Technical University of Denmark

Annual Report **2015**

DTU Chemical Engineering
Department of Chemical and Biochemical Engineering

Key numbers of 2015

The vision of DTU Chemical Engineering is to be acknowledged as a world leading chemical and biochemical engineering department. Below we have listed a selection of our key results of 2015* to show how they support our strategic objectives.

STRATEGIC AREA	VISION	RESULTS IN 2015
RESEARCH	Supports the development of sustainable solutions in the fields of chemistry, biotechnology, food, pharma and energy through research and scientific advice.	**180** SCIENTIFIC ARTICLES IN WoS-INDEXED JOURNALS **7** CONTRIBUTIONS TO BOOKS **23** PHD THESES
INNOVATION	An attractive partner for university departments and research-based industry.	**10** PATENTS AND PATENT IDEAS **8** INDUSTRIAL PHDS
EDUCATION	Helps to retain, develop and attract knowledge-based national working places, including companies with affiliates abroad.	**260** STUDENTS (STÅ**) **19** COMPLETED BENG PROJECTS **78** COMPLETED MSC PROJECTS
ORGANIZATION	Attractive place to work for ambitious and technology-passionate staff members.	**31** ADMINISTRATIVE EMPLOYEES **98** PHD STUDENTS **86** SCIENTIFIC EMPLOYEES **24** TECHNICAL EMPLOYEES **4** TRAINEES **243** EMPLOYEES IN TOTAL

STAFF DISTRIBUTED BY AGE:

38% 20-29
28% 30-39
15% 40-49
10% 50-59
9% 60-69

FOREIGN SCIENTIFIC STAFF:

4% AFRICA
24% ASIA
61% EUROPE
6% MIDDLE EAST
1% NORTH AMERICA
4% SOUTH AMERICA

* 1 JANUARY - 1 DECEMBER 2015

** ONE STÅ IS THE EQUIVALENT OF ONE STUDENT STUDYING FULL TIME FOR A YEAR

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ANNUAL REVIEW

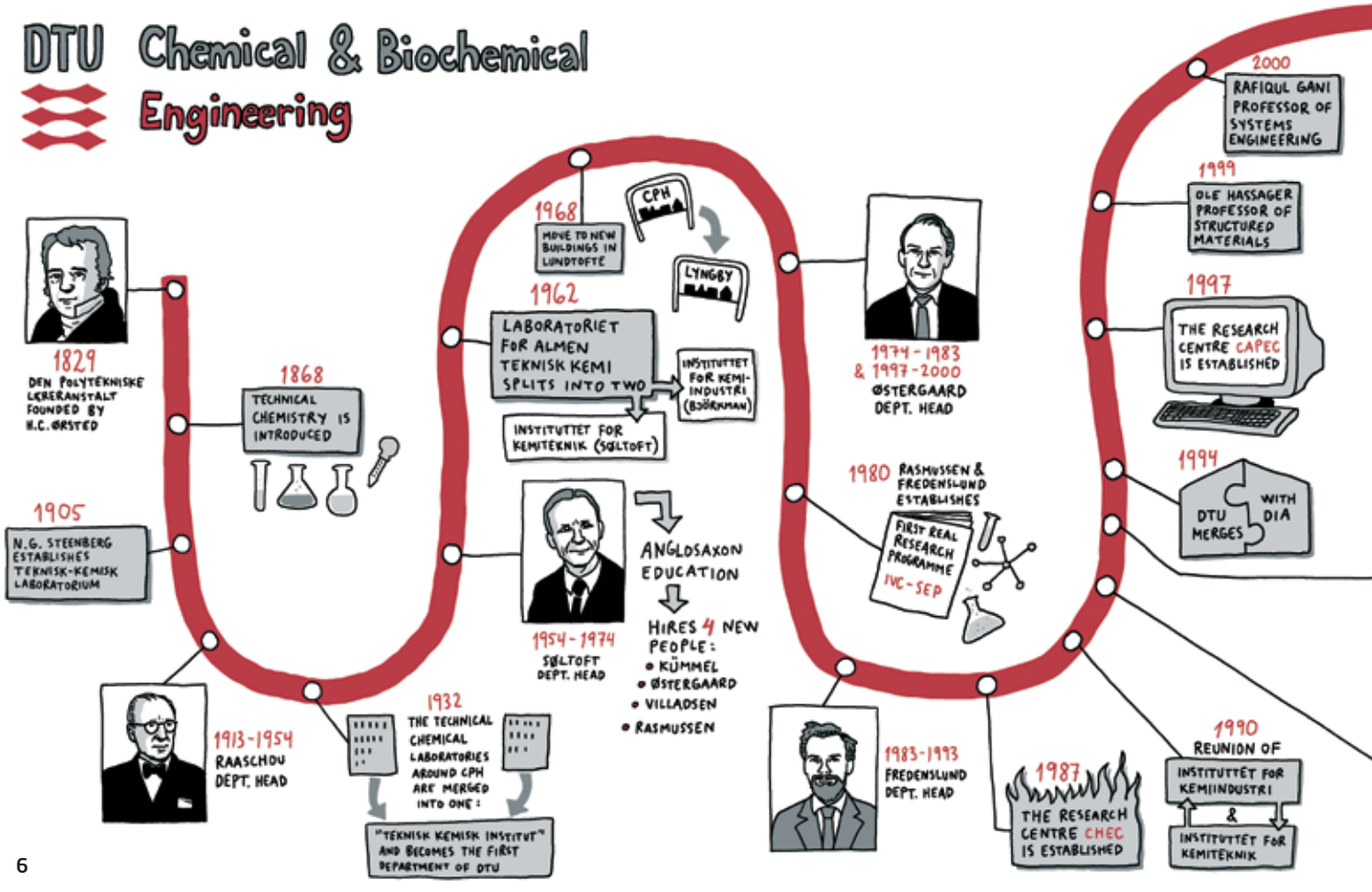
Photo: Students from the Sino-Danish Center in Beijing working in DTU Chemical Engineering's pilot plant
In all, 91 students from universities around the world visited Lyngby Campus for three and four-week summer university courses where they were challenged with designing and operating pilot plants. The majority came from the US; however, students also travelled from Singapore, Brazil, China, Spain, Portugal, and Romania.

WELCOME

Almost 150 years ago, technical chemistry was introduced at DTU, and in 1954 Professor Søltoft was employed as Head of the Department of Technical Chemistry. Eight years later, this department was separated into the Department of Chemical Industry and the Department of Chemical Engineering, which then 25 years later were successfully unified again under Professor Fredenslund – an important anniversary that we celebrated this year.

The important developments following the merger were moreover due to the work of Professor Kümmel and Professor Østergaard who headed our department before I got the honour of taking over in 2000. The early 00's were an exciting time, as DTU established itself as a self-owning university. During these years, we had a strong focus on developing the field of biochemical engineering, and in 2008 our activities in this field had grown to a size that led us to change our name to Department of Chemical and Biochemical Engineering.

Since then, our department has grown even further. We have included activities from the previous Risø National Laboratory for Sustainable Energy, and we have developed a new and efficient organization consisting of six research centres in total.



25 years since the reunification – What's next?

In 2015, we have further strengthened our organization. We have employed several new faculty members who are bringing extensive knowledge to our department and to our 260 current students. We have also set up a new Research & Innovation Committee headed by Professor Ole Hassager, and we have further developed our research by establishing a new research centre called PILOT PLANT. I would like to welcome Technical Manager Lars Kiørboe as Head of the new centre. Furthermore, I would like to welcome Associate Professor Anne Ladegaard Skov as the new Head of our Danish Polymer Centre (DPC).

