Technical University of Denmark

Annual Report **2013**

DTU Chemical Engineering
Department of Chemical and Biochemical Engineering

Annual Report 2013
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ANNUAL REVIEW

Head of Department

Kim Dam-Johansen
Professor, Head of Department

INTERNATIONALIZATION & INNOVATION

With a responsibility for research, education and innovation, the mission of DTU Chemical Engineering is to develop knowledge, methods, technologies and sustainable solutions within

- **Chemical and Biochemical Process Engineering and Production**
- **Design of Chemical and Biochemical Products and Processes**
- **Energy and Environment**

Based on long traditions and a strong focus on the core disciplines of Chemical and Biochemical Engineering, the department develops mathematical models and conducts experiments at micro-scale, at laboratory scale, in pilot facilities and at industrial scale. The department enjoys a very close and mutually beneficial relationship with Danish-based industrial enterprises as well as with leading universities and enterprises from all over the world. In this way, innovation through industrial implementation of our research results is a natural element of the department's strategy.

Close Industrial Relations

Over the years, our close industrial relations have resulted in several Faculty positions fully or partially sponsored by research-based industrial companies, such as Novozymes, Dong Energy, Vattenfall, Danisco/Dupont and Haldor Topsøe. This year, we received new grants from Novozymes for a position in Industrial Fermentation Technology to complete our research portfolio within Biochemical Engineering. From Haldor Topsøe we also received new funding for a position in Catalysis and Chemical Engineering to further strengthen our capabilities and competences within this important field. In this relation, I wish to extend a sincere welcome to Professor Krist Gernaey and Assistant Professor Jakob Munkholt Christensen from

whom we expect fast and competent development of their respective research fields.

Strong International Links

Internationalization has always been of utmost importance for the department. Over the years, we have established strong links to leading universities from all over the world. During recent years, we have offered other universities to use our pilot facilities within unit operations and process technology through summer university courses during the month of July. In 2013, we had the pleasure of welcoming more than 60 international students – mostly from US universities. In parallel to this, we also established a full MSc program for Danish and Chinese students on Chemical and Biochemical Engineering in Beijing as part of the Sino-Danish Center for Education and Research. Close cooperation has been established to the Chinese Academy of Sciences, Institute of Process Engineering and we expect to grow this activity further in the years to come.

Europe is the home-base for DTU Chemical Engineering and I am proud to announce that Professor Rafiqul Gani during 2013 was elected president of the EFCE to serve a two-year term starting on 1 January 2014. We are looking forward to contributing even more to the development of our profession in Europe.

Active Students and Professional Organization

Also our student organization was very active during 2013. The most important new activity was probably the participation of 15 students from the department at the AIChE annual meeting in San Francisco, USA. The students all took active part with poster presentations and met the opportunity to forge new international relations. We also hope to have our students participate in important international meetings and conferences in the coming years.

A strong university department needs professional administrative support and in order to grow our capabilities in this field, I am happy to welcome our new Head of Secretariat, Gitte Brandt. Gitte comes from 25 years at the Danish national broadcasting company, Danmarks Radio, representing a strong infusion of experience to run a professional secretariat.

After more than 13 years as Head of Department, I received the honour of being reappointed for a new period in 2013. Over the years, I have thoroughly enjoyed the challenges and together with colleagues at the department I am looking forward to further develop DTU Chemical Engineering in leading the way and continuously break new ground in the exiting field of Chemical and Biochemical Engineering.

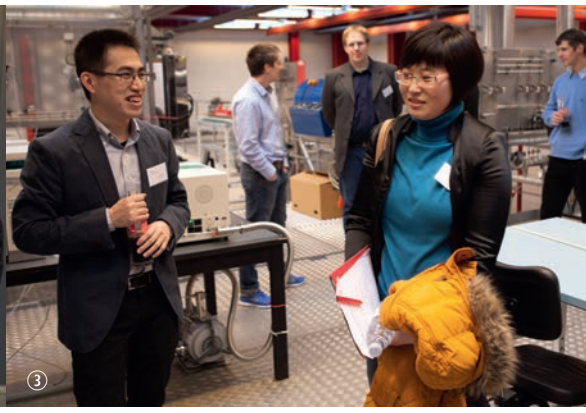
I hope you will enjoy reading our 2013 Annual Report.

Kim Dam-Johansen
Professor, Head of Department


HOT

HIGHLIGHTS 2013





1) Professor Krist Gernaey with some of his PhD students. **2)** Professor Kim Pilegaard (right) at his inauguration lecture and subsequent reception. **3, 4)** CHEC Annual Day 2013 – reception and poster session at CHEC pilot facilities.

HIGHLIGHTS 2013

JANUARY

1 JANUARY ①

Krist V. Gernaey appointed full professor

The professorship is sponsored by a grant by Novozymes A/S within Industrial Fermentation Technology. Applications for the professorship were announced internationally and evaluated by a committee composed of Professor Georgios Kontogeorgis, Executive Vice President Per Falholt (Novozymes) and Professor Gunnar Liden (Sweden). Interviews were held during December 2012. Professor Gernaey holds his inauguration lecture on 10 June.

28-29 JANUARY

Faculty meeting discussing future research and education at the department

All of faculty gathered in external meeting for two days to discuss and plan future research and education at the department.

FEBRUARY

1 FEBRUARY

PROCESS and CAPEC in new strong biotech cluster - BIOPRO

PROCESS becomes part of new research cooperation, BIOPRO. Industrial partners are Danish heavyweights Novozymes, Novo Nordisk and DONG Energy and CP Kelco. The objective is to strengthen Denmark's strong position in the biotech industry – and the ambition is to find new ways of making biotech production more efficient and sustainable.

21 FEBRUARY

Departmental seminar by Dr.-Ing. Andreas Bode

Each year, visiting professors are invited to hold a key lecture at the department. On this day, Dr.-Ing. Andreas Bode presented BASF's strategy on key trends within the chemical industry. See full list of speakers on page 81.

22 FEBRUARY ②

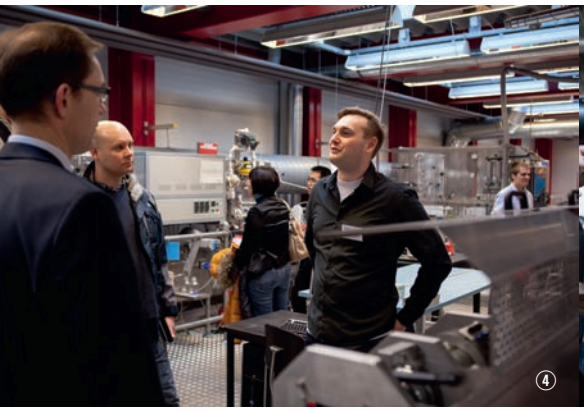
Inauguration lecture by Professor Kim Pilegaard

Professor MSA (with special responsibilities) Kim Pilegaard holds his inauguration lecture, "From Beech Leaf to Earth System", on carbon sequestration in terrestrial ecosystems, on the relations to global climate change, and on possibilities for enhancing carbon sequestration by natural and engineered processes. Kim Pilegaard was appointed Professor MSA in 2012 with a view to consolidating and disseminating knowledge from a long professional research career at DTU.

28 FEBRUARY

Professor John Woodley organizes 1st International Transaminases Conference in Stockholm

28 February to 1 March Professor John Woodley organizes, together with KTH Royal Institute of Technology and AstraZeneca Sweden, the 1st International Conference on Industrial Applications of Transaminases in Stockholm, Sweden.



5) The Bregentved event received much media attention. **6)** PhD student Veronika Hansen interviewed for television.

MARCH

4 MARCH ③④

CHEC Annual Day 2013

CHEC's Annual Day 2013 was a tremendous success with record participation from industry, 70, bringing the total number of participants to 137. Professor Kim Dam-Johansen opened the day with an overview of 25 years' research at CHEC – and a view into future activities. Key presentations were given by senior professors and scientists at CHEC. The day concluded with a reception and poster presentations at the CHEC pilot facilities.

5 MARCH

Professor Rafiqul Gani 2013 Bayer Lecturer

Professor Rafiqul Gani, Head of CAPEC research centre at DTU Chemical Engineering is this year's Bayer lecturer in process systems engineering at Carnegie Mellon University. The goal of the Bayer Lecture Series at Carnegie Mellon is to "present state-of-the-art research work in the area of Process Systems Engineering" by "speakers of international recognition". Professor Gani is the 13th speaker in the series.

22 MARCH ⑤⑥⑦⑧

Visit by the Crown Prince and the Minister for Climate, Energy and Building

Crown Prince Frederik and Minister Martin Lidegaard lent lustre to an event on sustainable solutions at Bregentved Gods on Zealand. The day's topic was grand – how do we secure energy and food in the future? Some of the answers to this question were given by scientists at ECO and CHEC – who have been looking into low-temperature gasification of biomass and resultant biochar. Low-temperature gasification is an efficient way to convert biomass and produces a biochar with valuable substances, such as fertilizers and carbon, which can be spread on farm land – and recycle valuable components to the soil.

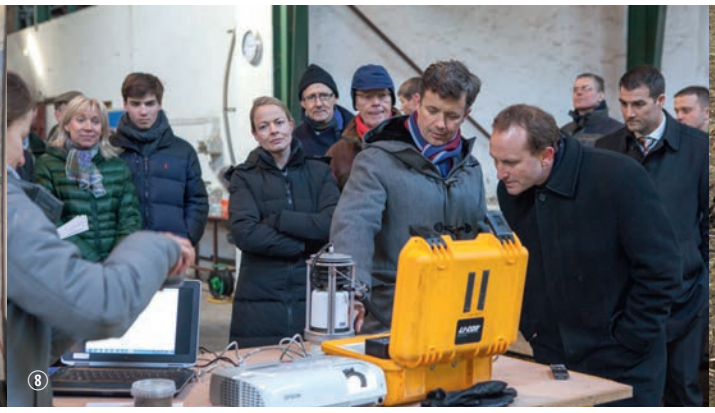
APRIL

15-30 APRIL ⑨

International field campaign at Campus Risø

As part of the EU FP7 infrastructure project InGOS (Integrated non-CO_2 Greenhouse Gas Observing System) the ECO research centre hosted an international field campaign. The aim of the campaign was to test and compare state-of-the-art applications and instrumentations for measurements of greenhouse gas fluxes between land surfaces and the atmosphere. The campaign was attended by five international groups from Germany (Karlsruhe Institute of Technology; University of Bremen; Thünen Institute in Braunschweig), Holland (ECN Amsterdam) and Italy (West Systems Inc., Pisa).

In parallel with the instrument campaign, a workshop was given to a group of 11 graduate and undergraduate students from countries in Asia, Africa, S-America and E-Europe. The workshop's objective was to introduce basic scientific skills concerning greenhouse gas flux measurement techniques to students from developing countries with no or limited access to relevant competences and infrastructure.


7) Senior Scientist Jesper Ahrenfeldt presenting results. **8)** Crown Prince Frederik and Minister Martin Lidegaard showing keen interest in Biochar research setup. **9)** ECO international InGOS field campaign.

HIGHLIGHTS 2013

MAY

29 MAY

FLSmidth Institute visits CHEC's pilot plant

FLSmidth Institute holds a 3-week long International Cement Production Seminar – a recurrent event for main customers every year. As previously, DTU Chemical Engineering took part with a day's teaching and an inspirational tour through CHEC's research facilities for the large group of participants.

30 MAY

New Project on minerals and cement receives public backing

The Danish National Advanced Technology Foundation supports a joint research project with FLSmidth A/S, Hempel A/S and DTU Chemical Engineering as participants. The aim is research-based development of efficient and environmentally friendly technologies for the mining and cement industry.

JUNE

5-7 JUNE ⑩

CAPEC-PROCESS Industrial Consortium Annual Meeting

The annual meeting was yet again a tremendous success with active and extensive participation from industry. The 90 participants met over three days with an ambitious programme comprising presentation of the ICAS software suite as well as presentations from both researchers and corporate members.

10 JUNE ⑪

Professor Kim-Dam Johansen reappointed as Head of Department

In his announcement of the appointment, President of DTU Anders Bjarklev stated that "Kim Dam-Johansen is the right person to lead DTU Chemical Engineering, also in the future. He can fulfil DTU's ambitious visions of continuing to be internationally leading within chemical engineering and thus highly contribute to DTU's status as a research-based university with strong focus on industrial applications"

14 JUNE

Research grant from BIO-VALUE SPIR (Strategic Platforms for Innovation and Research)

Center for Bioprocess Engineering receives large BIO-VALUE SPIR grant on value-added products from biomass. Partnership between University of Copenhagen, Aarhus University, DTU and a number of companies to support the development of a world-class research and innovation platform for biorefining. BioEng is also receiving substantial support from Novozymes for this, and will play a leading role.

