Sidsel; Shapiro, A. Alexander; Michelsen, L. Michael; Stenby, H. Erling. **Mathematical Model for Microbial Enhanced Oil Recovery with Surfactant Distributed Between Phases**. Presented at the 30th IEA-EOR, Canberra, Australia, September 2009

Niu, Ben; Yan, Wei; Shapiro, Wei Yan; Stenby, Erling Halfdan. **Phase Identification and Saturation Determination in Carbon Dioxide Flooding of Water Flooded Chalk Using X-Ray Computed Tomography**. Presented at: International Symposium of the Society of Core Analysists. Noordwijl aan Zee, The Netherlands, 2009 Proceeding from International Symposium of the Society of Core Analysists

Niu, Ben; Yan, Wei; Shapiro, Alexander; Stenby, Erling Halfdan. **Coupling Miscible Flow and Geochemistry for Carbon Dioxide Flooding into North Sea Chalk Reservoir**. Presented at: European COMSOL Conference 2009. Milan, Italy, 2009 Proceeding in CD from European COMSOL Conference

PUBLICATIONS CONTINUED

Olsen, Dres Foged; Jørgensen, John Bagterp; Villadsen, John; Sin, Gürkan; Jørgensen, Sten Bay. **Modelling, Simulation and Optimization of Single-Cell Protein Production in a U-Loop Reactor**. Presented at: AIChE Annual Meeting. Nashville, TN, USA, 8-13 November, 2009

Petersen, Nanna; Ödman, Peter; Cervera Padrell, Albert Emili; Eliasson Lantz, Anna; Stocks, S.; Gernaey, Krist. **Monitoring of S. coelicolor fermentations using in-situ NIR**. Presented at: 14th European Congress on Biotechnology (ECB14). Barcelona, Spain, 2009

Prado Rubio, Oscar Andres; Jørgensen, Sten Bay; Jonsson, Gunnar Eigil. **Lactic Acid Recovery in Electro-Enhanced Dialysis: Modelling and Validation**. Presented at: 19th European Symposium on Computer Aided Process Engineering – ESCAPE19. Krakow, Poland, 14-17 June, 2009

Prado Rubio, Oscar Andres; Jørgensen, Sten Bay; Jonsson, Gunnar Eigil. **Modeling Reverse Electro-Enhanced Dialysis for Integration with Lactic Acid Fermentation**. Presented at: Nordic Process Control Workshop '09, NPCW09. Porsgrunn, Norway, 29-30 January, 2009

Prado Rubio, Oscar Andres; Jørgensen, Sten Bay; Jonsson, Gunnar Eigil. **Tool for Optimizing the Design and Operation of Reverse Electro-Enhanced Dialysis of Monoprotic Carboxylic Acids**. Presented at: 10th International Symposium on Process System Engineering, PSE2009. Salvador de Bahia, Brazil, 16-20 August, 2009

Pratsinis, Sotiris E.; Elmøe, Tobias Dokkedal; Tricoli, Antonio; Grunwaldt, Jan-Dierk. **Filtration of Nanoparticles: Evolution of Cake Structure and Pressure-Drop**. Presented at: American Association for Aerosol Research. Minneapolis, Minnesota, USA, 2009

Privat, Romain; Gani, Rafiqul; Jaubert, Jean-Noël. **Application of the GC-plus approach to PC-SAFT EOS and prediction of phase Equilibria**. Presented at: 24th European Symposium on Applied Thermodynamics, ESAT-2009. Santiato de Compostela, Spain, 27 June – 1 July, 2009

Privat, Romain; Gani, Rafiqul; Jaubert, Jean-Noel. **Direct Calculation of PC-SAFT Parameters From Experimental LVE Data and From a GC-Plus Approach**. Presented at: AIChE Annual Meeting. Nashville, TN, USA, 8-13 November, 2009

Privat, Romain; Gani, Rafiqul; Jaubert, Jean-Noël. **Prediction of thermodynamic properties of pure components and mixtures: cubic equations of state versus molecular theory-derived equations of state: a short comparison**. Presented at: JETC10. Copenhagen, DK, 22-24 June, 2009

Puder, K. Simonsen; O. Jørgensen; C.I Jensen, A.D. **Phytase Inactivation in the Animal Feed Pelleting Process.** Colorado Protein Stability Conference (Breckenridge), USA, 16-18 July, 2009