During the year, we were also proud to host important conferences with a large number of delegates such as the joint PSE2015/ESCAPE25 conference, the Thermodynamics 2015 and the Nordic Flame Days 2015. In the coming year, we look forward to many more enlightening conferences, among others the PetroPhase 2016 conference in June. We also look forward to leading the establishment of new curriculums for the two Bachelor of Engineering programmes 'Chemical and Biochemical Engineering' and 'Chemistry and International Business'. Finally, we look forward to further developing our great construction project that will provide our students and employees with an improved research environment.

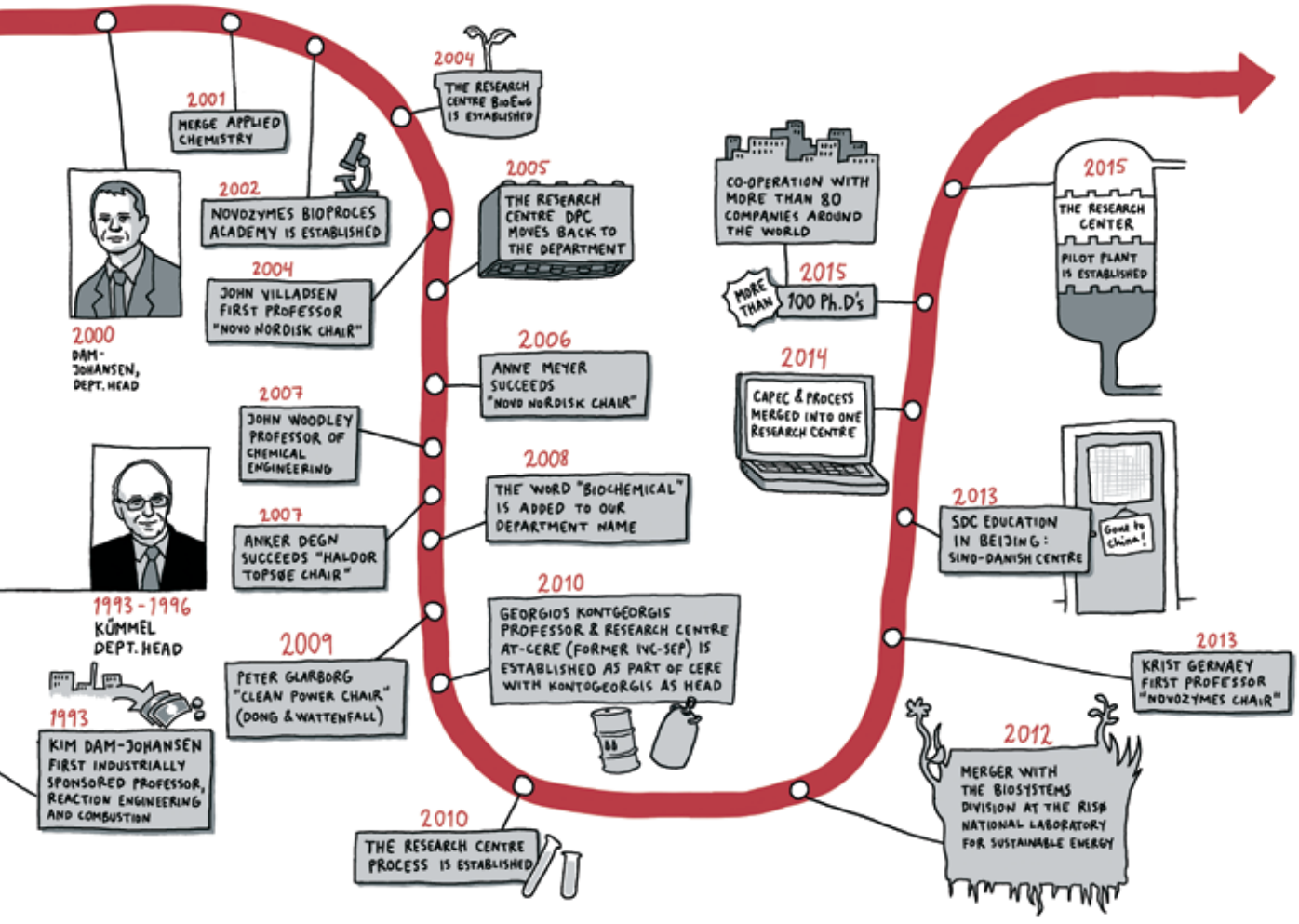
Thank you

Today, we feel more than ready to meet the many different challenges of education, innovation and research in a highly competitive environment. This is thanks to our many dedicated employees to whom I would like to express my deepest gratitude for their hard work. I would also like to thank our many national and international partners in industry and academia for making our journey possible.

This annual report offers a glimpse into this year's many exciting activities which I hope you will enjoy reading about in the following pages.

Yours sincerely,

Kim Dam-Johansen
Professor, Head of Department



HIGHLIGHTS

Photo: Minister inaugurates new fermentation facility
The ceremonial red ribbon is cut by the Danish Minister for Energy, Utilities and Climate, Lars Christian Lilleholt together with CEO of UniBio A/S Henrik Busch-Larsen and Professor John Villadsen, which marks the opening of a new fermentation facility in DTU Chemical Engineering's pilot plant. The fermentation facility is based on technology which uses natural gas in the production of protein for animal feed.

HIGHLIGHTS **2015**

JANUARY

13 January

BIOPRO COLLABORATION RECEIVES 128 MILLION

Thanks to investments from several parties – including Region Zealand, Innovation Fund Denmark, companies and universities – the BIOPRO collaboration will continue in the period 2015-2019. The objective of BIOPRO is to boost Denmark's strong position in the field of biotechnological production.

29 January ①

OLE HASSAGER - 40 YEARS IN SERVICE OF THE STATE

Professor Ole Hassager's impressive 40 years in service of the state was celebrated on 2 February where he gave an interesting look back at his long career including his time at the University of Wisconsin – Madison where he wrote his PhD thesis.

FEBRUARY

18-23 February

VISIT TO GHANA

In the beginning of this year, Head of BioEng Professor Anne S. Meyer, Project Leader Anders Thygesen, Researcher Marcel Tutor Ale and PhD student Nanna Rhein-Knudsen travelled to Ghana in connection with their newly started SeaBioGha project funded mainly by Danida. The main objectives of the trip was to visit potential coastline areas for offshore seaweed farming, collect seaweed samples and to meet the Ghanaian partners.

MARCH

06 March ②

DTU OPEN HOUSE EVENT

A record number of 2600 young people from all over Denmark visited the DTU Open House. That is 800 more than last year and a clear indication of the increasing interest in engineering educations. To inform and engage the potential students were current students from our BEng programmes Chemical and Biochemical Engineering and Chemistry and Business Economy.

APRIL

26-30 April

DPC WINS HOSTING OF ISPO 2017

Danish Polymer Centre (DPC) won the hosting of the 2017 edition of the international workshop in silicone-based polymers, ISPO. At the same occasion, Frederikke Bahrt Madsen won the award for Best Presentation by a Young Lecturer 2015.