14 JUNE

Department seminar with focus on future cooperation and activities

All employees of the department meet at Campus Lyngby for an active day of exchanging information, planning future cross-central cooperation and activities topped with an afternoon of social activities.



10) CAPEC-PROCESS Industrial Consortium Annual Meeting 2013. **11)** Professor Kim Dam-Johansen and President of DTU Anders Bjarklev (right). **12)** Social moment at CERE Discussion Meeting. Head of AT-CERE Professor Georgios Kontogeorgis (left).

19-21 JUNE ⑫

CERE Discussion Meeting with representation from 24 companies

With 24 companies represented, the 2013 CERE Discussion Meeting set a new record in industry participation. The annual event brings together industrial consortium members and CERE researchers to share experiences, new research results and exchange ideas.While thermodynamics and reservoir engineering remained in high focus, the DTU Chemical Engineering Center AT CERE stays at the forefront of Petrochemical Engineering research.

JULY

1-4 JULY

PhD summer course on M3C

Second PhD summer course on measurement, monitoring, modelling and control (M3C) applied to biochemical engineering processes. The three days comprise teaching and computer exercises, followed by a one day excursion to Novo Nordisk production facilities. The course was attended by 32 participants, PhD students and industrial participants, from all over Europe.

1-26 JULY ⑬⑭⑮

International Summer University with 60 participants

The International Summer University again attracted many students from especially the USA. In total, 60 students took part in the summer course which is focused on unit operations and process technology at the department's unique pilot plant. Students came from several US-based universities. The department plans to continue and even expand our summer school's activities in the coming years and thus making it possible to host even more international students.

AUGUST

2 AUGUST

Professor John Woodley gives plenary lecture at SINAFERM

30 July - 2 August Professor John Woodley gives plenary lecture at SINAFERM National Brazilian Congress on Bioprocesses at Foz do Iguacu, PR, Brazil. The topic is process intensification of bioprocesses.

SEPTEMBER

9 SEPTEMBER

New MSc programme started in China

A full MSc programme on Chemical and Biochemical Engineering, with added focus on Biomass, is launched in Beijing, China. The programme offers Danish and Chinese students the possibility of obtaining a dual degree from DTU and the University of Chinese Academy of Sciences (UCAS). Students pursue the entire degree in Beijing and are taught by professors from both DTU Chemical Engineering and UCAS. The programme is part of the Chinese-Danish initiative, Sino-Danish Center for Education and Research (SDC).

13, 14, 15) Summer University at DTU Chemical Engineering. Photos: Lars G. Kiørboe.

HIGHLIGHTS 2013

22-26 SEPTEMBER

Professor John Woodley chair keynote speaker in Toyama, Japan

John Woodley gives keynote lecture and chairs the process engineering session at the Enzyme Engineering XXII at Toyama, Japan.

OCTOBER

1 OCTOBER ⑯

Gitte Brandt as new Head of Secretariat

Gitte Brandt has been employed as Head of Secretariat to lead a 20-strong team of administrative and technical staff. Gitte comes from 25 years at the Danish national broadcasting company, Danmarks Radio, and a couple of years as a freelance consultant and head of administration in the service industry.

2-3 OCTOBER

Students visit leading Danish chemical and engineering companies

Students of our local student organisation went on a tour to Jutland to visit three major companies - Maersk Oil, Cheminova and FLSmidth. The purpose of the trip was to experience companies with real-life setups relevant for our students. An objective of this year's trip was also to visit companies further away from DTU/Lyngby.

20-26 OCTOBER

BIOPRO World Talent Campus

20 of the most talented young biotech students from 14 leading universities around the world took part in this first World Talent Campus (WTC) held by the BIOPRO consortium, including the PROCESS research at DTU Chemical Engineering. The overall mission of the WTC is to establish an international network amongst the biotech elite – bringing together students, universities and biotech companies – under the auspices of the BIOPRO research centre.

31 OCTOBER

PetroChallenge online event attracted 1300 pupils

PetroChallenge is a simulation event held online at Danish upper secondary schools. The purpose is to increase knowledge of the oil and gas industry and to inspire youths to consider studies within science and engineering. This year more than 30 upper secondary schools (STX, HHX, and HTX) participated in the event with about 1300 active participants distributed over 340 teams.

NOVEMBER

1 NOVEMBER

Jakob Munkholt Christensen employed as Assistant Professor with sponsorship from Haldor Topsøe A/S

Jakob Munkholt Christensen obtained his MSc and PhD degrees


16) New Head of Secretariat Gitte Brandt. Photo: Stefan Mogensen. **17)** DPC Annual Polymer Day. Photo: Stefan Mogensen.

at DTU Chemical Engineering working within the field of heterogeneous catalysis. After obtaining his PhD degree he has worked as a postdoc first at Oxford University and then at DTU Chemical Engineering. Jakob Munkholt Christensen's primary research focus is in the fields of heterogeneous catalysis, reaction kinetics and reaction engineering.

1-9 NOVEMBER

Our students at AIChE Annual Meeting in San Francisco

15 Master students and a group of postdocs from our department took part in AIChE's Annual Meeting in San Francisco. The students took active part with poster presentations on life cycle analysis and sustainability of chemical processes.

21 NOVEMBER

Professor Anne S. Meyer

Anne Meyer appointed to have a seat in the National Bioeconomy Panel under the Ministry of Food, Agriculture and Fisheries of Denmark.

22 NOVEMBER ⑰

DPC Annual Polymer Day

The Annual Polymer Day, arranged by the Danish Polymer Centre (DPC) at DTU Chemical Engineering, attracted colleagues and partners from both the industry and partner universities. The objective is to exchange new knowledge and ideas on polymer chemistry and technology. Approximately 50 people participated and this year's guest speaker was Professor Patrick Anderson of the Eindhoven University of Technology.

DECEMBER

2 DECEMBER

Professor Rafiqul Gani elected president for EFCE in 2014 & 2015

At the EFCE meeting in Frankfurt, Professor Rafiqul Gani was elected president for EFCE to serve a two-year term starting on 1 January 2014.

13 DECEMBER

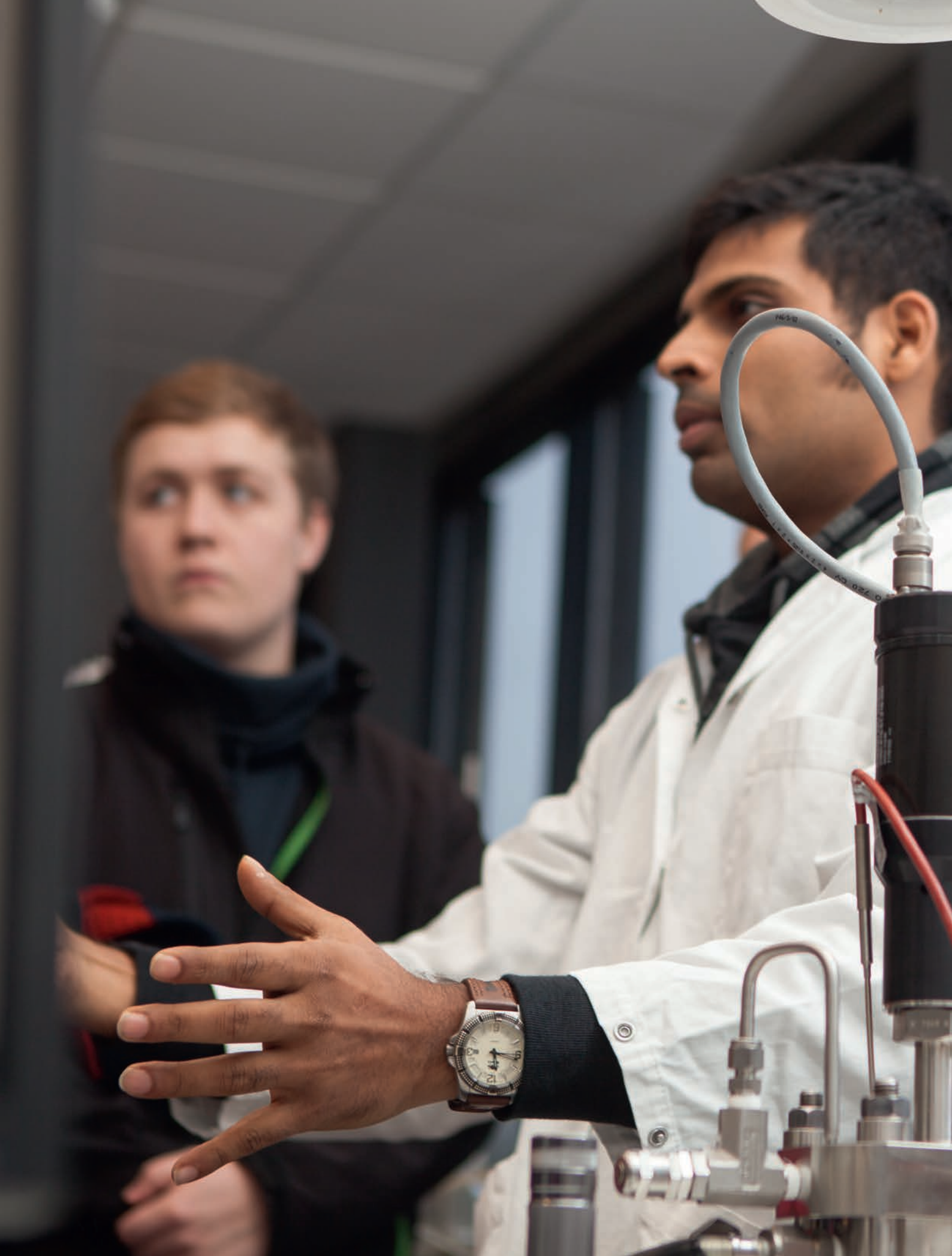
Annual departmental Christmas seminar

This year the department's annual Christmas seminar kick started the 2014 strategy process followed by our traditional lunch.

16 DECEMBER

Research symposium on thermal conversion of biomass and potential value of biochar

On 16 December DTU Chemical Engineering with partner universities holds an EU Interreg IVB supported research symposium on thermal conversion of biomass and the potential offered by biochar / bioash. Biochar is produced in an oxygen-limited environment producing a recalcitrant carbon-matrix also feasible to apply to soil in order to enhance soil fertility and at the same time mitigate climate change by sequestering carbon in the soil.



RESEARCH CENTRES & FEATURE ARTICLES

AT CERE
Applied Thermodynamics – Center for Energy Resources Engineering

BIOENG
Center for BioProcess Engineering

CAPEC
Computer Aided Process-Product Engineering Center

CHEC RESEARCH CENTER

DPC
Danish Polymer Center

ECO
Ecosystems and Environmental Sustainability

PROCESS
Center for Process Engineering and Technology

AT CERE

AT CERE is a dynamic research group with an excellent track record and international reputation in the areas of applied thermodynamics, transport processes, and mathematical modeling. The center is committed to perform high quality experimental and theoretical research with international impact. There are extensive collaborations, first of all within CERE and DTU Chemical Engineering but also with universities and industries around the world. It shares the same industry consortium with CERE which in 2012 includes 29 companies, of which 22 are international.

www.cere.dtu.dk

Contact:
Professor Georgios Kontogeorgis
gk@kt.dtu.dk
Phone: +45 4525 2859

In 2013 the CERE Consortium consisted of the following members:

- Akzo Nobel (NL)
- BP (GB)
- Chevron (US)
- Conocophillips (US)
- DONG Energy A/S (DK)
- Eni (IT)
- ExxonMobil (US)
- GASSCO (NO)
- GASSNOVA (NO)
- GDF-SUEZ (FR)
- Haldor Topsøe (DK)
- Hess (DK)
- IFP (FR)
- Infochem (GB)
- Linde (DE)
- Lloyd's Register ODS (DK)
- Maersk Oil (DK)
- National Oilwell Varco (US)
- OMV (AT)
- Petrobras (BR)
- RWE (DE)
- Schlumberger (US)
- Shell (NL)
- Sinopec (CN)
- Statoil (NO)
- SQM (CL)
- Total (FR)
- Vattenfall A/S (DK)
- Welltec (DK)

MAKING RESEARCH DATA AND MODELS ACCESSIBLE AND OPERATIONAL

In AT-CERE valuable research data and knowledge is made easily accessible through development and application of extensions to commercial process simulators. A team of scientists at the centre work to pair research data with thermodynamic models and models for unit operations. PhD student Bjørn Maribo-Mogensen has worked with packaging this setup in user-friendly software packages.