Qin, K. Jensen; P.A, Lin, W. and Jensen, A.D. **Influence of operation conditions on gas composition, soot and tar in entrained flow gasification of biomass.** International Conference on Polygeneration strategies. Snekkersten, Denmark, September, 2009 (paper with oral presentation for Ke Qin)

Qin, K. Jensen; P.A, Lin, W and Jensen, A.D. **Effect of experimental conditions on biomass gasificaton in an entrained-flow reactor.** Nordic-French Section of the Combustion Institute. Snekkersten, Denmark, 9-10 September, 2009

Rashed, Jamal Elbashir Ali; Gani, Rafiqul. **Model-based retrofit design and analysis of petrochemical processes.** Presented at: 1st Annual Gas Processing Symposium. Doha, Qatar, 10-12 January, 2009

Rashed, Jamal Elbashir Ali; Gani, Rafiqul. **Model-based retrofit design and analysis of petrochemical processes**. Presented at: 19th European Symposium on Computer Aided Process Engineering – ESCAPE19. Krakow, Poland, 14-17 June, 2009

Rasmussen, Martin Hagsted; Wedel, Stig; Illerup, Jytte Boll; Dam-Johansen, Kim; Thomsen, Kent. **The Role of CaO in SO_2Abatement in Cement Preheaters**. Presented at: 8th World Congress of Chemical Engineering (WCCE8). Montréal, August 23 to 27, 2009

Riisager, A.; Hansen, T.S.; Ståhlberg, T.; Klitgaard, S.K.; Jensen, J.S.; Woodley, John; Boisen, A.; Pedersen, S. **Conversion of Biomass Resources Into Chemicals with Integrated Catalytic Technologies**. Presented at: 13th Annual Green Chemistry and Engineering Conference. College Park, MD, USA, 23-25 June, 2009

Román-Martinez, Alicia; Gani, Rafiqul; Woodley, John. **A Systems Approach for Design of Intensified Bio-Pharmaceutical Processes**. Presented at: AIChE Annual Meeting 2009. Nashville, TN, US, 8-13 November, 2009

Román-Martinez, Alicia; Gani, Rafiqul; Woodley, John. **Design methodology for intensified bioprocesses**. Presented at: AMIDIQ XXX (Academia Mexicana de Investigación y Docencia en Ingenería Química 2009). Mazatlan, Mexico, 19-22 May, 2009

Román-Martinez, Alicia; Gani, Rafiqul; Woodley, John. **Design Strategies for Neuraminic Acid Synthesis: Comparative Study of Chemical and Biochemical Routes and Integration of Purification Steps**. Presented at: Biotrans 2009. Berne, Switzerland, 5-9 July, 2009

Rossing, Netta Liin; Lind, Morten; Jensen, Niels; Jørgensen, Sten Bay. **A Goal Based HAZOP Assistant**. Presented at: 19th European Symposium on Computer Aided Process Engineering – ESCAPE19. Krakow, Poland, 14-17 June, 2009

Sadegh, Negar; Thomsen, Kaj; Stenby, Erling Halfdan; Kontogeorgis, Georgios. **Thermodynamic Modeling of Water-Acid Gases-Alkanolamine Systems**. Presented at the 9th AIChE Annual Meeting 2009, Nashville, TN, USA

Satyanarayana, Kavitha Chelakara; Abildskov, Jens; Gani, Rafiqul; Tsolou, Georgia; Mavrantzas, Vlasis G. **Multiscale Modelling for Computer Aided Polymer Design**. Presented at: 10th International Symposium on Process Systems Engineering, PSE2009. Salvador do Bahia, Brazil, 16–20 August, 2009

Schäpper, Daniel; Eliasson Lantz, Anna; Stocks, S.; Szita, Nicolas; Gernaey, Krist. **Continuous culture microbioreactors**. Presented at: Society of General Microbiology Autumn 2009 Meeting. Heriot-Watt University, Edinburgh, Scotland, September 7-10, 2009

Shapiro, A.A.; Bedrikovetsky, P.G.; **Stochastic Modeling of Particle Migration in Porous Media Accounting for Dispersion and Size Distributions**. Presented at the 30th IEA-EOR, Canberra, Australia, September 2009