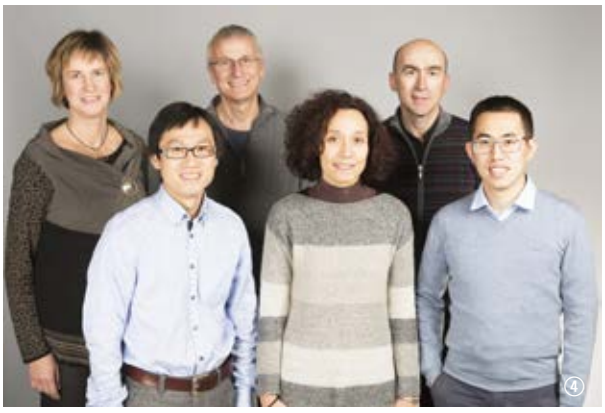
28 April ③

HEMPEL DTU PRIZE AWARDED TO 'YOUNG SCIENTISTS'

Professor and Head of Department, Kim Dam-Johansen awarded the Hempel-DTU prize to the two winners, Odense Tekniske Gymnasium and Borupgaard Gymnasium for their extraordinary effort in engaging students in science and technical subjects. The winners were handed the prize of DKK 100.000 during the Unge Forskere (Young Scientists) competition in Copenhagen.

KICK-OFF OF BLUEINNOSHIP PROJECTS

DTU Chemical Engineering participates in the large multidisciplinary project Blue INNOship, and this year we kicked off three related projects: The 'Multi Fuel Burner' project aimed at developing a multi fuel burner which can be used in marine applications fulfilling new environmental requirements for NOx, Sox, and particles; the 'Selective Catalytic Reduction of NOx on Ships' project which will to provide the tools, mathematical models, and knowledge needed for industrial partners to supply optimal and competitive SCR technology solutions for ships; and the 'Slow Steaming Anti Fouling Paint' project which aims to develop and validate new antifouling paint for slow-steaming container vessels. Collaborators in these projects are Alfa Laval Aalborg, Clean Combustion, Haldor Topsøe, Maersk Maritime Technology, and Hempel.



MAY

01 May

NEW RESEARCH & INNOVATION COMMITTEE

The Research Committee and the Innovation Committee have been unified into one. The new Research & Innovation Committee, chaired by Professor Ole Hassager, is expected to contribute significantly to the development of activities within research, PhD education and innovation across our research centres.

01-03 May

NEW PROJECT TO INCREASE OUR INDEPENDENCE ON OIL

The importance of formaldehyde is expected to increase in the transition to an oil-free society. A wide range of products such as plastics, synthetic fibers, glue and industrial chemicals can be created from formaldehyde. The project called 'Next Generation Methanol to Formaldehyde Selective Oxidation Catalysts' is funded by the Danish Council for Independent Research. It aims to develop effective catalysts with slow deactivation for the manufacture of formaldehyde by the reaction of methanol and air.

NEW FACULTY MEMBERS ④

This year, we have added several new members to our faculty: Associate Professor Hariklia N. Gavala, who is doing research in biological processing of biomass for the sustainable production of biofuels and chemicals with emphasis on fermentation technology with mixed microbial consortia and development of innovative concepts for cost-efficient bioconversions. Assistant Professor Xiaodong Liang who researches the development of the advanced thermodynamic models and numerical algorithms for homogeneous and inhomogeneous complex fluids. Assistant Professor Hao Wu who researches industrial high temperature processes with focuses on experimental and modelling of biomass and waste thermochemical processes. Associate Professor Anna Eliasson Lantz, whose research aims at finding strategies for optimization of fermentation processes and equipment with special focus on challenges related to scaling and implementation of process-analytical technology (PAT) and Associate Professor Loannis V. Skiadas whose research focuses on the development (from laboratory to pilot plant scale) of new biorefining concepts for the sustainable production of fuels and chemicals from biomasses. Furthermore, we have welcomed Special Consultant Ivan Hundebøl to our faculty, who will be co-supervising PhD students.

JUNE

30 May - 04 June ⑤

PSE2015/ESCAPE25 CONFERENCE 2015

546 abstracts, 41 keynote presentations, 191 oral presentations, 312 poster presentations and 600 participants from more than 50 countries. The numbers were high at the PSE2015/ESCAPE25 conference in Copenhagen which was hosted by the CAPEC-PROCESS research centre.

10 June

SEYED SOHEIL MANSOURI WINS TWO AWARDS AT ADCHEM 2015

After participating in the ADCHEM 2015 conference in June, PhD student Seyed Soheil Mansouri was able to travel home from Canada with no less than two awards; the Best Oral Presentation Award and the Travel Fellowship Award.

14 June

DR. BJØRN MARIBO-MOGENSEN AWARDED EFCE AWARD

The 'EFCE Excellence Award in Thermodynamics and Transport Properties 2015' was given to Dr Bjørn Maribo-Mogensen in recognition of his excellent PhD work on the modelling of electrolyte solutions. The award was presented in Athens at the European Symposium on Applied Thermodynamics (ESAT).

26 June

GREEN CHALLENGE ⑥

Students from all over the world were gathered to compete against each other in this year's Green Challenge. 138 abstracts were presented to the judges - 11 of which came from DTU Chemical Engineering. 5 of these contributions came from students of our MSc-programme at Sino-Danish Centre in China who were visiting Denmark to attend courses and visit the production sites of Novozymes, Haldor Topsøe and Hempel.

HIGHLIGHTS **2015**

JULY

01 July

NEW RESEARCH CENTRE ESTABLISHED

A new research centre called PILOT PLANT - Center for Experimental Process and Equipment Design has been established. The new centre, headed by Lars G. Kiørboe, will conduct its research and teaching in the pilot plant of DTU Chemical and Biochemical Engineering.

1 July

KICK-OFF OF SYNFERON PROJECT

SYNFERON aims to make biofuel conversion more efficient by developing a new technological platform that will advance the existent knowledge of the syngas fermentation and downstream processing of the liquids products. The project is interdisciplinary with a lot of expertise from both the academic and the industrial world. Furthermore, four of our research centres cooperates in the project, these are AT-CERE, CAPEC-PROCESS, BIOENG, PILOT PLANT. The SYNFERON project is mainly funded by the Innovation Fund Denmark.

AUGUST

15-22 August

BIOPRO WORLD TALENT CAMPUS ⑦

25 selected science talents gathered from all over the world for the third BIOPRO World Talent Campus case competition to solve some real-life challenges of Novo Nordisk, Novozymes, CP Kelco, DONG Energy and Chr. Hansen.

20 August ⑧

NOVOZYMES NAMES AWARD AFTER JOHN VILLADSEN

John Villadsen, an important figure and Professor Emeritus at DTU Chemical Engineering received the very first 'Novozymes Award for Excellence in Biochemical and Chemical Engineering'. The award will be given annually to individuals in his honour.

SEPTEMBER

15-18 September ⑨

THERMODYNAMICS 2015

For the fourth time since the early 1960s, the Thermodynamics conference took place outside the UK and for the first time Denmark was host. Organized by Professor Georgios Kontogeorgis and his team from AT-CERE, the Thermodynamics 2015 conference was well received by its around 160 participants.

25 September

CAPEC-PROCESS ANNUAL LECTURE 2015

Professor Greg Stephanopoulos from the Chemical Engineering Department of MIT a gave an insightful lecture on "The Vision of a Sustainable Bioeconomy in an Era of 50-dollar Oil" at the second CAPEC-PROCESS Annual Lecture 2015.

OCTOBER

06 October

SOCIETY OF PETROLEUM ENGINEERS (SPE) AT LYNGBY CAMPUS

DTU hosted the meeting of the Copenhagen section of the Society of Petroleum Engineers (SPE) which was organized by the Center for Energy Resources Engineering (CERE) in collaboration with the new Centre for Oil and Gas. 140 delegates from academia and industry participated.

06-07 October ⑩

NORDIC FLAME DAYS

Covering subjects such as power plant combustion, diesel engine combustion, ash formation and gasification, the 2015 edition of the Nordic Flame Days provided a solid insight into the different and significant behaviour of flames for the 120 researchers and industrial partners who participated in the conference.