The industry needs thermodynamic models that can adequately describe the physical properties and phase equilibrium of complex mixtures to design and optimize processing plants. While the academic community has been developing a range of advanced models that can give more accurate representation of these properties and be used to tackle new challenges (such as CO_2 capture), engineers cannot take advantage of the latest research as these models are not available in the existing tools.

To mitigate the knowledge gap between industry and university, PhD student Bjørn Maribo-Mogensen has taken thermodynamic models of Associate Professor Kaj Thomsen and Professor Georgios Kontogeorgis and made them accessible by process simulators such as Aspen Plus. Aspen Plus is a comprehensive chemical process modelling system allowing chemical companies to design and improve their process plants.

Kaj Thomsen's Extended UNIQUAC (UNIversal QUAsiChemical) model was made accessible in Aspen Plus by Bjørn Maribo-Mogensen, which enabled former industrial PhD student at AT-CERE, Victor Dardé, to design and optimize a novel process for capturing carbon dioxide from the flue gas of power plants using ammonia in collaboration with researchers from Politecnico di Milano.

Another example is taking Professor Kontogeorgis' CPA (Cubic-Plus-Association) model that is being developed in the Joint-Industry-Project (CHIGP), which is becoming increasingly accepted by industry for modelling of oil, gas, water, and chemicals and has been made available to member companies for many years. Bjørn's PhD project has extended the CPA to handle mixtures containing salts, and the new model will also become available for use in process simulation when Bjørn's PhD is completed by the spring of 2014.

When the models are 'operationalized' and put into e.g. Aspen Plus, they can be used by a host of other universities – and companies. As an industrial example, Gassnova SF has successfully applied the model and simulation tool to build large carbon capture and storage (CCS) facilities in Norway.

"It's about making research applicable – and taking it out of its comfort zone."
PhD student, Bjørn Maribo-Mogensen

Thus the overall objective of Bjørn's and research colleagues work is to make models that are easily available and applicable by others – both universities and companies. As Bjørn puts it, "It's about making research applicable – and taking it out of its comfort zone."

That, however, is not a trivial task. To set up models and simulation tools requires a lot of in-depth expertise and knowledge. You have to have expertise in setting up models, understanding the problems to overcome, be skilled at process modelling and programming. Finally you have to combine these expert skills with in-depth research understanding and knowledge.

Good Business Case for both Industry and DTU

For DTU, valuable research is made accessible. Thus, knowledge and research data go from one professor to a tool, or set of tools, which can be used by students – and also enable interdisciplinary cooperation; at DTU Chemical Engineering and across universities.

Thermodynamic models produced at the department can be integrated and transferred into improved process simulators, and process simulators are made

Bjørn Maribo-Mogensen with fellow PhD students.

more ready and better for cooperation. In this way, good tools outside people's professional field are made available to them and open up for new types of projects.

Furthermore, research at the university can be combined with and related to research and practical work in companies – and give rise to fruitful cooperation for both parties. It is not always easy to relate research work to challenges faced by industry – but "it is easier to get to know the more precise needs and requirements of companies when they use the tools; as they communicate the needs and the problems or obstacles they face when using the tools and applying them to real-life issues." Bjørn points out.

Sometimes, experimental data is not available, and this data gap can lead to new student/research projects at DTU. And data can be retrieved from companies – or lead to collaborative projects with companies. When data are needed or shortcoming, models have to be evaluated – do they still work? This can again lead to new experimental projects, and frequently, students take part in projects in companies – e.g. STATOIL or BP.

Companies are not "married" to any specific set of tools but have a wish for new tools to design their processes. They already have and apply tools, but may not have updated tools for new conditions (parameters), like e.g. ultra deep exploration of oil or gas fields, with changed conditions like pressure and temperature, or new processes related to much larger scale facilities for e.g. biodiesel. Few universities make usable and applicable models – and here DTU and AT-CERE are among the leading.

PhD Student with a Global Perspective

Bjørn has thoroughly enjoyed pursuing a PhD at AT-CERE which has included much travel abroad and international cooperation: "It is really exciting work – to do basic research and break new ground. I wanted to try out in-depth research work and the research role – and it has been very gratifying. It is also hard work and at times very lonely to do your PhD. In particular, when you choose a very specialised topic like mine. However, I have received very good professional feedback and discussion from the faculty at AT-CERE and in working with other universities and companies abroad. In that way, my PhD has had a very international dimension – and that has been, and is, really exciting! There is a kind of before and after picture in my life – before my PhD I considered a job to be in Denmark but when doing my PhD the whole world has opened up to me. This has come by through my cooperation with companies abroad – and it has taught me a lot."

BIOENG

Center for BioProcess Engineering

Our MISSION is to conduct research that provides new knowledge, new enzymes, and new process strategies for sustainable resource utilization and industrial bioconversion processes and new products supporting a sustainable development. At the same time we are dedicated to hatch out top-qualified M.Sc. and Ph.D. candidates through research based teaching and structured supervision.

www.bioeng.kt.dtu.dk

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Center for BioProcess Engineering currently collaborates with the following industrial partners:

- Aminord ApS
- Arla Foods Amba
- DONG Energy A/S
- DuPont|Danisco
- Foss A/S
- Haldor Topsøe A/S
- KMC
- Novozymes A/S

REVOLUTIONIZING INFANT NUTRITION – WITH DREAM ENZYME

Professor Jørn Dalgaard Mikkelsen is a happy man – he has produced his "dream enzyme". The enzyme goes by the name, TR13, and can help to partly mimic human breast milk. The health-related benefits of human breast milk are well-documented and substantial – and the breakthrough may revolutionize the nutrition of infants and overcome some disadvantages of infant formula.

In short, the dream enzyme, TR13, can break sugar-linkages and transfer an important ingredient - sialic acid - to other sugars. By doing so, human breast milk is "mimicked" and important and complex sugars, Human Milk Oligosaccharides (HMO), are produced.

Why the great interest in human breast milk? Well, first and foremost human breast milk has many well-documented and significant health-related benefits. Breast milk is made up of three main elements: fats, proteins and the important third element; complex sugars (oligosaccharides). The first 2-3 months after the mother has given birth, her breast milk is particularly rich in oligosaccharides. These complex sugars are believed to be very potent against pathogens. When pathogenic microorganisms infect babies, they may cause infections and diarrhoea – which are contributing factors to infant mortality rates. Breast milk may also bind to various viruses, including flu virus and HIV, and thereby reduce the infection, but the study is controversial and need further experimental data to confirm the initial results.

Not all mothers can or choose to breastfeed their babies. Reasons include sickness in mother or child, cultures in which breastfeeding is not viewed favourably and complications in relation to the mother's breastfeeding of the child. In these cases, mothers traditionally turn to infant formula – which is most commonly produced from purified cow's milk (protein), fortified with addition of vegetable oils (fats), fructooligosaccharides and galactooligosaccharides, which give a good prebiotic and protective effect. However, infant formula lack the special human milk sugar structures containing sialic acid and fucose and may therefore be less potent.

"Well – Tr13 is the dream enzyme. It is the most complex and interesting enzyme we have generated by molecular evolution by changing 13 of the 648 building blocks (amino acid residues) in the polypeptide chain of the Tr13 enzyme. This transformed the enzyme activity from a strong hydrolytic activity to a powerful transferase activity."
Professor Jørn Dalgaard Mikkelsen.

HMO Molecules Act as Decoys Luring Pathogens

So what does TR13 do differently? Through bio-catalysis of whey protein, TR13 transfers sialic acid to lactose and other HMO molecules. By doing so, some of the human milk sugar structures are produced by a natural bio-

Professor Jørn Dalgaard Mikkelsen

logical process. There are approx. 100 different sugar structures and we have so far only produced a few of the major structures. The human milk oligosaccharides may also vary from person to person and the level and distribution may change from time of lactation. However, the HMO molecules are potent, as they "lure" pathogens present in the intestinal system to attack them instead of human cells and thus the pathogens are deceived and washed out through the intestinal system – instead of leading to infections and diseases. Furthermore, the complex HMO sugars have prebiotic effect, i.e. they stimulate the beneficial bacteria in the intestinal system and thus prevent harmful bacteria from establishing themselves.

Whey protein is available in large quantities, millions of tons, from the dairy industry. At the Center for Bioprocess Engineering, Professor Jørn Dalgaard Mikkelsen and his research team has conducted the proof-of-concept for the dream enzyme and produced several products, biochemically identical to human milk sugar. Reactions have been performed from 1 ml to 50 litre samples producing > 10 grams of product. The enzyme was patented in mid-2013, which together with the proof-of-concept, constitute the culmination of three years' intense research work at Center for Bioprocess Engineering.

Next Steps in Producing HMO

Professor Jørn Dalgaard Mikkelsen and his research group are technically ready to scale up production of the HMO compound sialyl lactose. However, production is costly and therefore focus is on establishing a financially sustainable process. At the same time, research is being conducted to produce other sugar structures present in human breast milk – presently with a focus on other HMO molecules.

The HMO research project is part of an overall programme at Center for Bioprocess Engineering focused on discovering methods to produce molecular structures with health-related benefits with an ultimate objective of contributing to the production of functional food.

The 3D structure of the dream enzyme used to produce the HMO molecules. We have introduced a special loop structure containing 7 amino acid residues, including 3 positive charges, which change the direction of the enzyme catalysed reaction to produce the desired breast milk HMO products.

SOME FACTS ABOUT THE RESEARCH PROJECT

The Danish Council for Strategic Research has granted DKK 20 million to university scientists for a project aimed at developing ways to produce a new kind of ingredient naturally present in human breast milk, namely "oligosaccharides". These complex sugars are present in breast milk at relatively high concentrations and help protect the infant from infections and diarrhoea. DuPont and Arla Foods are the industrial partners in the project and contribute to the research programme. Partnering universities are the Technical University of Denmark, Department of Chemical & Biochemical Engineering, and Department of Chemistry, University of Copenhagen, University of Southern Denmark and University of Reading.

CAPEC

Briefly, the research objective of CAPEC is to develop computer-aided systems for efficient and reliable process simulation; for systematic synthesis, design and analysis of sustainable chemical products and their manufacturing processes; for robust control, operation and monitoring of processes from principally chemical, petrochemical, pharmaceutical and biochemical industries.
The computer-aided systems are to be developed based on fundamental and/or data-based modelling studies that incorporate correlation and estimation of thermo-physical and phase equilibrium properties as well as modelling the underlying principles / behaviour of the process-product. That is, by managing the complexity in a systematic and efficient manner.

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In 2013 CAPEC was supported by the following industrial consortium

- Akzo Nobel (NL)
- Alfa Laval A/S (DK)
- AstraZeneca (SE)
- BASF (DE)
- Bayer Technology Services (DE)
- Céondo (UK)
- Chemtura Netherlands B.V. (NL)
- ConocoPhillips Company (US)
- DSM (CH)
- DuPont Nutrition and Biosciences Denmark (DK)
- Firmenich (CH)
- GlaxoSmithKline (US)
- Harper & Vedel (DK)
- Huntsman Europe (NL)
- Invensys Simsci-Esscor (US)
- Janssen Pharmaceutica N.V. (BE)
- Kongsberg Oil and Gas (NO)
- Lonza AG (CH)
- Mitsubishi (JP)
- Neste Jacobs Oy (FI)
- Novozymes A/S (DK)
- Optience Corporation (US)
- Petrobras (BR)
- Pfizer Inc (US)
- Processium (FR)
- ProSim (FR)
- SCG Chemicals Co. Ltd. (TH)
- Syngenta (GB)
- VTT (FI)
- Welcron Hantec Co. Ltd. (KR)

CHEMICALS-BASED PRODUCT DESIGN AND ANALYSIS

A wide range of chemicals-based products, such as cosmetics, detergents, blended fuels, edible oils and many more sustain the modern society. At CAPEC, we have been working on developing systematic methods and tools that help to discover new products, to "tailor" these products to the needs of society and to analyse/improve them. PhD students and MSc students work on various aspects of chemicals-based product design and analysis. This article highlights the works of three PhD students at various stages of their PhD studies.

Nor Alafiza Yunus is at the last stage of her PhD study and she has developed a systematic method for design and analysis of blended products (gasoline, lubricants, etc.). Michele Mattei is a final year PhD student who has extended our methods and tools for liquid formulated products to emulsion-based formulated products. Sawitree Kalakul is a first year PhD student who is extending the blended product design method to include a wide range of blended fuels, such as synthetic fuels and jet-fuels, as well as further develop our software, VPPD-lab (Virtual Product-Process Design Laboratory), incorporating the results of all the current and past PhD projects in the area of product design.