Sin, Gürkan. **Multi-criteria decision making under uncertainty: Energy efficient and low-carbon wastewater treatment**. Presented at: 5th Dubrovnik conference on sustainable Development of Energy Water and Environment Systems. Dubrovnik, Croatia, 29 September – 3 October (Keynote Lecture), 2009

Sin, Gürkan. **Reliability of Cellulose Hydrolysis Models to Support Biofuel Process Design - Identifiability and Uncertainty Analysis**. Presented at: Invited Seminar, DuPont Engineering Research and Technology, Wilmington, Delaware, USA, 13 November, 2009

Singh, Ravendra; Gernaey, Krist; Gani, Rafiqul. **ICAS-PAT: A new software tool for systematic design/validation of process monitoring and analysis systems (PAT systems)**. Presented at: APACT-09. Glasgow, UK, 5-7 May, 2009

Swangkotchakorn, Chutima; Gani, Rafiqul; Woodley, John; Grunwaldt, Jan-Dierk. **Optimization of tailor-made chemicals from renewable and non-renewable sources**. Presented at: Biotrans 2009. Berne, Switzerland, 5-9 July, 2009

Swangkotchakorn, Chutima; Gani, Rafiqul; Woodley, John; Grunwaldt, Jan-Dierk. **Sustainable Bioprocess Synthesis Routes for Tailor-Made Chemicals**. Presented at: AIChE Annual Meeting, Nashville. TN, USA, 8-13 November, 2009

Thomsen, Kaj. **Phase Equilibria in Aqueous Solutions of Fly-ash From Biomass Combustion**. Presented at: 24th ESAT European Symposium on Applied Thermodynamics. Santiago de Compostela, Spain, 2009 Book of abstracts: 24th ESAT, 62

Tsivintzelis, Ioannis; Economou, Ioannis; Kontogeorgis, Georgios. **Modeling the Solubility of Pharmaceuticals in Liquid and Supercritical Pure and Mixed Solvents**. Presented at: 24th ESAT European Symposium on Applied Thermodynamics. Santiago de Compostela, Spain, 2009 Book of abstracts: 24th ESAT, 157

Tindal, Stuart; Archer, I.; Carr, R.; Farid, S.; Hailes, H.C.; Woodley, John. **Reactor design and selection for improved stability of immobilized amino-acid oxidase from Trigonopsis variabilis**. Presented at: ProStab 2009. Graz, Austria, 14-17 April, 2009

Tufvesson, Pär; Schurmann, M.; Vogel, A.; Woodley, John. **Process engineering tools to guide biocatalyst modification**. Presented at: Biotrans 09. Bern, Switzerland, 5-9 July, 2009

von Solms, Nicolas; Swaminathan, Saravana; Michelsen, Michael Locht; Kontogeorgis, Georgios. **Modeling Gas Hydrates Using Simplified PC-SAFT**. Presented at: 24th ESAT European Symposium on Applied Thermodynamics. Santiago de Compostela, Spain, 2009 Book of abstracts: 24th ESAT, 180

von Solms, Nicolas. **Inhibition of Gas Hydrate Formation by Low-Dosage, Environmentally Benigh Inhibitors**. Presented at: Equifase 2009 - VIII Iberoamerican Conference on Phase Equilibria and Fluid Properties for Process Design, 2009 Book of abstracts: Equifase 2009, 45

Wang, Yanwei; Hansen, Flemming Yssing; Peters, Günther H.J.; Hassager, Ole. **Equilibrium partitioning of polymers between bulk dilute solution and confining pores**. Presented at: Annual March meeting of the American Physical Society. Pittsburgh, USA, 2009 Bulletin of The American Physical Society; 54, 710

Wang, Yanwei; Hansen, Flemming Yssing; Peters, Günther H.J.; Hassager, Ole. **Equilibrium Partitioning of Polymers between Bulk Dilute Solution and Confining Pores**. Presented at: The American Physical Society Meeting. Pittsburgh, PA, U.S.A., 2009

PUBLICATIONS CONTINUED

Wang, Yanwei; Tang, Meng; Hassager, Ole. **Stochastic Simulation of Filament Gliding Powered by Molecular Motor**. Presented at: 5th Annual European Rheology Conference. Cardiff-Wales, 2009