⑩

⑪


⑫

30 October ⑪

FREDERIKKE BAHRT MADSEN RECEIVES THE DTU YOUNG RESEARCHER AWARD

The 'DTU Young Researcher Award' for researchers who have made an extraordinary effort and who have shown great potential for further development was given to Frederikke Bahrt Madsen for her PhD thesis. Furthermore, earlier this year, she also received a postdoc grant of DKK 3 million from the Danish Council for Independent Research for a project which aims to improve the current silicone rubbers.

NOVEMBER

01 November ⑫

ANNE LADEGAARD SKOV IS THE NEW HEAD OF DPC

Professor Ole Hassager has passed on the title 'Head of the Danish Polymer Centre (DPC)' to Associate Professor, Anne Ladegaard Skov. Anne Ladegaard Skov is specialized in elastomers with main emphasis on silicone elastomers utilized as dielectric elastomers. She has a broad knowledge on mechanical, electrical and electromechanical characterization of elastomers.

19-20 November

MODLIFE PROJECT KICK-OFF

The ModLife project aims to develop Advanced Model-Based Optimization, Monitoring and Control as Enabling Technologies for bioprocess-product development and innovation tailored for the needs in life science industries. The ModLife European Training Network will address excellence in research and training of next generation biochemical and process engineers in life sciences industries.

8-13 November

AICHE ANNUAL MEETING IN SALT LAKE CITY

Six PhD students, two postdocs, two faculty members and twelve MSc students from DTU Chemical Engineering travelled across the Atlantic to discuss and share their knowledge at the AIChE Annual Meeting 2015 in Salt Lake City in Utah. One of the PhD students, Stefano Cignitti had his paper upgraded to the plenary session of the CAST division.

DECEMBER

01 December

NEW PROJECT ON INCREASED UTILIZATION OF BIOMASS

The cell walls of plants are reinforced with lignin which constitutes 10-30% of plant biomass. The conversion of lignin is a huge challenge in biorefining of plant material. The project 'Laccase structure-function relations for enzymatic lignin modification' aims to provide a better understanding of the details of the laccase protein structure as a key to the development of efficient enzymes which can be used in practice to gently and efficiently modify lignin. The project is funded by the Danish Council for Independent Research.

2 December

NEW BOOK ON BIO-ENGINEERING

A new book entitled 'Fundamental Bio-Engineering' explains how the Biosciences and Chemical Engineering work together to create new products and procedures in Biotechnology. Published by Wiley, the book is edited by the prominent Professor John Villadsen who has moreover contributed with 8 out of the in all 16 chapters. Furthermore, Associate Professor Jakob Huusom has contributed with a chapter, making the representation from DTU Chemical Engineering quite visible.

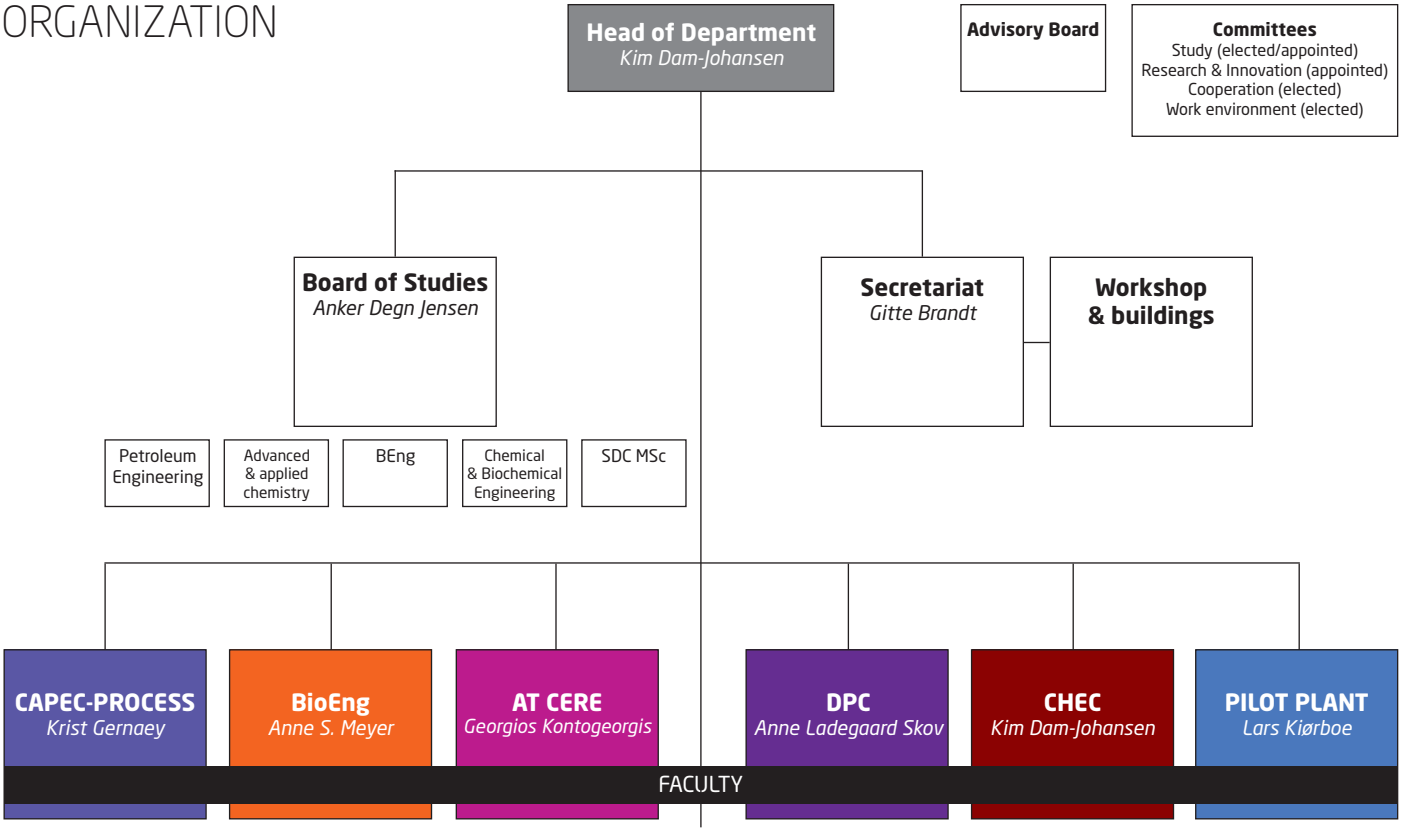
EIGHT DEPARTMENTAL SEMINARS

During this year, we have held no less than eight departmental seminars with invited speakers from industry and academia around the world. Organized by Associate Professor Gürkan Sin, the seminars were a success thanks to the interesting lectures given by Hallvard FjøsneSvendsen from NTNU, Michael Steffensen from COWI, Jinghai Li from CAS, Giancarlo Galli from University of Pisa, Ronald G. Larson from University of Michigan, Jan-Dierk Grunwaldt from Karlsruher Institut für Technologie, Gregory Stephanopoulous from MIT and Yujun Wang from Tsinghua University.

CHEMICAL ENGINEERING IN BRIEF

Photo: Employees celebrate 25 years as DTU Chemical Engineering
25th, 50th, 100th. We have definitely had our share of anniversaries, depending on which year you count from. This year, we celebrated the 25th anniversary of the important merger of the two departments Chemical Industry and Chemical Engineering in 1990.

ORGANIZATION



ADVISORY BOARD

LARS BANG

GROUP 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 partnership with DTU Chemical Engineering for several years, collaborating on PhD projects and recruiting several of the department's 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.'

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 co-operation 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, benefitting their own and the company's development.'