Michele studied for his MSc degree at the University of Padova, Italy, and completed his MSc thesis at DTU Chemical Engineering under a joint supervision of Professor Gani and his home university in Padova. Michele liked Copenhagen and the international environment at DTU so much that he came back in August 2011 to pursue his PhD study at CAPEC.

Michele receives joint supervision from CAPEC (main supervisor Professor Rafiqul Gani, RaG) and AT-CERE (co-supervisor Professor Georgios Kontogeorgis, GK) – a collaboration that Michele praises and enjoys very much. Michele works with emulsions, and so far a sunscreen, a hand-wash and an industrial detergent have been designed through his product design method and accompanying tools.

Michele explains how the overall objective of meeting the modern society's needs for chemicals-based products are translated and met at CAPEC and in his research work. Instead of designing these products through basically an experiment-based trial-error approach, the product design methods of all three projects propose an initial computer-aided step to narrow the search region and then a focused experimental verification and final selection on the most promising candidates. In this way, valu-

PhD students Sawitree Kalakul, Michele Mattei and Nor Alafiza Yunus

able time and money can be saved and better and more innovative products can be found.

Michele explains this in further detail: "The first step comes from the industry. We start with the industry's experience of consumers' needs and wishes – e.g. that a soap not only cleans, but also foams. The next step is to translate this information into properties. Properties can e.g. be the cleaning performance of a soap product, its foaming capability, etc. The crucial step is then – can we calculate these properties in a reliable and predictive way? A predictive way means that property values can be calculated based only on the molecular structure of the involved chemicals. Then we can think out of the box: maybe we have an ingredient which has never been tested – but does our model tell us that this could be a suitable candidate?"

"The next step is to screen candidates, that is, either reject or recommend these. This is a smarter and cheaper way of finding candidates, as we can quickly come up with maybe four or five candidates to be tested in experimental facilities, instead of thousands." Throughout this work, the model-based stage is combined with actual experimental work and the models used are verified.

"The actual design phase of the product is to find the best ingredients and evaluate these on parameters including performance, safety, toxicology and environment. Boundaries (minimum requirements, ed.) are defined for these parameters – and the final parameter is usually the cost. Depending on cost, a candidate ingredient may be replaced by another."

Michele concludes by describing the symbiosis between the industry and the university. "The industry provides real-life information for us. We give back models to the industry – so that they can solve their own challenges." The process is a continuous one of further refinement, extension and sophistication.

Nor Alafiza Yunus' and Sawitree Kalakul's PhD projects are closely related to each other – Sawitree will carry on and

See also publications from CAPEC for more details on their chemical product design work.

extend the work done by Alafiza in the area of tailor-made design of blended chemical products. Alafiza's project is a collaboration between CAPEC (RaG is the main supervisor) and PROCESS (professors John Woodley and Krist V Gernaey are the co-supervisors). Alafiza comes with a scholarship from the Government of Malaysia. Sawitree's project is a collaboration between CAPEC (RaG is the supervisor), AT-CERE (GK is the co-supervisor) and Alfa Laval Copenhagen (Dr. Bent Sarup is a co-supervisor). It is funded by the QNRF (Qatar National Fund), Alfa Laval and DTU. Alafiza and Sawitree both wrote their MSc theses at CAPEC – in collaboration with their home universities in Malaysia (Alafiza) and Thailand (Sawitree) – and both applied to CAPEC and DTU to pursue their PhD studies here. For Alafiza, the main driver was the presence of a product design community and expertise centre at CAPEC, "I really find product design interesting! And there are no courses in this in Malaysia." Alafiza would like to stay, but also has a commitment to her home university (UTM), "I really like the working environment here. There is so little bureaucracy – things are so simple and easy; and best of all, it is based on trust." Alafiza concludes with a warm smile.

Alafiza primarily works on new gasoline blends for cars (spark-ignition engine) and lubricant blends. The lubricant blends are engine oils where different lubricant sources are used – including greener alternatives, like waste cooking oil which is today not reused. She has also looked at another lubricant; waste from polyethylene production, which has good viscosity property.

Alafiza has employed much the same concepts as Michele and before him, Dr. Elisa Conte (who finished her PhD at CAPEC in 2009) but has developed her own systematic methodology to design tailor-made blended products. In her work, she employs ICAS tools (Integrated Computer Aided System developed at CAPEC) such as ProPred for property prediction, CAMD for molecular design and CAPEC database for chemical database development. She has used MATLAB for solving the mixture (blend) design problem as a linear and/or non-linear optimization problem, which later will be integrated into VPPD-lab. VPPD-lab is one of the available product design tools in ICAS, currently used for design of some formulated products (such as paints and sunscreen lotion). The application of this tool will be extended to a wider range of chemicals-based product design (Michele's, Alafiza's and Sawitree's work). With the aid of computer-aided tools, VPPD-lab makes the selection of the right candidate ingredients faster, more reliable and systematic, and a lot less costly in both terms of time and money.

Sawitree Kalakul's work is a good example of this. She works with design of synthetic fuels – more specifically Gas-to-Liquids (GTL) jet-fuel. Her target fuel will probably be based on 10-30 ingredients that must be tested in terms of the desired (target) properties. The amount of data to be processed is enormous – and to this end property models, good databases and computer tools are needed.

Thus, product design and analysis work is significantly aided by a systematic methodology and application of sophisticated and reliable software tools. These tools are also made available to industry through CAPEC's extensive industrial consortium with world-leading companies within the chemical and biochemical engineering world.

CHEC

CHEC Research Center

CHEC's main activities cover industrial high temperature processes, emissions control, catalysis and catalytic processes, particle technology, product design and production. The main disciplinary research is within reaction engineering and transport processes and cover theoretical modeling based on experiments carried out from microscale over pilot plants to full-scale industrial production plants. The research is carried out in close cooperation with industrial companies.

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The CHEC Research Center primarily collaborates with the following industrial partners

- Babcock & Wilcox Vølund ApS
- B&W Energy A/S
- DONG Energy A/S
- FLSmidth A/S
- H. Lundbeck A/S
- Haldor Topsøe A/S
- Hempel A/S
- Hwam A/S
- MAN Diesel & Turbo A/S
- Novozymes A/S
- Topsøe Fuel Cell A/S
- Vattenfall AB

NEW CEMENT PRODUCTION TECHNOLOGY – FROM RESEARCH TO INDUSTRIAL SOLUTIONS

In 2013, the joint advanced technology platform "New Cement Production Technology" between CHEC and FLSmidth A/S came to its successful conclusion. The platform has focused on new process technology for improved energy efficiency and lower emissions. The outcome of the platform will be instrumental in securing FLSmidth's competitive performance in the future cement market characterized by increasing competition and stricter environmental regulation. The close collaboration between the partners has supported the development of significant industrial solutions and many PhD, MSc and BSc candidates have been trained to work in the field. The successful cooperation established in the cement platform will be further extended in a new joint research platform on technologies for cement production and mineral processing with FLSmidth A/S and Hempel A/S as partners, and with financial support from the Danish National Advanced Technology Foundation.

There was a strong business case for establishing the cement platform. Approximately 5 % of all man-made CO_2 emissions originate from cement production. The production process is extremely energy-intensive and the energy savings potential is significant. Denmark has for many years held a strong position in the global cement technology market and the Danish-based enterprise FLSmidth A/S is at the forefront of the market. The aim of the research platform was to further strengthen this position through development of renewed, cleaner and more energy-efficient production processes and equipment.

The advanced technology research platform has established fundamental and science-based knowledge which can be used to upgrade cement production technology for the present market and to develop new and more efficient concepts with lower emissions of harmful compounds and CO_2.

The research has focussed on:

- Alternative fuels
- Reduction of harmful emissions
- Clinker formation
- Improved energy efficiency

Use of alternative fuels in cement production may lower both process costs and emissions of CO_2. The research has evaluated the potential of replacing fossil fuels with waste. Through theoretical investigations and experiments conducted in advanced

A new lab-scale rotary kiln simulator has been designed and constructed to study clinker formation mechanisms and kinetics. (Photo: Klaus Holsting)

test facilities at both laboratory and pilot scale, increased knowledge about the mixing and combustion processes in a cement rotary kiln has been established. The experimental part of the work has been carried out in a cold model rotary kiln, in a single particle burner, in entrained flow reactors, in a rotary drum reactor and in full scale kiln systems. Some of the main outcomes are IPR, new test methods, fulfillment of performance guarantees, recommendations of optimal firing and process stability, and update of design manuals.

During cement production, harmful compounds are formed both during the pre-heating process, in the calciner and in the rotary kiln. The focus in this part of the platform has been to provide fundamental knowledge about formation and reduction of emissions of SO_2, Hg and CO_2 in order to be able to design cleaner processes. In this way, FLSmidth has launched a project for full-scale trials aiming at developing a new and improved emissions-reduction process. Furthermore, new lab and pilot-scale facilities for CO_2 capture have been established, and new methods to measure and predict Hg have been developed.

In the *Clinker formation* part of the platform, the burning mechanisms for various raw meals have been studied in order to improve knowledge about clinker formation mechanisms and kinetics. In practise, it is not possible to take samples of clinker material in large-scale industrial ovens, and therefore a new lab-scale rotary kiln simulator has been designed and built. In this set-up, clinker formation can be studied in detail under realistic conditions.

In the *Energy efficiency* project a new preheater concept – which may be competitive with the existing preheater designs – has been designed and tested in both small-scale cold facilities and in hot pilot systems, and the technology is ready for further scale-up.

The many students involved in the work have been of great value to the platform as stated by Hannibal Nielsen, Department Manager, Cement Research at FLSmidth: "A PhD student going into depth on a very specific topic raises the general awareness in the rest of

Key figures for the cement platform:

The research platform was financed by the Danish National Advanced Technology Foundation, FLSmidth A/S and DTU Chemical Engineering.

The budget was DKK 50 mill. (EUR 7 mill.), and the platform period was 6 years (2007 - 2013).

Through the period 9 PhDs, 16 Master students and 28 Bachelor students have been conducting projects under the platform.

Based on the knowledge obtained through the platform FLSmidth has established a full-scale trial-rig with the purpose of increasing the SO_2 reduction. (Photo: Martin Hagsted Rasmussen)

the organization. The knowledge bar on alternative fuels, clinker formation, emissions, and energy efficiency has directly or indirectly been raised significantly."

For the involved students, the close cooperation with industry has meant realistic and real-life challenges and access to the facilities at FLSmidth's test centre Dania.

Looking Ahead – MiCeTech

The vision for the new research platform "Mineral and Cement process Technology" (MiCeTech) is to form a partnership and joint research project between FLSmidth A/S, Hempel A/S and DTU Chemical Engineering with the aim of placing the companies at the forefront of the global industries.

Processing of minerals and metals holds great research potential as the demand for minerals and metals is expected to further increase and the mineral industry needs effective solutions to improve recovery rates and, at the same time, reduce energy consumption and the environmental impact.

The cooperation between Hempel and FLSmidth on one hand and DTU Chemical Engineering on the other hand is expected to give a significant boost to the development of new and improved production technology.

Further Information
Contact Professor and Head of Department Kim Dam-Johansen or see this video produced with FLSmidth.

Strong environmental and financial motives to increase energy efficiency and control emissions in the cement industry:

Global yearly production of cement: 3,300 million tonnes

Fuel consumption: 3.5 GJ (~ 0.14 tonnes coal) per tonne cement clinker produced

CO_2 emissions: 0.9 tonnes per tonne cement produced

DPC

Danish Polymer Centre

The vision of The Danish Polymer Centre is to serve society by training candidates for the polymer industry and for the public sector. 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.

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The Danish Polymer Center primarily collaborates with the following industrial partners

- Alfa Laval Nakskov A/S (DK)
- Coloplast A/S (DK)
- Dana Lim A/S (DK)
- Dyrup A/S (DK)
- Grundfos Management A/S (DK)
- Hempel A/S (DK)
- Novo Nordisk A/S (DK)
- Tetra Pak Packaging Solutions AB (SE)
- Bang&Olufsen
- LEGO
- Radiometer Medical
- Mærsk Olie & Gas, Qatar Research
- Wavestar
- ESS Technology
- Danfoss PolyPower

TOMORROW'S HEARING AIDS – RUNNING ON METHANOL

Professor Søren Hvilsted at DPC is involved in the development of tomorrow's hearing aids – which run on methanol. The industry sees great potential in the new technology with an ambition to become world leading. DPC's part in the joint research project is the production of new and better polymer electrolyte membranes encapsulating the methanol used in the micro-size fuel cell.