Wedberg, Rasmus; O'Connell, John P.; Peters, Günther H.j.; Abildskov, Jens. **Accurate Kirkwood-Buff integrals from molecular dynamics simulations**. Presented at: FOMMS. Blaine, WA, USA, 12-16 July, 2009

Wedberg, Rasmus; O'Connell, John P.; Peters, Günther H.J.; Abildskov, Jens. **Accurate Kirkwood-Buff Integrals From Molecular Dynamics Simulations**. Presented at: AIChE Annual Meeting 2009. Nashville, TN, US, 8-13 November, 2009

Wedberg, Rasmus; O'Connell, John P.; Peters, Günther H.J.; Abildskov, Jens. **Accurate Kirkwood-Buff Integrals from Molecular Dynamics Simulations**. Presented at: 2009 AIChE Annual Meeting. Nashville, TN, U.S.A., 2009

Woodley, John. **New opportunities for PSE in industrial biotechnology**. Presented at: 10th International Symposium on Process System Engineering, PSE2009. Salvador de Bahia, Brazil, 16-20 August (Keynote lecture), 2009

Woodley, John. **Scale-up of biocatalytic processes**. Presented at: ACHEMA. Frankfurt, Germany, 11-15 May, 2009

Woodley, John. **Tools for Biocatalytic Process Design**. Presented at: ECB 14. Barcelona, Spain, 13-16 September, 2009

Xu, Yuan; Nordblad, Mathias; Nielsen, P.M.; Brask, Jesper; Woodley, John. **Dyeing Method for Determination of Glycerol Partitioning in Biodiesel Production**. Presented at: 2nd International Congress on Biodiesel: The Science and The Technologies. Munich, Germany, 15-17 November, 2009

Xu, Yuan; Vargas, C.A.G.; Guisan, J.M.; Nordblad, Mathias; Nielsen, P.M.; Brask, Jesper; Woodley, John. **Mechanical Stability of Immobilized Lipases and the Supports in a Stirred Tank Reactor**. Presented at: 2nd International Congress on Biodiesel: The Science and The Technologies. Munich, Germany, 15-17 November, 2009

Yan, Wei; Huang, Shengi; Stenby, Erling Halfdan. **Measurements and Modelling of CO_2 Solubility in Brine and CO_2-Saturated Brine Densities at High Pressures**. Presented at: International Conference on Deep Saline Aquifers for Geological Storage of CO_2 and Energy. IFP, Rueil-Malmaison, France, 2009

Yan, Wei; Stenby, Erling Halfdan. **The Influence of CO_2 Solubility in Brine on CO_2 Flooding Simulation**. Presented at: 2009 SPE ATCE. New Orleans, LA, USA, 2009 SPE; 124628

Yuan, Linfeng; Korsholm, Lars; Jakobsen, Sune; Woodley, John; Jonsson, Gunnar Eigil. **Study of Electro-membrane Filtration in Enzyme Fractionation using Amino Acid**. Presented at: PERMEA2009. Prague, Czech Republic, 7-11 June, 2009

MASTER'S AND BACHELOR COURSES

The department participates in a 3 ½ year education for the Bachelor of Engineering, a 3 year education for Bachelor of Science and a 2 year education for the Master of Science degree. Below, course numbers and names are shown for 2009 with the number of students attending shown in brackets. Courses for the Bachelor of Engineering are marked with (B). The other courses are for the Bachelor and Master of Science education.

SPRING-SEMESTER

28001 Introduction to Chemistry and Chemical Engineering (50)
28012 Chemical and Biochemical Process Engineering (12) (B)
28014 Chemical and Biochemical Process Engineering II (11) (B)
28020 Introduction to Chemical and Biochemical Engineering (65)
28022 Unit Operations of Chemical Engineering and Biotechnology (35) (B)
28110 Chemical and biochemical product analysis (23)
28121 Chemical Unit Operations Laboratory (24)
28122 Chemical Unit Operations Laboratory – Summer University for Europeen (10)
28156 Process and product design (39) (B)
28160 Mathematical models for chemical systems (37)
28212 Polymer Chemistry (18)
28221 Chemical Engineering Thermodynamics (24)
28231 Laboratory in Chemical and Biochemical Engineering (21)
28241 Chemical Kinetics and Catalysis (20)
28322 Chemical Engineering Thermodynamics (28) (B)
28342 Chemical Reaction Engineering (43) (B)
28345 Chemical Reaction Engineering (20)
28350 Process Design: Principles and Methods (28)
28352 Chemical Process Control (38) (B)
28375 Air Pollution Control (10)
28415 Oil and Gas Production (25)
28423 Phase Equilibria for Separation Processes (12)
28434 Membrane Technology (24)
28443 Industrial Reaction Engineering (23)
28451 Optimizing Plantwide Control (7)
28852 Risk Assessment in Chemical Industry (16)
28855 Good Manufactoring Practice (66)
28863 Introduction to Fortran Programming (4)
28864 Introduction to Matlab Programming (36)
28885 Technology and Economy of Oil and Gas Production (16) (B)