KIM PANDRUP CHRISTENSEN

CHIEF TECHNICAL OFFICER AT ORECO A/S

'The close cooperation with DTU Chemical Engineering has ensured significant results in 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.'

RESEARCH CENTRES

CAPEC-PROCESS

The research activities of the CAPEC-PROCESS research centre are performed in close collaboration with the chemical, petrochemical, pharmaceutical, and biochemical industries and are divided into two areas:

- Process Systems Engineering (PSE), where the focus is on developing model-based tools and methods for solving complex problems in (bio) chemical products and processes
- Process Intensification and Integration (PII), where we engage in research activities comprising intensified/integrated processes that contribute to more resource-efficient processes and production concepts.

www.capec-process.kt.dtu.dk
Contact: Professor Krist Gernaey
kvg@kt.dtu.dk
Phone: +45 4525 2970

PILOT PLANT

The research activities of PILOT PLANT are based on the path from laboratory scale to pilot scale experimental processes with particular focus on industrial practice. This includes unit operations, reaction engineering, process control, process and plant design, instrumentation, automation, and industrial measuring technology, but also topics such as scale up and scale down as well as batch versus continuous processes. Special focus areas are fermentation – mainly from a process point-of-view, but also innovative technology and particle technology.

www.kt.dtu.dk/research
Contact: Lars G. Kiørboe
lgk@kt.dtu.dk
Phone +45 4525 2857

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 modelling. The centre is committed to performing high-quality experimental and theoretical research with international impact. There is extensive collaboration, first of all within CERE and DTU Chemical Engineering, but also with universities and industries around the world. It shares industry consortium with CERE, which in 2015 included 31 companies, of which 23 were international.

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

BIOENG

The mission of BioEng is to conduct research that provides new knowledge, new enzymes, and new innovative process strategies for resource utilization, industrial bioconversion processes, and new products supporting a sustainable development. The centre is also dedicated to hatching top-qualified MSc and PhD candidates through research-based teaching and structured supervision.

www.kt.dtu.dk/research
Contact: Professor Anne S. Meyer
am@kt.dtu.dk
Phone: +45 4525 2800

CHEC

The research activities of CHEC cover industrial high-temperature processes, emissions control, catalysis and catalytic processes, particle technology, coatings, and production. Furthermore, the main disciplinary research is within reaction engineering and transport processes and cover theoretical modelling 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.

www.kt.dtu.dk/research
Contact: Professor Kim Dam-Johansen
kdj@kt.dtu.dk
Phone: +45 4525 2845

DPC

The vision of the Danish Polymer Centre (DPC) is to serve society by training candidates for the polymer industry and for the public sector. The centre is devoted to the application of molecular design, synthesis, and processing of polymers to create materials and products with unlimited ranges of properties and applications. DPC strives towards this goal in a balanced environment of education, research, and industrial cooperation.

www.kt.dtu.dk/research
Contact: Associate Professor Anne Ladegaard Skov
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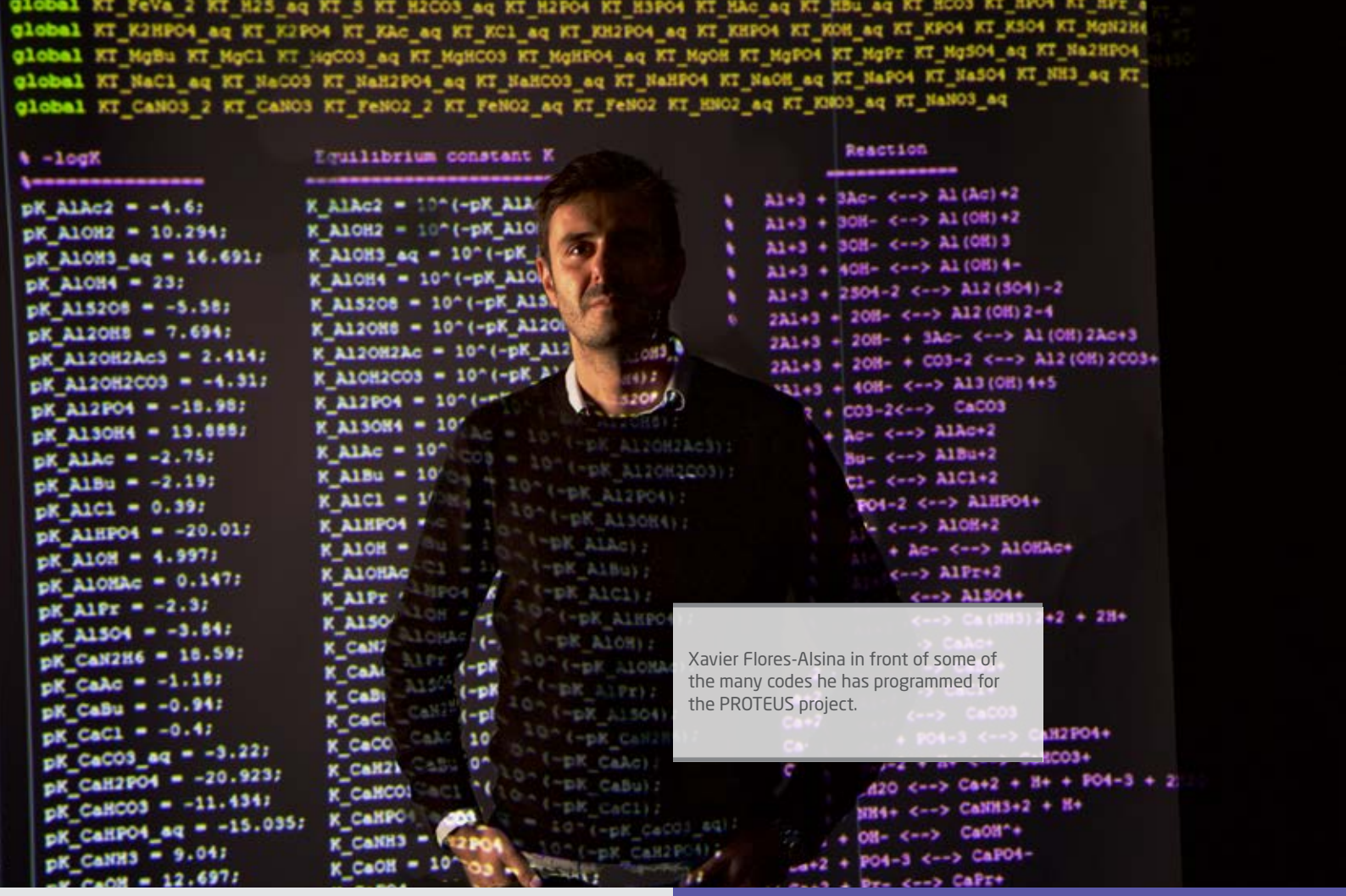
COOPERATING COMPANIES

A.P. Møller-Mærsk
A/S Einar Willumsen
Akzo Nobel
Alfa Laval
Aminord
Aquaporin
Arla Foods
AstraZeneca UK Limited
B&W Energy
Babcock & Wilcox Vølund
Bang & Olufsen
BASF AG
Bayer Technology Services
Biomatics Technology
Biomodics
BP
Calsep
Chevron
Chr. Hansen
Coloplast
Conocophillips
Dana Lim
Dansk Gasteknisk Center
DONG Energy
DSM, Viktor Wallimann
DuPont
Emmelev
Eni
Envidan
ExxonMobil
Firmenich
FLSmidth
Foss
GASSCO
GASSNOVA
Genel Energy
GlaxoSmithKline
Grundfos
H. Lundbeck
Haldor Topsøe
Harper & Vedel
Hempel
Hess
HOFOR
Huntsman Europe
Hwam
IFP
Janssen Pharmaceutica
KBC
KMC
LEGO
Linde
Lloyd's Register ODS
Lonza AG
Maersk Oil
MAN Diesel & Turbo
Mitsubishi
National Oilwell Varco
Neste Jacobs Oy
Nordic Bioenergy
Novo Nordisk A/S
Novozymes A/S
OMV
Optience Corporation
Palsgaard
Petrobras
Pfizer
PPG Industries
Processium
ProSim
Radiometer Medical
RWE
SCG Chemicals Co.
Schlumberger
Schneider Electric
Shell
Sinopec
SQM
Statoil
Syngenta
Tetra Pak Packaging Solutions
Total
Unibio
Union Engineering