Fuel cells running on methanol are expected to be tomorrow's standard in hearing aids. No more flat batteries that need recharging – instead micro-size fuel cells are integrated. It is expected that fuel cells can be reloaded in just 30 seconds providing enough power for 24 hours' operation. This scenario is brilliant news to users of hearing aids, often elderly people who struggle with the small batteries in current hearing aids. Today's hearing aids are very small – a brilliant and cosmetically aesthetic feature. However, the small size also means small parts that are tricky for elderly people to see, handle and replace. Furthermore, hearing aids are getting smarter and smarter, requiring increasing amounts of energy – and battery changes or recharging.

Professor Søren Hvilsted is part of the project, called Fuel Scale Integrate (FSI). As current membranes have too low methanol retention, Professor Hvilsted has set out to come up with polymer electrolyte membranes with much lower methanol permeability. His team is combining their experience with controlled radical polymerization techniques and suitable monomers to design novel polymer architectures that in addition to high methanol retention favour good film forming properties and higher long-term service temperatures.

This research work is firmly founded on research experience and competences developed at DPC over the years. Based on former projects, supported by the Danish Council for Strategic Research, Professor Hvilsted has built an excellence and knowledge base together with postdoc Irakli Javakhishvili.

Strong Research Consortium Set out to Solve Users' Problems

Modern hearing aids communicate with other devices and more and more technology is integrated in the aids. This requires more and more energy and often daily change of batteries. However, 58 % of the users are over 70 years of age and do not always possess the required motoric capabilities to change increasingly smaller batteries. Thus, the challenge is to deliver, and develop, a reliable energy source, which at the same time makes battery changes easier. This was the challenge posed to the consortium which was established in 2010 under the

MicroPower project. This project developed an external demonstration version of the fuel cell – setting a world record in energy efficiency and resulting in five patents applications.

The current consortium is made up of the Danish Technological Institute (main driver), hearing aid producers Widex and GN Resound, and finally Aarhus University and DTU DPC.

The hearing aid powered by a direct methanol fuel cell - to be further developed by Fuel Scale Integrate.

ECO

Ecosystems and Environmental Sustainability

The ECO center at DTU Chemical Engineering conducts research to understand and demonstrate environmental impacts of technologies and industrial processes in chemical and biochemical engineering in order to assess and analyse the environmental sustainability..

Collaboration and Public Sector Consultancy

We collaborate with universities, EU, policymakers, public companies and private industry. We hereby apply concepts and results derived from our research to practical problems. In this way we also ensure dissemination of our research.

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Ecosystems and Environmental Sustainability currently collaborates with the following industrial partners

- AgroTech (DK)
- Air Liquide (DK)
- Boreal (FIN)
- Bregentved Estate (DK)
- Carlsberg (DK)
- DLF Trifolium (DK)
- DONG Energy (DK)
- GCM (DK)
- GramiNor (NO)
- HedeDanmark (DK)
- Hempel (DK)
- LI-COR Biosciences (US)
- Nordic Seed (DK)
- Novozymes (DK)
- Sejet Plant Breeding (DK)
- SW Seed/Lantmännen (SE)
- VEGA Solar Panels (DK)
- Videncenter for Landbrug (DK)

AQUATIC BIOMASS – GREEN WITH A TWIST

Algae are a renewable and potentially very large biomass resource useful for energy purposes and bio-refinery products in a fossil-free future. The large productivity of aquatic biomass and the fact that it does not compete with agricultural food production makes this biomass resource very attractive. However, research at ECO shows that algae release nitrous oxide, a very potent greenhouse gas (GHG), during their growth. This discovery must be considered in life cycle analysis and GHG accounting in large scale algae cultivation systems.

It is known that terrestrial plants produce nitrous oxide (N_2O) in the leaves during photosynthesis. However, it is unknown if N_2O may also be produced by green plants and algae living in aquatic environments. Therefore, ECO researchers set up experiments to investigate N_2O emission from the green algae, Sea lettuce (Ulva lactuca), which has a potential for biomass production that by far exceed the yields of terrestrial energy production systems.

The focus of the experiment was to test whether N_2O is released when the Sea lettuce grows at relevant cultivation conditions, and to measure the balance of photosynthetic CO_2 uptake in parallel to the N_2O emission. Experiments were set up both in the laboratory (ECO at Risø Campus) and in cultivation ponds in Grenå (Algae Center Denmark, Aarhus University).

Kristian is fascinated by the productivity of aquatic biomass, "The numbers for Sea lettuce productivity are just wild and the technology for harvesting large quantities of biomass are available (…) of course; Sea lettuce can also be cultivated in man-made facilities, like the one at AlgaeCenter Denmark, where large experimental cultivation ponds have been set up for testing a variety of algae species in different media."

Batches of Sea lettuce were sampled from Roskilde Fjord and Hjarbæk Fjord. Before experimentation in the laboratory, the Sea lettuce had to be washed thoroughly - up to 15 times to get rid of dirt, small animals and microorganisms attached to the surface. Microbial activity in the algae surface biofilm could release N_2O and could thus potentially infer with the experimental results.

The laboratory work showed that significant N_2O emissions, along with photosynthetic carbon dioxide (CO_2) uptake, occurred when Sea lettuce was grown under light conditions and when nutrients were abundant in the water. Production of N_2O could not be obser-

Postdoc Kristian R. Albert performing GHG measurements by Roskilde Fjord at Risø Campus.

ved in darkness where photosynthesis did not take place. This indicates that algae metabolism produces N_2O during active photosynthesis.

The in-situ pond experiments in Grenå turned out inconclusive as no N_2O emission was measured in the floating chambers. Kristian provides several explanations to this. The density of biomass was low, rates of photosynthesis were low due to the low light levels in the bottom of the tank where the algae had sunken down, and the nitrate concentration was low. Each of these conditions negates N_2O emission from the algae itself. When pond biomass was brought back to the laboratory for control experiments, a significant N_2O production could be observed.

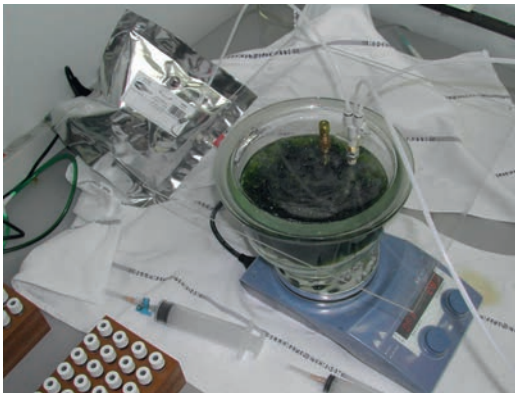
The million dollar question is of course how the potential Sea lettuce N_2O production affects the overall GHG balance in an algae based biomass production system, i.e. what is the ratio between N_2O production and CO_2 fixation? This is important, not least as the global warming potential (GWP) of N_2O is 296 times higher than CO_2. Based on the laboratory incubations, Kristian finds that algae biomass can still be considered a CO_2 neutral energy source, as the apparent CO_2 benefit is counterbalanced by no more than 0.1% by the algae N_2O production.

The N_2O emission observed from algae in batch cultures emphasizes the need for further experiments under natural

Large cultivation ponds at AlgaeCenter Denmark. The floating incubation chamber is placed in a cultivation pond containing natural seawater and Sea lettuce. Transparent chamber enabled solar light energy to the photosynthesis of the algae. Vigorous air bubbling ensured biomass mixing.

conditions in order to evaluate the greenhouse gas balance associated with large-scale algae production. Another issue that has to be considered is the production of N_2O caused by biomass degradation, which probably is inevitable in large-scale facilities. In a global perspective, the findings have significance for the GHG budgeting and projections of the IPCC, which do not include N_2O produced from living aquatic biomass.

Laboratory setup for measuring gas exchange in Sea lettuce cultures. Sea lettuce biomass was exposed to variable environments concerning light and nutrients. Measurements of gas concentrations were conducted real-time by photo-acoustic GHG analysis or by conventional gas chromatography.



FACTS

Algae biomass has potential for energy purposes and for bio-refinery products.

This study demonstrated for the first time that photosynthetic active algae emit N_2O.

This source of N_2O is almost completely ignored in the literature budgeting GHG balances in aquatic systems.

All sources leading to the N_2O emissions should be included when life cycle analysis of algae biomass production and GHG balances are to be assessed.

Project was funded by Energinet.dk (PSO-project 2008-1-0050). Partners were DONG Energy, Danish Technological Institute, Aarhus University Department of Bioscience and DTU Chemical Engineering.

Kristian Rost Albert, Annette Bruhn and Per Ambus (2013) Nitrous oxide emission from Ulva lactuca incubated in batch cultures is stimulated by nitrite, nitrate and light. Journal of Experimental Marine Biology and Ecology 448: 37–45.

PROCESS

Center for Process Engineering and Technology

The vision of the Center for Process Engineering and Technology is to provide the necessary support to enable the next generation of industrial production processes to be implemented. 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.

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Primary academic collaborators include:

- The University of Manchester (UK)
- University College London (UK)
- TU Graz (Austria)
- LTH (Sweden)
- TU Dortmund (Germany)
- Slovak Technical University (Slovakia)
- Copenhagen University (Denmark)

Major industrial collaborators include:

- Novozymes (Denmark)
- Novo Nordisk (Denmark)
- BASF (Germany)
- c-LEcta (Germany)
- CLEA technologies (The Netherlands)
- DSM (The Netherlands)
- Evonik Industries (Germany)
- Astra Zeneca (Sweden).

In addition PROCESS is part of the CAPEC-PROCESS industrial consortium.

BIOPRO – CREATING A LEADING BIOTECH CLUSTER

The Center for Process Engineering and Technology (PROCESS) is one of the founding partners of the BIOPRO research collaboration which was officially inaugurated on 1 February 2013. BIOPRO is a collaboration between Danish industry (CP Kelco, DONG Energy, Novo Nordisk and Novozymes), the development agency for region Zealand (CAT), DTU (PROCESS) and the University of Copenhagen. The focus of the project is on optimisation of large-scale production processes. PROCESS – in close collaboration with CAPEC – participates in 3 projects within BIOPRO:

- Distillation is one of the most energy-demanding separation processes for several BIOPRO partners. The focus of our activities is therefore on achieving a more efficient, less energy-consuming operation of distillation processes at CP Kelco, DONG Energy (Inbicon) and Novo Nordisk.

- Efficient data management. Industrial production generates a considerable amount of data about the production process, and in most cases the data are not used in order to achieve improved process operation. We work on facilitating more efficient use of data, for example by developing tools that allow to efficiently combine data from different database systems such that calibration of online systems can easily be validated with lab data.

- Fermentation with bacteria, yeast or fungi is used for production of bioethanol, enzymes and pharmaceuticals by the BIOPRO industrial partners. The research work is aimed at optimisation of oxygen transfer and mixing in full-scale bioreactors, and thus on reduction of the overall energy consumption in aerobic fermentation processes. Development of mathematical models forms an essential part of these activities as well.

World Talent Campus 2013

As part of the public-sector/ private-industry collaboration, the BIOPRO consortium established a World Talent Campus for particularly gifted international biotech university students with the support of the Novo Nordisk Foundation. Participants were selected from a strong field of applicants from invited universities around the world. The overall mission of the World Talent Campus is to establish an international network amongst the biotech elite – bringing together students, universities and bio-


LEGO
CREATOR
7-12
31010
3 IN 1
Danmarks Tekniske Universitet
LEGO
CITY
5+
60023

Winning team: Laura Jeffrey, Hilde Larsson, Stephen Goldrick, Aditya M. Kunjapur and Tobias Ladner.

tech companies. The 2013 World Talent Campus has been the first in a series of similar annual events.

The World Talent Campus is an advanced one week course at PhD level, where students learn and are challenged with cutting edge knowledge within biotechnology manufacturing. The course this year focused on bioprocess modelling, monitoring and optimisation, by addressing e.g. online measurement techniques, development and implementation of sensors in large-scale facilities, chemometrics etc.

The course also included social events and teambuilding activities in order to foster the creation of a global network.

The one week talent campus comprised two days of lectures by Professor Krist V. Gernaey and Professor John M. Woodley of PROCESS and Associate Professor Frans van den Berg of the University of Copenhagen, along with presentations from the industrial BIOPRO partners. The 20 participants were divided into four groups and given a real-life challenge faced by the participating industrial partners. The groups should come up with an analysis of the challenge and propose new ways of meeting this challenge. The teamwork spanned two days of work – and to facilitate teamwork and visualise the challenge, the groups visited the production facilities of the industrial partner that was responsible for each team.