Course given in co-operation with other departments:

26010 Introductory Project in Chemistry (1)
26316 Analysis and Chromatography (34)
27944 Biotechnology and process design (33) (B)
31525 Physiological transport phenomena (14)
41015 Mechanics and Materials (6)
41683 Materials Science (31) (B)

EDUCATION CONTINUED

MASTER'S AND BACHELOR COURSES

FALL-SEMESTER

28012 Chemical and Biochemical Process Engineering (44) (**B**)
28013 Chemical and Biochemical Process Engineering, I (19) (**B**)
28015 Mathematical models for chemical and biochemical systems (23) (**B**)
28020 Introduction to Chemical and Biochemical Engineering (65)
28022 Unit Operations of Chemical Engineering and Biotechnology (36) (**B**)
28121 Chemical Unit Operations Laboratory (18)
28140 Introduction to Chemical Reaction Engineering (41)
28150 Introduction to Process Control (31)
28156 Process and product design (34) (**B**)
28213 Polymer Technology (29)
28233 Recovery and Purification of Biological Products (25)
28244 Combustion and High Temperature Process (48)
28246 Applied Enzyme Technology and Kinetics (41)
28247 Advanced Enzyme Technology (9)
28310 Chemical and Biochemical Product Design (23)
28315 Colloid and Surface Chemistry (34)
28316 Laboratory Course in Colloid and Surface Chemistry (12)
28322 Chemical Engineering Thermodynamics (32) (**B**)
28342 Chemical Reaction Engineering (40) (**B**)
28352 Chemical Process Control (37) (**B**)
28361 Chemical Engineering Model Analysis (23)
28420 Separation Processes (13)
28515 Enhanced Oil Recovery (10)
28530 Transport Processes (32)
28811 Polymers in Processes and Products (16)
28845 Chemical Reaction Engineering Laboratory (23)
28851 Chemical Plant Operation (9)
28864 Introduction to Matlab Programming (25)

Courses given in co-operation with other departments:

10336 Fundamentals Problems in Fluid Dynamics (12)
12411 Introduction to Petroleum Technology (25)
23522 Rheology of food and biological materials (15)
26010 Introductory Project in Chemistry (44)
27004 Health, Diseases and Technology (24)
27102 Research and Development (75)
27944 Biotechnology and process design (28) (**B**)
41015 Mechanics and Materials (66)
41683 Materials Science (27) (**B**)

MASTER OF SCIENCE DEGREES

39 students finished their research projects for the MSc degree. The project titles and names of the students are listed below:

Albæk, Mads Orla
Fermentation Process in a Stirred Tank where the Conditions of Agitation and Aeration are Varied

Andersen, Maria Friberg
Low CO_2 cement production

Awad, Susanne and Huma Malik
Analysis of cell adhedsion in microchannels

Bruun, Johan
Modelling of distillation column

Butrimaité, Monika
Stability of Polymer Brushes and Proteins

Chaaban, Joussef Hussein
Simulation and costing of a process for dehydration of D-fructose to 5-hydroxy-2-methylfuraldehyde

Chalkiadaki, Maria
Flue Gas Desulfirization

Correia, Ana
Porous polymers derived from interpenetration polymer networks

Feliu Castells, Anna
Steam Reforming Kinetics over Ni-YSZ Used as Anode Material for Solid Oxide Fuel Cells

Frankær, Sarah Maria
Optimisation of the reaction between beta-hydroxyalkyl amine and organic acid anhydrides