RESEARCH & INNOVATION

Photo: Founder of HWAM, Vagn Hvam Pedersen together with Senior Advisor Jytte Boll Illerup
A more environmentally friendly wood-burning stove with a remote control that allows you to set the room temperature and alerts you when it is time to refuel - the first electronically controlled wood-burning stove is on the market. The stove ensures optimal combustion by controlling the combustion air electronically via regulation of three independent air inlets. © Joachim Rode



Xavier Flores-Alsina in front of some of the many codes he has programmed for the PROTEUS project.

PROTEUS funding and partners

The project was sponsored by Marie Curie Actions: International European Fellowships (IEF) for career development and hosted by the Department of Chemical and Biochemical Engineering at the Technical University of Denmark (DTU) with extensive collaboration with other research centres, including:

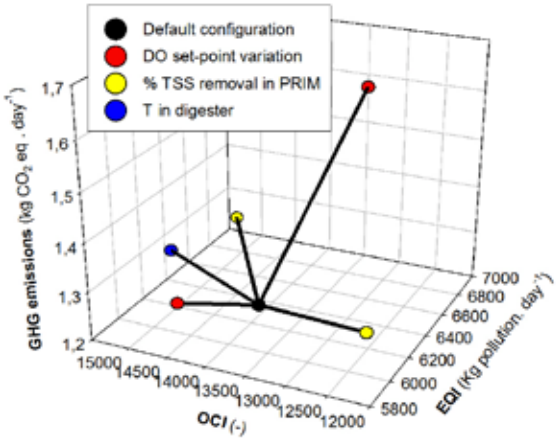
- inside DTU (Department of Environmental Engineering)
- in Europe (Lund University, Sweden / Catalan Institute of Water Research, Spain)
- outside Europe (University of Queensland, Australia / University of Cape Town, South Africa)
- Specialized Groups of the Internal Water Association (IWA) (physicho-chemical framework, greenhouse gas emissions, benchmarking control strategies on wastewater treatment plants).

PROTEUS outcomes: Software prototypes

The software is used for consultancy, research and it is further developed. Below are the prototypes and final users:

- greenhouse gas emissions (BSM2-GHG): Catalan Institute of Water Research (Spain), Lund University (Sweden), University of Exeter (UK), Stockholm Water (Sweden), IVL (Sweden)
- micro-pollutants (BSM1-MICRO): Catalan Institute of Water Research (Spain), Lund University (Sweden), University of Lorraine (France)
- nutrient recovery (BSM1-pH / BSM2-PCM): University of Lund (Sweden), University of Queensland (Australia), Josef Stefan Institue (Slovenia), University of Cape Town (South Africa), INRA (France), Bioentech (France), EAWG-ETH (Switzerland), Veolia (France).

In Greek Mythology, Proteus is the god with the ability to transform water. In the world of science, the PROTEUS project is all about the same. The mastermind behind it, Xavier Flores-Alsina, has proposed a new set of mathematical models that will assist process engineers in turning wastewater into a clean and sustainable supply of resources.



New mathematical models will help clean and recycle your water

'Out of sight, out of mind.' The vision for wastewater treatment has largely revolved around these six words, but times are changing, as the increasing demands for water and energy and their related costs push the scientific community to change its vision. Instead, wastewater is seen as a valuable resource with great potential: Water can be reused to minimize the impacts of exploiting new sources of supply. Nutrients, such as phosphorus, can be recovered in various forms for use in agricultural fertilizers. Energy, in the form of heat and electricity, can be extracted from organics in the wasterwater via anaerobic digestion to offset the power demands of the treatment facility.

This year, Xavier Flores-Alsina, a former Marie Curie Research Fellow at the CAPEC-PROCESS research centre, finished his development of a new set of mathematical models which describe exactly these resource recovery challenges. The name of his Marie Curie project was PROTEUS (PROcess models to simulaTE, benchmark and control Urban wastewater treatment Systems).

According to Xavier Flores-Alsina, the PROTEUS project will have a very positive impact within the water industry as engineering companies make extensive use of wastewater treatment models for design optimization and control of water treatment facilities.

The models should be available for everyone

The new set of models will help make these processes more efficient in terms of improving effluent quality, reducing energy consumption, increasing energy recovery and finally minimizing greenhouse gas emissions. As such, the model library offers great potential to a wide audience of professionals.

'It's very important for me and the research group to make the models available in order to increase international exposure. We distribute these models to support decision-making among water professionals, process managers and environmental engineers around the world,' says Xavier Flores-Alsina.

He expects that many of the new models will also be implemented by specialized software companies. The models will be integrated into software packages that will allow users to evaluate and explore new ways to operate wastewater treatment facilities by developing, implementing and simulating new plant-wide control strategies and operational procedures.

In addition, the models will play an important role in education. According to Krist Gernaey, Head of the CAPEC-PROCESS research centre, Xavier Flores-Alsina's research work has first of all demonstrated the growing importance of mathematical modelling and the use of chemical engineering methods and tools to the wastewater treatment field.

'By distributing the models resulting from the PROTEUS project, CAPEC-PROCESS has become one of the leading groups in this field. In future, we expect Xavier to further develop this area and to establish a small research team within the centre with focus on resource recovery,' says Krist Gernaey.

Strong international collaboration made it possible

Xavier Flores-Alsina stresses that international collaboration was a key factor for the success of the PROTEUS project. During the development of the project, he had research stays at the University of Queensland in Australia and the University of Cape Town in South Africa and also collaborated with Lund University and several Specialist Groups of the International Water Association (IWA).

In general, he feels that his international experiences have brought him far. In particular, they played a big role in 2013 when he got the exciting news that his PROTEUS project was awarded within the competitive Marie Curie Actions call for Intra-European Fellowships for career development.

'I think my strong international background and long history of collaboration with many different universities from different countries were crucial to get the grant. For example, all my publications involve at least three research groups and I did my PhD between the University of Girona in Spain, the University of Oxford in the UK and DTU in Denmark,' says Xavier Flores-Alsina.

< The figure shows a tree dimensional representation of different wastewater treatment operational procedures. The different axes represent effluent quality (x), economical cost (y) and greenhouse gas emissions (z), all of which are quantified by the models developed within the PROTEUS project.

The employees of the new research centre PILOT PLANT in their natural habitat – the DTU Chemical Engineering's pilot plant. From the left: Associate Professor Anna Lantz, Head of PILOT PLANT Lars Kiørboe, Associate Professor Loannis Skiadas, Technician Ann Marie (Mie) Andersson, Special Consultant Ivan Hundebøl, and Laboratory Technician Ingelis Larsen.

Main activities of PILOT PLANT

The large scale experimental process activities of PILOT PLANT will be conducted with a strong focus on industrial practice. As a result, the main activities include unit operations, reaction engineering, process control, process and plant design, instrumentation, automation and industrial measuring technology, scale-up and scale-down as well as batch versus continuous processes. Special focus areas are fermentation mainly from a process point-of-view and particle technology.