The talent campus culminated on Friday 25 October when the groups presented the results of the workshops. The young talents – most of them pursuing a PhD degree – all made powerful presentations that gave rise to many questions and much interest from the audience, and not the least from the representatives from industry. The 'judges', DTU Professor Krist V. Gernaey and KU Associate Professor Frans van den Berg, found it hard to decide which team should win – with such a strong field. Team 4 were finally declared as the winners with their presentation on a Novozymes challenge. Team 4 are Laura Jeffrey (University of Strathclyde, Glasgow), Stephen Goldrick (Newcastle University, Newcastle), Tobias Ladner (RWTH Aachen, Aachen), Aditya M. Kunjapur (MIT, Boston) and Hilde Larsson (DTU, Lyngby).

HOW THE STUDENTS PERCEIVED THE WORLD TALENT CAMPUS

We have selected some feedback from the students that have participated in the World Talent Campus.

PhD student Aydin Golabgir-Anbarani of the Vienna University of Technology was very satisfied with the WTC:

"It's been a great week – good bonding with the team members – a lot of learning – industrial experience, so a really good experience ... the best experience a PhD student can wish for."
"The best part for me was the industrial contacts and visits – though, it is difficult to say what part was the best – but it was the most exciting because although I have been to a factory before – this time we had a chance to get a grasp of what are the challenges they have – talk to them in more detail, go open one of these huge reactors and look inside them, which I have never done before, so it's huge – and really makes an impression on you, the scale of their task."

Ester Martinez' group worked with a case within DONG Energy's area – and Ester very much enjoyed both the presentation by DONG's contact, the visit to DONG Inbicon and having Jesper Dohrup (DONG Energy) as a mentor in the teamwork on improving a real-life process.

"It was really nice to have someone from industry … especially as the process we worked with is a process you will experience in reality."

Ester Martinez is pursuing a PhD at the Vienna University of Technology.

Thomas Wasylenko, PhD student at MIT: "I work in a biofuels lab – we do everything in a shake flask scale, so to see what goes into scaling that up and actually doing that at a huge scale to make money – yeah, that was really eye-opening to see what goes into that!"

"We have made some good friends – and if we wish to go to a different area, we know some people who are experts – so I think that could also be very useful," Thomas adds.


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PRODUCTIVITY

Staff 2013
Productivity
Publications
Education

STAFF 2013

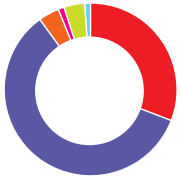
TYPE OF STAFF

(Total 260 persons)

- 37 % PhD students
- 36 % Scientific
- 12 % Technical
- 13 % Administrative
- 2 % Trainees a. o.

FOREIGN SCIENTIFIC STAFF

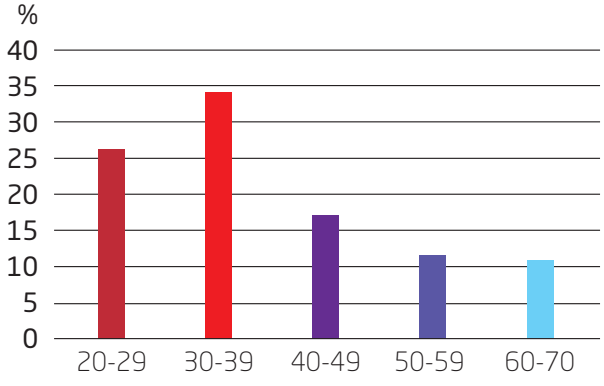
(Total 108 persons)



- 31 % Asia
- 59 % Europe
- 4 % Middle East
- 1 % North America
- 4 % South America
- 1 % Africa

STAFF DISTRIBUTED BY AGE

(Total 260 persons)



PRODUCTIVITY

TEACHING & EDUCATION 2013

STUDENTS, EDUCATIONAL RESOURCES AND IMPACT

Students (STÅ*)	**203**
Completed BSc projects	**25**
Completed MSc projects	**50**

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

RESEARCH & INNOVATION 2013

1.1.2013 – 30.11.2013

Scientific articles with referee in ISI-indexed journals (WoS)	**143**
Scientific articles with referee (non-WoS)	**15**
Contributions to refereed conference proceedings (and book series)	**120**
Monographs	**0**
Contributions to books	**3**
PhD Theses	**30**
Scientific publications and conference contributions with no peer-review	**20**
Contribution indicated as popular	**6**
Scientific reports	**3**
Patents	**5**

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Chaaban, Joussef Hussein (2013): **Novel reactor design for organic-chemical crystallization of active pharmaceutical ingredients.**

Evseev, Vadim; Clausen (2013): **Optical Tomography in Combustion.**

Frankær, Sarah Maria Grundahl (2013): **Stimuli-Adaptable Materials.**

Gavlighi, Hassan Ahmadi (2013): **Process development: Enzymatic upgrading of pectin from sugar beet pulp.**

Huang, Qian (2013): **Molecular Rheology of Complex Fluids.**

Hukkerikar, Amol Shivajirao (2013): **Development of pure component property models for chemical product-process design and analysis.**

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Lachouani, Petra (2013): **Nitrogen cycle assessments and greenhouse gas emission in low-input legume managements.**

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Markussen, Mads Ville (2013): **Systemic approach to sustainability assessment of food and bioenergy production in a societal context.**

Musko, Nikolay E. (2013): **Heterogeneously catalysed reactions in supercritical carbon dioxide as innovative and green solvent.**

Mustaffa, Azizul Azri (2013): **Development and Analysis of Group Contribution Plus Models for Property Prediction of Organic Chemical Systems.**

Nielsen, Mads Møller (2013): **New Polymer Architectures for Proton Conducting Fuel Cell Membranes.**

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Ramos, Joana (2013): **Guiding biocatalytic process improvements using engineering evaluation tools.**

Reinsch, Sabine (2013): **Long Term Climate Change Effects on Dynamics of Microorganisms and Carbon in the Root Zone**.

Sadegh, Negar (2013): **Thermodynamic modelling of acid gases - Alkanolamine systems.**

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Sitarz, Anna Katarzyna (2013): **Laccase enzymology in relation to lignocellulose processing.**

Thaysen, Eike Marie (2013): **Climate Change Mitigation by Plant mediated transfer and storeage of carbon in aquifers.**

Trinh, Ngoc Trung (2013): **Fast pyrolysis of lignin, macroalgae and sewage sludge.**

Tsai, Chien-Tai (2013): **Enzymatic upgrading of plant biomass**

Vangsgaard, Anna Katrine (2013): **Modeling, Experimentation, and Control of Autotrophic Nitrogen Removal in Granular Sludge Systems.**

Wu, Qiongxiao (2013): **Catalytic synthesis of alcoholic fuels for transportation from syngas.**

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Examples of scientific reports

Glarborg, Peter; Jensen, Peter Arendt; Dam-Johansen, Kim; Illerup, Jytte Boll; Karlström, Oskar; Brink, Anders; Zevenhoven, Maria; Huoa, Mikko; Scharler, Robert; Brunner, Thomas; Obernberger, Ingwald; Løvås, Terese ; Jappe Frandsen, Flemming (Editor) / **Scientific Tools for Fuel Characterization for Clean and Efficient Biomass Combustion : SciToBiCom Final Report**. 2013. 212 p.

Jensen, Peter Arendt; Shafique Bashir, Muhammad; Wedel, Stig; Jappe Frandsen, Flemming; Wadenbäck, Johan; Pedersen, Søren Thaaning; Dam-Johansen, Kim / **Characterization and quantification of deposits build up and removal in straw suspension fired boilers.** Technical University of Denmark, Department of chemical and Biochemical Engineering, 2013. 216 p.

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MASTER'S AND BACHELOR COURSES

The department participates in a 3½ year education for the Bachelor of Engineering, a 3 year education for Bachelor of Science and a 2 year education for the Master of Engineering. Below, course numbers and names are shown for 2013, with the number of students attending shown in brackets. Courses for Bachelor of Engineering are marked with (**B**). The other courses are Master's courses or common courses.

SPRING SEMESTER

28016 Mathematical models for chemical and biochemical systems (19) (**B**)
28018 Chemical and Biochemical Process Engineering (40) (**B**)
28019 Chemical and Biochemical Process Engineering (9) (**B**)
28020 Introduction to Chemical and Biochemical Engineering (73)
28022 Unit Operations of Chemical Engineering and Biotechnology (18) (**B**)
28025 Bio Process Technology (35)
28121 Chemical Unit Operations Laboratory (16)
28122 Chemical Unit Operations Laboratory – Summer University for Europeen (4)
28157 Process Design (24) (**B**)
28160 Mathematical models for chemical systems (31)
28212 Polymer Chemistry (19)
28214 Polymer Synthesis and Characterization (7)
28221 Chemical Engineering Thermodynamics (12)
28231 Laboratory in Chemical and Biochemical Engineering (26)
28270 Industrial Ecology (12)
28271 Bioenergy and sustainability - recycling of ash fractions from thermal gasification (10)
28322 Chemical Engineering Thermodynamics (27) (**B**)
28342 Chemical Reaction Engineering (38) (**B**)
28345 Chemical Reaction Engineering (18)
28350 Process Design: Principles and Methods (52)
28352 Chemical Process Control (26) (**B**)
28415 Oil and Gas Production (39)
28423 Phase Equilibria for Separation Processes (28)
28434 Membrane Technology (42)
28443 Industrial Reaction Engineering (27)
28451 Optimizing Plantwide Control (16)
28850 Quality by Design (QbD): Integration of product and process development (32)
28852 Risk Assessment in Chemical Industry (31)
28855 Good Manufactoring Practice (62)
28864 Introduction to Matlab Programming (13)
28871 Production of Biofuels (21)
28885 Technology and Economy of Oil and Gas Production (34) (**B**)

Courses given in cooperation with other departments:

26316 Analysis and Chromatography (46)
27944 Biotechnology and process design (16) (**B**)
41683 Materials Science (25) (**B**)

EDUCATION CONTINUED

MASTER'S AND BACHELOR COURSES

FALL SEMESTER

28001 Introduction to Chemistry and Chemical Engineering (64)
28016 Mathematical models for chemical and biochemical systems (27) (B)
28018 Chemical and Biochemical Process Engineering (47) (B)
28022 Unit Operations of Chemical Engineering and Biotechnology (22) (B)
28121 Chemical Unit Operations Laboratory (29)
28140 Introduction to Chemical Reaction Engineering (32)
28150 Introduction to Process Control (23)
28157 Process and product design (27) (B)
28213 Polymer Technology (31)
28233 Recovery and Purification of Biological Products (36)
28242 Chemical Kinetics and Catalysis (37)
28244 Combustion and High Temperature Process (46)
28246 Applied Enzyme Technology and Kinetics (33)
28247 Advanced Enzyme Technology (11)
28310 Chemical and Biochemical Product Design (36)
28315 Colloid and Surface Chemistry (45)
28316 Laboratory Course in Colloid and Surface Chemistry (16)
28322 Chemical Engineering Thermodynamics (16) (B)
28342 Chemical Reaction Engineering (16) (B)
28352 Chemical Process Control (19) (B)
28361 Chemical Engineering Model Analysis (34)
28420 Separation Processes (30)
28515 Enhanced Oil Recovery (26)
28530 Transport Processes (42)
28811 Polymers in Processes and Products (10)
28845 Chemical Reaction Engineering Laboratory (20)
28864 Introduction to Matlab Programming (18)
28870 Energy and Sustainability (64)
28872 Biorefinery (30)

Courses given in cooperation with other departments:

10336 Fundamentals Problems in Fluid Dynamics (7)
26010 Introductory Project in Chemistry (56)
27004 Health, Diseases and Technology (59)
27405 Cell factories: Design, engineering and analysis (37)
27944 Biotechnology and process design (13) (B)
41657 Materials Science for Chemists (25)
41683 Materials Science (22) B)

Courses given under the SDC programme in Beijing

88700 Industrial Reaction Engineering (16)
88701 Transport Processes (16)
88702 BioProcess Engineering (16)

MASTER OF SCIENCE DEGREES

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

Al-Saidi, Helen Lufti
Proces Optimization via QbD and DOE

Anantpinijwatna, Amata
Synthesis and design of water and wastewater network for optimal water conservation

Andersen, Søren Henckel
Modelling the influence of CO on $CaSO_4$

Boiocchi, Riccardo
N2O formation in biological wastewater treatment: a benchmarking study