Grydgaard, Anne
Modeling of Absorption Cooling in a Process Plant

Hansen, Rasmus
Anomaious Diffusion of Macromolecules on Interfaces

Hansen, Stine
Chemical engineering model of oxy-fuel combustion and NOx formation

Herslund, Peter Jørgensen og Claus Maarup Rasmussen
Effect of Environmental and Operational Conditions on Solar Evaporation Ponds

Huertas Osta, Pedro Ignacio
Simulation, design and analysis of a reaction separation process

Jensen, Michael Tvedebrink
Modeling of wax depositions in pipelines

Jensen, Thomas
Investigation of adhesion of water born wood stains

Johansen, Lars
Continuous production of pharmaceuticals

Jørgensen, Astrid Norman
Synthesis and Characterization of Polymer Brushes on Biomedical Polymer Surfaces

Jørgensen, Tommy Lykke
Kinetics of noble metal steam reforming catalysts

Kinch, Svend Kristian
Ammonia based energy storage for fuel cell applications

Laursen, Anders Bo
A study of novel "plum-pudding"-type catalysts

Lorentz-Petersen, Janus
Phase equilibria and properties of CO_2-water mixtures

Mam Taha, Daniela Hassan
Determination of transport coefficients in catalytic single-pellet-string reactors

Martins Geraldo, Paulo
Chemical Looping Reforming

Olsen, Dres Foged
Modeling and Simulation of Single Cell Protein Production

Pathi, Sharat Kumar
Innovative reactor design for the enzymatic hydrolysis of ligno-cellulose

EDUCATION CONTINUED

MASTER OF SCIENCE DEGREES

Pedersen, Mikael
Novel reactor design for organic-chemical production of pharmaceuticals

Rehal, Gurpreet Kaur
Low emission cement production

Reves, Jacob Birke
Optimising rotational speed for mixing by rotary jet heads

Tapia Vallejo, Alfonso
Swelling Polymers as Sealing Agents in Horizontal Oil Wells

Utrilla Marco, Rubén
Chemical Looping Reforming of Biomass Gasification Gas

Waseem Arshad, Muhammad
CO_2 Capture using ionic liquids

Wildberger, Patricia
Comparison of the Cultivation of S . Cerevisiae in Microbioreactors and Bench-scale Fermentors

Wu, Haiping
Drying of fruit products

Yasin, Soniasara
Analysis of scaling risks in oil and gas production systems

Yuan, Hao
Enhanced Oil Recovery

BACHELOR OF SCIENCE IN ENGINEERING DEGREES

29 students finished their research program for the BSc degree. The project titles and names of the students are listed below:

Ahmad, Muqeet and Hashim Ali Ahmed Al-Nakeeb
Relative Permeabilities for Critical Fluid Systems

Akbas, Erkan
Preparation of Amphiphilic Random Copolymers Through a Click Chemistry Approach

Attar, Sazan and Dorte Jørgensen
Analysis methods for CO_2-alkanolamine-water solutions

Binau, Chano Marcel
Operation and modelling of a novel high-temperature mixing principle for bio

Christensen, Troels Juel and Tais Bjerg Claridge
Effect of additives on soot formation

Christiansen, Camilla Stæhr and Sanne Steen Kristensen
Evaluation of economical aspects of biodiesel production

Ejlertsen, Lennart Zøllner and Henrik Gert Kristensen
Construction and Operation of a CO_2 absorber-stripper pilot plant for removal of CO_2 from combustion flue gases

Friedrich, Kim and Mads Gotha Vest
Upscale of antistatic impregnation in liquid carbon dioxide

Gansted, Gustav
Formation of NO from char oxidation

Gilbe, Teis Nielsen
Spectroscopic, rheological and thermal analysis of polyether polyois for poly-urethan manufacturing

Graversen, Majken Boesgaard and Malene Kaab
Vacuum Filtration of Pectine Solution

Görmez, Osman and Huma Shahzadi
Tribology of chemically modified PP and POM polymers

Hansen, Rasmus Spuur and Thomas Hornum
Characterisation of Cement and Raw Meal

Hendriksen, Simon Bach
Development of Production Method for Phosphate From Biomass Ash

Mohn, Thomas Uffelmann
Model for scale deposition in oil and gas production

Pedersen, Jannie Søs
Deposition initiated corrosion in biomass-fired furnaces

Pedersen, Jannik Blaabjerg and Per Donskov Rams
Modification of SCR catalysts for improved deactivation properties