Current projects

The project portfolio of the PILOT PLANT research centre currently includes participation in projects on, for instance, microbial conversion of slaughterhouse waste, syngas fermentation and downstream processing of the liquids products, along with fermentation experiments for the new bio-tech cluster BIOPRO.

Technical competences:

- Designing and building large scale plants (engineering, construction)
- Unit operations (theory and practice)
- Industrial chemical processes (designing the entire process)
- Operational experience, solving practical process problems
- Project management
- Plant safety
- GMP (Good Manufacturing Practice)
- Wide industry contact

This year, a new research centre has been established at DTU Chemical and Biochemical Engineering. The centre, with the eloquent short name PILOT PLANT, will be doing research in and teach experimental process and equipment design – and that is good news for students, researchers and companies.

A new research centre for experimental process and equipment design

Whenever a new medicine is invented or a new way of turning biomass into chemicals, materials or energy sees the light of day, it is the result of a process. More often than not, this process is highly complex and consists of many unit operations and reactions each playing a specific and important role in creating the perfect mix of process conditions. In food and pharma for instance, reliability in the process is essential as even a slight change may cause danger to the consumer. Similarly, production safety is critical in order to avoid causing harm to plant workers or to the environment. The new research centre aims to improve these processes by giving students, researchers and companies an opportunity to test them in real-life conditions in pilot plants.

A pilot plant with state-of-the-art facilities

The research centre may be new, but the pilot plant in which it operates is not. In fact, the pilot plant is the result of a long strategic process. For many years, DTU Chemical Engineering has invested in developing its pilot scale facilities with state-of-the-art equipment.

'While other universities were cutting their investments in pilot plants, we were increasing our efforts, and that means we have some quite unique facilities today. And, the large scale facilities are really needed,' says Head of the new PILOT PLANT research centre, Lars Kiørboe and continues, *'Too many ideas never go beyond laboratory level because of practical problems associated with upscaling and full-scale implementation. Many processes are not implemented in an optimal way because of lack of know-how.'*

According to Lars Kiørboe, SMEs can also benefit from the new research centre as they often do not have the opportunity to establish pilot plants whenever they need to test a new process. At the PILOT PLANT research centre, SMEs will get access to a wide range of units staffed with experts. By providing access to research facilities and expert knowledge of industrial processes, the new research centre aims to help improve the market positions of the partners of DTU Chemical Engineering.

'Our research is aimed at improving existing industrial processes by making them more efficient, more economical and, not least, greener. In this way, we hope to contribute to making our industrial partners more competitive,' says Lars Kiørboe.

Programmes that put theory into practice

According to Lars Kiørboe who together with his team of colleagues from PILOT PLANT teaches courses in unit operations, the competitiveness of the industry will not come only from researching processes – the processes also have to be operated properly. That involves educating competent engineers that are not notoriously tied to their desk. Therefore, the courses that are conducted at the pilot plant have a strong focus on practical application. Furthermore, the purpose of the courses is to make sure that future engineers have the necessary practical background in terms of knowing how processes are connected, how to design and construct processing plants, equipment and components and how to work with large plants themselves.

'It's the combination of theory and practice that makes a real difference, because the engineers that we're educating are ready to go straight to work, and that will be a great benefit for companies now and in the future,' explains Kiørboe.

< 91 students from all over the world attended the three and four-week courses of this year's Summer University where they were taught how to operate pilot plants and utilize the results for design and scale-up purposes. Photo by Rasmus Højmark Ravn

Christine Malmos Perfeldt (right) shows a sample of 'frozen' gas hydrates that have been under pressure in the stirred cell for 24 hours.

Close-up on ignited gas hydrates also known as 'burning ice'.

Gas hydrates can seriously threaten the recovery of oil and gas from the seas as they can block the transmission lines leading to a stop in production – or worse – an explosion. New research shows that antifreeze proteins from fish combined with lower solid surface tension in the pipelines can ensure a continuous flow and at the same time reduce the use of toxic or hazardous chemicals.

- The BioRec programme runs from 2011 to 2016. Funding is provided by the Innovation Fund Denmark and by the industry partners.
- Partners of the BioRec programme are: DTU, the Danish Institute of Technology (DTI), the world's leading enzyme producer, Novozymes, and the two Danish energy corporations Maersk Oil and DONG Energy. Roskilde University was also a partner in BioRec. Their task was to supply protein and to upscale the insect protein production.

Fish and insects may save the oil industry barrels of money

There is still much oil and gas to be found in the underground; however, retrieving it calls for new technologies. The BioRec project investigates how microbes and enzymes may be used to enhance oil recovery, how to avoid microbially induced corrosion, and whether antifreeze proteins can be applied for inhibition of gas hydrates in the pipelines. The last-mentioned research objective was realised this year through a PhD project by Christine Malmos Perfeldt.

Gas hydrates are formed when the transmission lines are exposed to the high pressures and low temperatures of the sea. The gas molecules are trapped inside 'cages' of frozen water molecules creating substances resembling ice that can block the lines. To avoid gas hydrates, oil producers are often left with a choice between using toxic and highly flammable chemicals or so-called kinetic inhibitors such as water-soluble polymers. Although the kinetic inhibitors may be a more sustainable solution, they are not allowed in the North Sea.

Proteins instead of polymers

Some plants, bacteria, fish, and insects, especially in arctic and other low temperature regions, develop a special protein that prevent them from freezing solid when temperatures drop to extreme lows. Antifreeze proteins from fish are already used commercially in, for instance, the food industry for preventing the formation of ice crystals in frozen vegetables. However, as Perfeldt's work shows, it can also potentially be used as a more sustainable solution for oil recovery in the North Sea.

'I found out that the combination of the naturally occurring proteins in fish and a hydrophobic surface could significantly reduce the hydrate formation. In fact, it was just as efficient as a ten times higher concentration in weight percentage of a commercial inhibitior in a stainless steel – or non-coated – surface', explains Perfeldt.

A promising little beetle

Perfeldt's thesis also shows that the antifreeze protein from the longhorn bark beetle *Rhagium mordax* could perform as efficiently as a commercially used polymer inhibitor.

'Compared to fish that show antifreeze activity up to 1.5°C, the antifreeze activity of the longhorn bark beetle is 8°C. However, the insect protein is still too expensive to be used commercially, and more research into why it works is needed in order to potentially imitate the protein synthetically. Yet, there's no doubt that this protein shows much promise,' concludes Christine Malmos Perfeldt.

Greener tools for exploration of the big blue

According to Associate Professor Nicolas von Solms, who is also a participant in the BioRec project, greener tools for oil and gas recovery will continue to be of high priority at the AT CERE research centre.

'Oil and gas will continue to be a major part of the global energy picture for a long time. Therefore, we need methods to produce oil and gas in a more sustainable way. The search for greener gas hydrate inhibitors is part of this strategy and fits in with our ongoing research in gas hydrates, their properties, their elimination, and their uses. It also contributes to current efforts aimed at producing oil and gas using cleaner and more efficient technology,' says Nicolas von Solms.

< The antifreeze protein from the longhorn bark beetle Rhagium mordax can potentially prevent gas hydrates from blocking the transmission lines that are used for oil and gas recovery. Photo by Erlend Kristiansen

Manuel Pinelo and Hariklia Gavala discuss the technology behind the newly developed membrane that has the ability to host millions of nano-bioreactors (enzymes). Behind them is the fermentor which Hariklia Gavala uses for her research in BioEng's laboratory.