Brull Costa, Jordi
Polymers as Barrier Membranes in Pipelines for Supercritical CO_2 in Offshore Applications

Bærentsen, Katja
Design of down stream processes for chiral amine produced by transamination - 1-methyl-3-phenylpropylamine

Carlsen, Kim Braad
Stability of Benzon Boilers at Low Load Operation

Duhn, Jakob Dragsbæk
Transforming an organic synthesis from batch to continuous processing in the pharmaceutical industry

Estevez Rubio, Noelia
Testing of intumescent coating system

Friedrich, Kim
Chemo-enzymatic production of sialic acid

Galambosi, Máté
Gas Flow in Tight Formations

Gonzales Londono, Jorge Enrique
Optimization of White Rot Fungi Pretreatment

Grossmann, Jesper Banke
Characterization and Engineered Liquid Lipases for Biodiesel Production

Hansen, Dennis Brian and Marianne Lund Madsen
Syntheses of polyurethanes based on poly(epsilon-caprolactone)

Hansen, Signe
Ignition of biomass particles

Hansen, Thomas Klint
Modeling and preparation of dual layer ammonia oxidation catalyst

Harboe, Kate
Modeling of H_2S removal with ZnO absorbent

Heltborg, Carsten Kirstejn
Optimizing process conditions for biodiesel production using soluble lipase

Hersi, Rage Mohamed
Process Intensification Case Studies

Ibrahim, Hulouvan Kamal
Solid-liquid Separation Processes in the Pharmaceutical Industry

Ismail, Muhammad Imran Bin
Sustainable Biodiesel Process Design from Various Palm Oil Sources

Jakobsen, Mia Kirstine
Enzyme encapsulation technology using biocompatible materials

Jørgensen, Steffen
Production Forecasting Technics in Reservoir Development

Kranker, Tine
Modelling of cake compaction for optimization of decanter centrifuges used for enzyme recovery

Lacroix, Gwendal Jean Pierre
Operating Strategies for the Chemo-enzymatic Synthesis of Sialic Acid

Lambrecht, Henri
Comparison between yeast cultivation in a miniature stirred bioreactor and a bench-scale reactor

Lind-Nielsen, Maja
Thermal insulating coatings for industrial applications

EDUCATION CONTINUED

MASTER OF SCIENCE DEGREES CONTINUED

Linde, Kasper
Investigation of the influence of autoclaving and spray drying conditions on the properties of alumina powder

Lunde, Anette
Application of enzymes for enhanced oil recovery

Mansouri, Seyed Soheil
A Phenomena based Process Intensification - A case study

Marques Brites, Rita João
Optimization of Fouling-Induced Enzyme Immobilisation in Membrane Support

Montero Castro, Ignacio
Feasisbility of Applying Self Optimizing Control for Sewer Systems

Mortensen, Asmus Ringlebjerg
Continuous Processing of Pharmaceutical Intermediates in Microreactors

Noguer, Albert Camós
Anticorrosive coatings and interlayer adhesion loss

Papadakis, Emmanouil
Modeling of unsaturated fatty acid oxidation with H_2O_2

Poschwatta, Hans Henrik
Wetting of Fibers: A Computational Study of the Wetting Dynamics

Quintanilla Hernandez, Daniea
Oxygen transfer in aerated stirred tanks of different sizes

Quintero, Johannes
Full scale process conditions of a gas/particle heat exchanger

Schmidt, Søren Dejgaard
Modeling of Mineral Scale Deposition in Oil Production

Shaukat, Chaudhary Bilal
Effect of Salinity on Waterflooding of Petroleum Reservoirs

Sigalas, Lykourgos
Effect of Salinity on Waterflooding of Petroleum Reservoirs

Svendsen, Lene
Enzymatic basket reactor technology

Thomsen, Tobias
Integration of low Temperature Thermal Gasification in Danish Wastewater Treatment - A Case Study Assessment of Society Oriented Optimization Potential Within Wastewater Treatment

Thormann, Lisa
Enzymatic Degradation of Plant Biomass: Effect of Biomass Composition

Tretow-Loof, Obehi
Design of down stream processes for chiral amine produced by transamination - 1-(4-bromophenyl)-ethanamine

von Freiesleben, Pernille
Characterization of mannanases for biomass conversion

Wilbek, Frederik Mads Hallkvist
Design study and characterization of a continuous flow reactor using a compressible and non-compressible immobilized glu

Wolf, Phillip Mutebi
Experimental Determination of Solid Formation from CO_2 Capture Solvents

Yang, Victoria Mengqi
BioFAME for High Free Fatty Acid Substrates

BACHELOR OF ENGINEERING DEGREES

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

Ahlmann-Ohlsen, Elisabeth
New laccases from metagenomic libraries

Beinthin, Anders
An Investigation of Single Use Reactor Technology

Bloch, Cæcilie Sejr
Construction of process control equipment and commissioning of a high temperature pilot plant

Franksen, Kirstine Hjort
Design, simulation, and optimization of promoted CO_2 capture processes

Holm-Petersen, Jakob
Design of Horizontal Distillation Systems

Jannerup, Mikkel Reple
Horizontal distillation

Javanmiri, Kaywan
Novel chemo-enzymatic cascade for the synthesis of epoxides using oxygen gas as oxygen donor

Jónsdóttir, Ágùsta Maren
Process simulation and monitoring of plant performance

Jørgensen, Jesper Skovby
An Investigation of Single Use Reactor Technology

Køhler, Pernille Staal
Selection and test of stabilizers and beta-glucans in cereal based beverages

Læssøe, Anders
Design of Horizontal Distillation Systems

Meyer, Kristian
Separation of Multi Component Mixtures

Moulud, Tolla
Modelling of the flow during a sugar crystallization process

Munck, Katrine
Evaluation and Comparison of Simulation Models for LNG Vapor Dispersion

Møller, Nanna Sloth
Selenium Removal from Waste Water

Nielsen, Niklas Kijak
Design of a Desorption Column for Removal of CO_2 from Flue Gas

Nørgaard, Daniel Stender
Selection and test of stabilizers and beta-glucans in cereal based beverages

Ortind, Elma á Gelini
Adsorption of selenium and arsen ic from waste water

Petersen, Morten Nedergaard
Additives for KCl Control in Biomass Combustion

Rabbany, Jasmin Soheila
Thermodynamic Modeleing of CO_2 Capture using Amino Acid Salt Solutions

Raun, Kristian Viegaard
Reaction and kinetics of adiabatic prereforming of propane

Sahlertz, Iggy Vincent
Design of a Desorption Column for Removal of CO_2 from Flue Gas

Sørensen, Kim Flugt
Characterisation of working mechanism in novel fouling control coating technology

Tendrup, Mette Natasha
Modeling of the flow behavior in a sugar centrifugal

Tulinius, Nikolaj Frederiksen
Optimization of Bag House Particle Filtration in Producer Gas from a LT-CFB Gasifier

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Advisory Board
Student Committee
Staff
Industrial PhDs and Guests
The Faculty
Departmental Seminars 2013

ADVISORY BOARD

LARS BANG

SENIOR VICE PRESIDENT, SUPPLY OPERATIONS & ENGINEERING
H. LUNDBECK A/S

Scientific research at 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/consultants.

KIM PANDRUP CHRISTENSEN

The close cooperation with DTU Chemical Engineering has ensured significant results within the biofuel technology which will benefit a lot of industries. Long-term focus on development and innovation is necessary to meet the ever changing opportunities, rules, legislation and profitability demands that all industries are faced with. DTU Chemical Engineering ensures a high level of education, motivated candidates and industrial cooperation in important research projects that will lead to technologies of the future.

BJERNE CLAUSEN

PRESIDENT AND CEO
HALDOR TOPSØE A/S

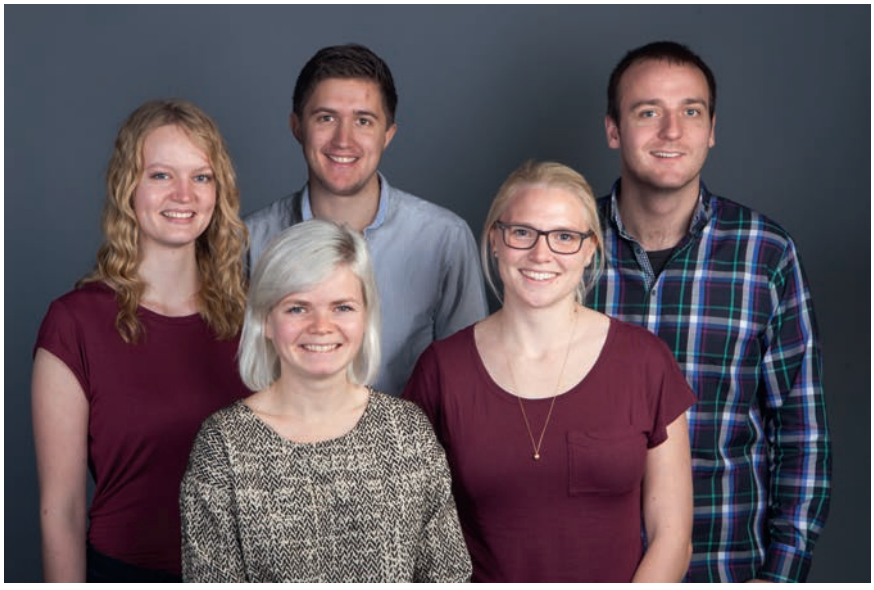
Working closely with the best research groups within the fields of our core competences is of major importance to Haldor Topsoe A/S. Our cooperation with DTU Chemical Engineering enables us to resolve research challenges beyond our competences and resources and is an important source of inspiration and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

PEDER HOLK NIELSEN

PRESIDENT & CEO
ENZYME BUSINESS · NOVOZYMES A/S

At Novozymes we see innovation-driven partnerships as a key element in delivering tomorrow's solutions. At university level we have had an exemplary cooperation with DTU Chemical Engineering for many years. This cooperation supports and complements our efforts in developing and testing new technologies, attracting new valuable employees and driving the world towards sustainability. DTU Chemical Engineering fully answers these demands.

STUDENT COMMITTEE



KTStudents is the student organization at DTU Chemical Engineering. KTStudents seek to provide engineering and non-engineering related activities for students that are part of or affiliated with the department. These activities span over a wide range and include:

1. **Company and Technical Presentations** – companies are invited to present an overview of their work and a technical lecture so the attending students have an idea of the type of R&D or engineering tasks faced at the company.

2. **Company Trips** – company sites are visited by the students. These events are normally fully funded by the companies themselves and the companies typically have production or pilot facilities which give students an image of the real world.

3. **Social Events** – The goal of these are to give students the opportunity to socialize and net-work with other students whom they would otherwise be unable to meet during the hectic semester.

4. **Research Opportunities** – This has been held by KTStudents for the past two years. The 7 research centers at the department present research opportunities at their centers ranging from BSc over MSc to PhD projects.

5. **Roundtable discussions** – This has been held jointly with the department the last two semesters. When a leading researcher visits the department, the students have an exclusive opportunity to meet the researcher and discuss a wide range of topics.

In November 2010, KTStudents became the 1st student chapter in Europe to house an American Institute of Chemical Engineers (AIChE) Student Chapter. The AIChE is the largest society for chemical engineers, offering technical information and networking for studying and practicing chemical engineers. KTStudents continues to expand with an ambitious plan in 2014 to hold our first annual one-day student conference where students from the BSc and MSc levels will have the opportunity to present their research and projects at oral and poster sessions.

Christian Bach, President,
KTStudents

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Patricio Quinteros	Visiting PhD Student	Universidad de Antofagasta, Chile
Ane Luisa Gracia Lario	Visiting PhD Student	Instituto de Carboquimica, CSIC, Spain
Gerald Striedner	Visiting postdoc	Graz University of Technology, Austria
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Shayane Pereira de Magalhães	Visiting PhD Student	UFRJ, Rio de Janeiro, Brasil
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Ping Feng	PhD student	Institute of Process Engineering, Beijing, China
Margarita González-Brambila	Visiting Professor	UAM-Iztapalapa, Mexico
Bjarne Uller	Concept Specialist	DONG Energy A/S

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Associate Professor

Per Ambus
Interim Head of Center

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Assistant Professor

Karsten H. Clement
Professor (Docent)

Kim Dam-Johansen
Professor,
Head of Dept.