Rørgren, Cindy Beha
Upgrading of flash pyrolysis bio-oil

Therkelsen, Niels Peter Vegger
Leaching of Arsenic From Impregnated Wood

"If two systems are at the same time in thermal equilibrium with a third system, they are in thermal equilibrium with each other."
Zeroth Law of Thermodynamics

Thermodynamics is defined as the study of energy, its forms and transformations, and the interactions of energy with matter.
The laws of thermodynamics set the theoretical stage for the industrial revolution and they will be integral to the 21st century engineering solutions that will shape the future.
They thus represent some of DTU Chemical Engineering's core values: Powerful innovation with solid roots in traditional chemical engineering disciplines.

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EXECUTIVE VICE PRESIDENT · H. LUNDBECK A/S

Scientific research at the university level is a prerequisite for the development of Lundbeck's chemical activities in Denmark. We have had a beneficial cooperation with DTU Chemical Engineering for several years, collaborating on PhD projects and recruiting several of its candidates. Furthermore, it has been a great advantage to be able to draw on the knowledge of DTU Chemical Engineering's scientific staff as advisors.

KIM PANDRUP CHRISTENSEN

DIRECTOR OF TECHNOLOGY · ANDRITZ FEED & BIOFUEL A/S

The close cooperation with DTU Chemical Engineering has ensured significant results within chemical technologies, results that Andritz Feed & Biofuel utilize to benefit a lot of different industries. Long-term focus on development and innovation is necessary to meet the increased focus on sustainable energy and food demands and the ever changing rules and legislation that most industries will have to comply with. DTU Chemical Engineering ensures a high level of education and important research projects that will lead to sustainable technologies in the future.

BJERNE CLAUSEN

DIRECTOR OF RESEARCH & DEVELOPMENT · HALDOR TOPSØE A/S

Working closely with the best research groups within the fields of our core competences is of major importance to Haldor Topsoe A/S. Our cooperation with DTU Chemical Engineering enables us to resolve research challenges beyond our competences and resources and is an important source of inspiration and knowledge for employees at Haldor Topsoe, benefiting both their own and the company's development.

PER FALHOLT

EXECUTIVE VICE PRESIDENT · NOVOZYMES A/S

In terms of industrial collaboration, DTU Chemical Engineering is at the front line and our cooperation is exemplary. To Novozymes, it is very important that possible future technologies are developed and tested within a university framework where new, valuable employees get their education and where real solutions to major challenges within society are found. DTU Chemical Engineering fully answers these demands, benefiting both society and Novozymes.

KNUD PETERSEN

VICE PRESIDENT · DONG ENERGY

Over the last 20 years a strong platform for cooperation has been established between DTU Chemical Engineering and the Danish energy sector, creating stability and competitiveness while allowing for fine-tuning of research in new areas benefiting both Dong Energy and DTU Chemical Engineering. This collaboration ensures an ongoing dialogue between researchers and employees in the energy sector. In addition, it has significantly optimized efficiency in the sector.

ALLAN SKOV

VICE PRESIDENT · CHEMINOVA A/S

Excellence in education and research is a precondition for Danish industry to stay competitive in the harsh environment of international business today. DTU Chemical Engineering's contributions in these fields are important for society in general and instrumental for the continuing development of Cheminova.

STUDENT COMMITTEE

Student Committee (from left to right): Lene Svendsen, Lars Jørgensen, Diana Hudecz, Thomas Petersen, Daniel Steen Haase Sørensen, Kasper Linde.

KTStudents is the student organization at DTU Chemical Engineering. The purpose of the organization is to create opportunities and great experiences for the students at the department. We do this through industry events, social gatherings, and KTStudent involvement within the department. We give the students an opportunity to network with other students interested in chemical engineering.

Thomas Petersen, President, KTStudents

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- Department of Chemical and Biochemical Engineering
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- Departments/centers
- Auditoriums
- Oticon Hall
- Halls of residence/shared facilities
- SCION.DTU
- Physical Plant
- Parking
- Bus stop

* The Danish Polymer Center (DPC) moves to building 227, 1 during the summer of 2010.

This Annual Report 2009 may be ordered
from the reception at the Department of
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