Anders Egede Daugaard
Assistant Professor

Philip Fosbøll
Assistant Professor

Rafiqul Gani
Professor

Krist V. B. Gernaey
Professor

Peter Glarborg
Professor

Ole Hassager
Professor

Søren Hvilsted
Professor (Research manager)

Jakob Kjøbsted Huusom
Assistant Professor

Anker D. Jensen
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Søren Kiil
Associate Professor

Georgios M. Kontogeorgis
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Ulrich Krühne
Associate Professor

Anne Meyer
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Jørn Dalgaard Mikkelsen
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Gürkan Sin
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Anne Ladegaard Skov
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Associate Professor

Peter Szabo
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Stig Wedel
Associate Professor

John Woodley
Professor

Hanne Østergård
Research Specialist

Lars Georg Kiørboe
Technical Manager

Gitte Brandt
Head of Secretariat

Gunnar Jonsson
Associate Professor Emeritus

Sten Bay Jørgensen
Professor Emeritus

Michael L. Michelsen
Professor Emeritus
(Docent)

John Villadsen
Professor Emeritus

DEPARTMENTAL SEMINARS AT DTU CHEMICAL ENGINEERING IN 2013

FEBRUARY 21

Dr.-Ing. Andreas Bode, Senior Manager Scouting with BASF New Business GmbH

"Cooperate Strategy, Scouting and the Role of Process Engineering"

MARCH 1

Professor, Dr. Katharina Kohse-Hoeinghaus, Universität Bielefeld, Germany

"Combustion Challenges from a Chemist's View"

APRIL 16

Professor Marianthi Ierapetritou, Rutgers University, USA

"Design and Optimization of Pharmaceutical Products and Processes: Challenges and Opportunities"

MAY 23

Senior Researcher Ulrik Birk Henriksen, DTU Chemical Engineering, Denmark

"Thermal gasification of Biomass"

SEPTEMBER 19

Visiting Professor Sunil Nath, Indian Institute of Technology, India

"Analysis of Key Experiments in Oxidative Phosphorylation Leads Us Beyond the Chemiosmotic Theory to a New Concept for Energy Coupling in ATP Synthesis"

NOVEMBER 13

Professor Per Ambus, DTU Chemical Engineering, Denmark

"The use of stable isotopes to study biogeochemical and chemical processes"

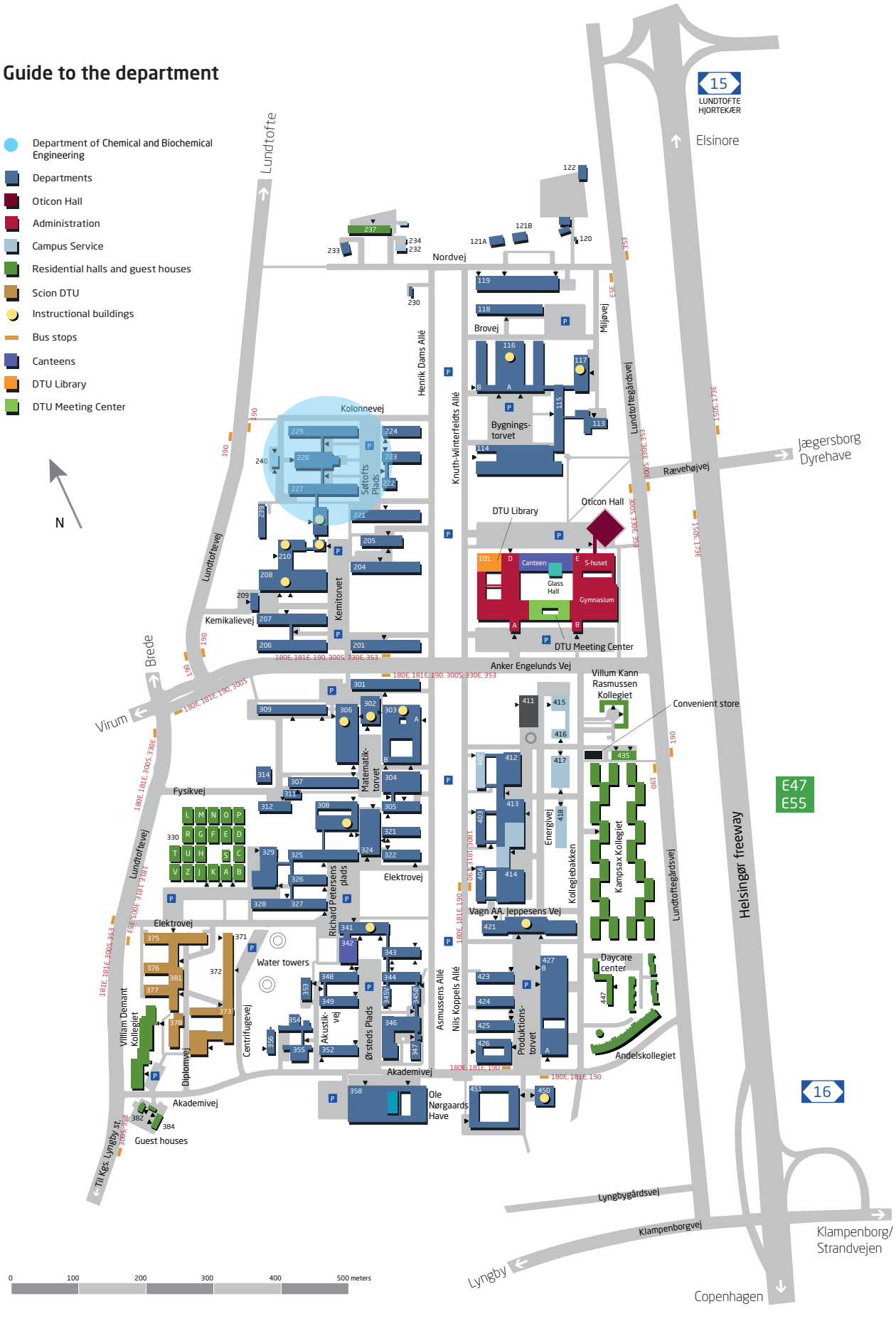
DECEMBER 3

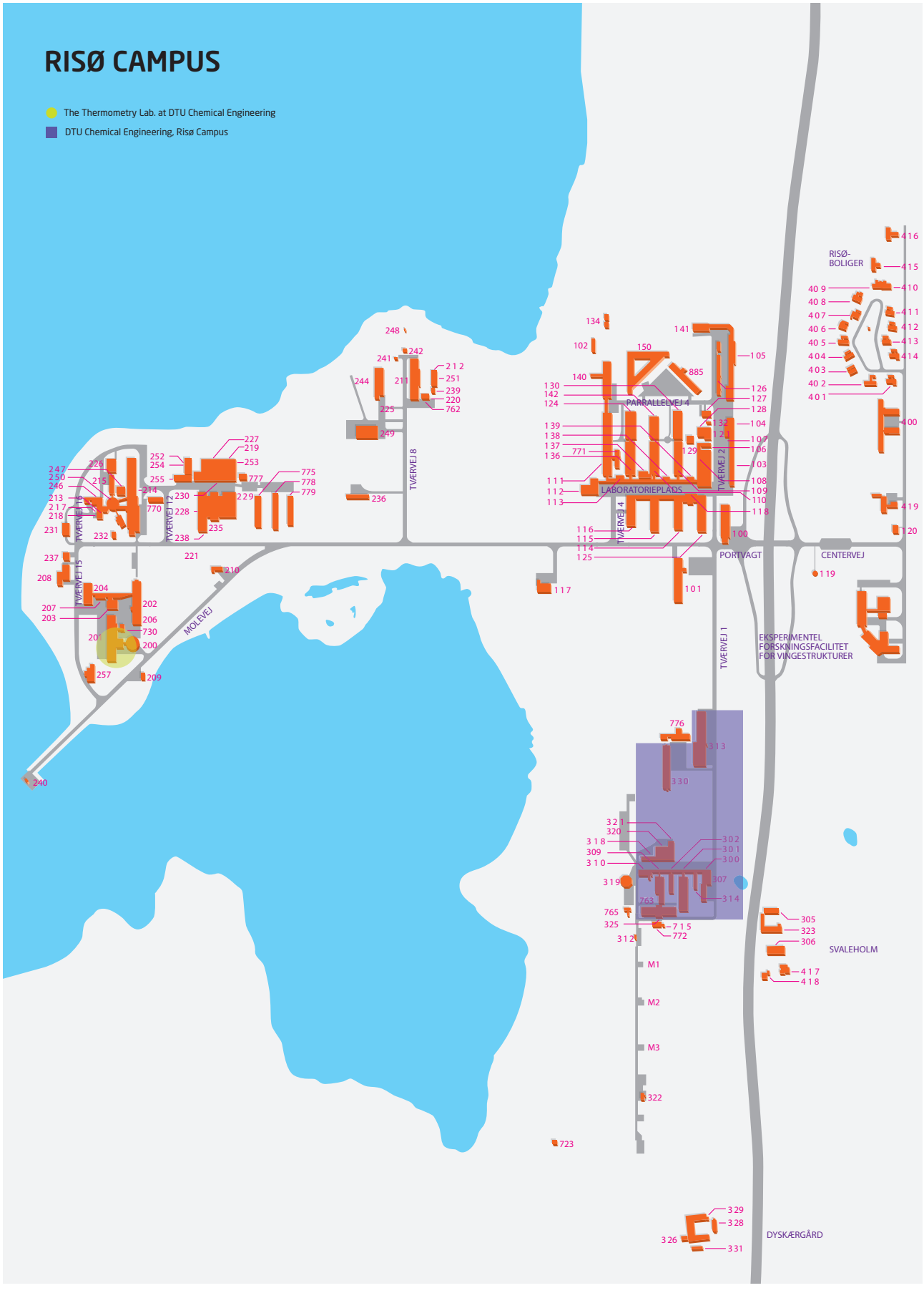
Assistant Professor, Jakob Kjøbsted Huusom, DTU Chemical Engineering, Denmark

"Process Control as a Chemical Engineering Discipline"

USEFUL INFORMATION

Guide to the department




RISØ CAMPUS
The Thermometry Lab. at DTU Chemical Engineering
DTU Chemical Engineering, Risø Campus
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BOLIGER
PARALLELVEJ 4
LABORATORIEPLADS
PORTVAGT
CENTERVEJ
TVÆRVEJ 1
TVÆRVEJ 2
TVÆRVEJ 4
TVÆRVEJ 8
TVÆRVEJ 12
TVÆRVEJ 16
TVÆRVEJ 15
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This Annual Report 2013 may be ordered from the reception at the Department of Chemical and Biochemical Engineering, DTU.

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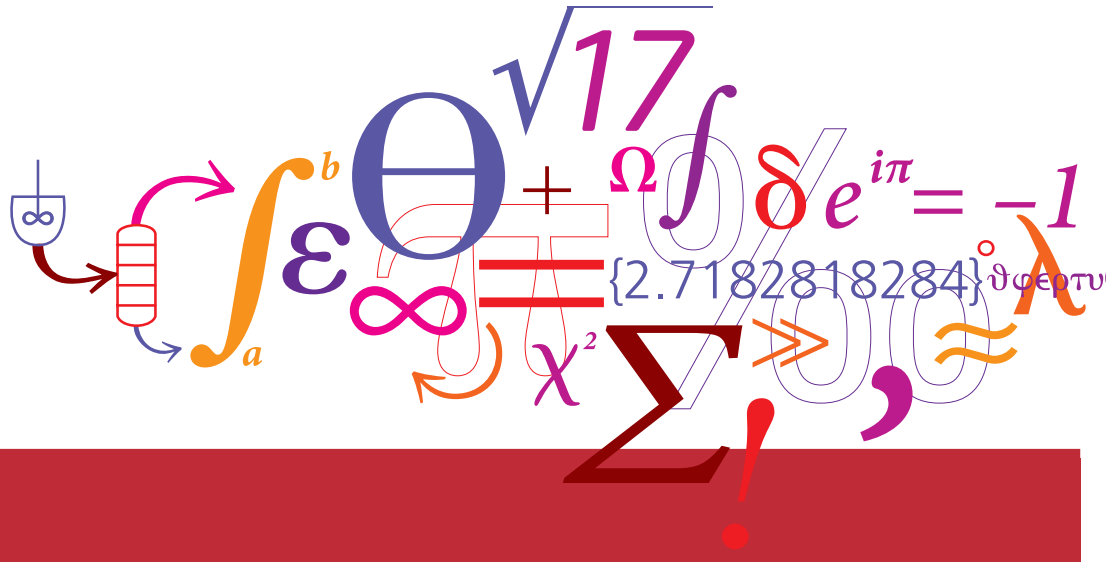
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