Facts about the technologies

The 'Fouling Induced Enzyme Immobilization' technique uses the support of polymer membranes as matrixes for enzyme immobilization. Once immobilized, the membrane support is coated with a layer of polydopamine, which prevents enzyme leakage and makes it possible to recover the initial permeability of the membrane. The technique is a result of BIOVALUE SPIR (Strategic Platform for Innovation and Research on Value-Added products from Biomass), in which four employees from BioEng participate: Manuel Pinelo, Anne Meyer, Lene Lange, and Henning Jørgensen.

The 'Forward Osmosis Aquaporin Membrane' technology is based on naturally occurring membrane-bound water transport proteins (aquaporins), which form channels through the cell membranes. The technology is a vital part of the Danish platform IBISS (Industrial Biomimetic and Biosensing Membranes), in which four employees from DTU Chemical Engineering are involved: Hariklia Gavala, Lene Lange, and Stavros Kalafatakis from BioEng as well as Loannis Skiadas from PILOT PLANT.

The potential of bio-based products depends strongly on how attractive they are in economic and environmental terms. New membrane technology from the BioEng research centre may be the solution needed to overcome some of the major hurdles that bio-products face.

Membranes pave the way for a brighter bio-future

The realization of a more bio-based future is well underway, but the journey toward solutions that are environmentally and economically attractive continues. For example, the use of enzymes in industrial production is often costly, while bio-based chemicals and fuels face several difficulties, which stand in the way of an attractive production.

The answers to these challenges, however, may not be far away, thanks to efforts from BioEng Research Center. The tools in question: new membrane technology concepts based on biological insight and innovative thinking, which makes it possible to enhance the stability and reuse potential of enzymes and offer highly promising solutions for water recovery in bio-refineries and reducing CO_2 levels.

The host of millions of enzymes

One of the major outcomes of BioEng's efforts is the creation of a membrane with the ability to host millions of enzymes. The foundation of this technology is the so-called 'Fouling-induced Enzyme Immobilization', a new technique developed at BioEng, which the research centre currently uses to convert CO_2 into formic acid, formaldehyde, and methanol.

The results of the technique have been positive: It increases the stability of the enzymes involved in an enzyme reaction, ensures good performance for several cycles, and allows the user to immobilize several and different types of enzymes in the same membrane. Remarkably, this makes it possible to regenerate important cofactors, which, in short, are molecules that help enzymes complete a reaction.

'Membrane bioreactors are easy to control and scale up. This makes them particularly interesting for the new generation of industrial products that are produced from metabolic pathways, a series of chemical reactions in which enzymes are costly and often require the use of cofactors,' says Associate Professor Manuel Pinelo.

A solid solution to some major bottlenecks

Membranes may also play a significant role in bio-refineries in the future. More specifically, the so-called 'Forward Osmosis Aquaporin Membrane' technology – developed by the Danish company Aquaporin A/S and tested by BioEng – could prove to be a very effective and important tool in the solution of several challenges.

In particular, substrate and product inhibition often hinder the formation of highly concentrated bio-products, such as fuels and chemicals. One of the main advantages of the 'Forward Osmosis Aquaporin Membrane' technology is the possibility to couple it to any bioconversion process that faces these difficulties in order to overcome them.

'Biological processing of biomass holds great potential for a sustainable production of bio-based chemicals and fuels, but we need to resolve some major bottlenecks in order to reach an environmentally and economically attractive solution. This technology could provide a solution for water recovery and up-concentration of products while reducing the cost of the separation,' says Associate Professor Hariklia Gavala.

In collaboration with the PILOT PLANT research centre, BioEng is currently developing a process scheme that will uncover and demonstrate the potential of water recovery and recirculation in bio-refineries.

Biofouling: When microorganisms, plants, algae, or animals accumulate on the hulls of ships. Biofouling causes increased friction between the water and the ship hull. Consequently, the amount of fuel needed to sail increases, causing harm to the environment and increasing costs for the maritime industry.

Coatings research in CHEC

Research into coatings is an important part of the portfolio of the CHEC research centre which provides in-depth knowledge on current coatings performance. The centre also develops mathematical models that quantify coating behaviour and designs experimental equipment for testing coatings. The CHEC's approach is based on classic chemical engineering tools combined with formulation expertise. The usefulness of the coatings research is secured through a close collaboration with the industry.

CHEC is currently active within a wide range of coatings:

- antifouling coatings for biofouling control
- anticorrosive coatings for corrosion prevention
- intumescent coatings for passive fire protection
- erosion-resistant blade coatings for wind turbines.

People. Planet. Profit. Coatings can contribute to improving the triple bottom line of companies. Whether they are providing people with longer escape times during fires, protecting the planet from excessive CO_2 emissions from the maritime industry or preventing production stops to secure the profit of the cement industry, they are doing so as a result of extensive research. Over the years, the CHEC research centre has brought important insights to the science of coatings.

Søren Kiil places a coating sample in the High Pressure Coatings Setup in order to test its ability to withstand exposure to seawater and gases at high pressure and high temperature, simulating the conditions of oil and gas pipelines.

Coatings for the protection of triple bottom lines

In the late 1990s, CHEC initiated some of the very first projects that were to create robust coatings to protect ships against biofouling, i.e. the accumulation of microorganisms, plants, algae, or animals on the hulls during their often long voyages. Fouling represents a serious environmental and financial challenge to the maritime industry, as the fuel consumption of the ships is directly related to the level of fouling. As the surface becomes more and more rough, the amount of energy needed to carry the same speed increases.

New methodologies for testing coatings

To a company delivering antifouling coatings to the maritime industry, producing a coating that does not live up to its promise can be devastating for business. Therefore, much time goes into testing. However, according to a PhD project published this year by Asger Lindholdt, currently applied testing methods do not always paint a realistic picture, as they only include testing of newly coated ships or they are only tested in a static environment that does not account for the fact that the ships are moving most of the time.

'In reality, the coating is exposed to many different marine environments, weathers, and amounts of friction depending on how much, where and at which speed the ship is sailing,' explains Lindholdt.

Together with a team of colleagues from CHEC, he designed a raft that was placed in the murky waters of Roskilde Bay for two fouling seasons, one year in total. On the raft were cylinders with different coatings that spend approximately 60% of the time turning in order to simulate sailing, and approximately 40% of the time staying still to simulate the ship lying in harbour.

'I hope this new method will give coating companies a better opportunity to discover faults in the coatings during the early stages of testing and thereby provide their customers with more accurate guarantees,' says Lindholdt.

Lindholdt's supervisors Professor Kim Dam-Johansen and Associate Professor Søren Kiil have 34 years of experience with coatings research between them, and according to Søren Kiil the testing of coatings is quite a significant research area.

'Another project that we completed this year was on blade coatings for wind turbines. In this project, we designed and constructed an accelerated test method for rain erosion and we were able to investigate the mechanisms underlying this complex phenomenon,' says Søren Kiil and continues, *'We also have some new and exciting projects for the testing of coatings. For instance, we have recently started a large project in collaboration with FLSmidth and Hempel. In this collaboration, which is supported by Innovation Fund Denmark, we aim to design new accelerated test methods and coatings for the cement and mineral industries to meet challenges related to acids and abrasive particles as well as sticky raw materials such as moist clay and gypsum. Last, but not least, we are also investigating anticorrosive coatings for high-pressure conditions which can be used in oil and gas pipelines. In this regard, a flexible pilot plant for testing under such extreme conditions has been built and we are now starting to experiment with various gases,'* *explains Søren Kiil.*

Coatings reduce costs and improve work environments

Anticorrosive coatings are also a way for companies to reduce their costs. The annual costs related to corrosion and corrosion prevention have been estimated to make up a significant part of the gross national product in the Western world. Furthermore, apart from economic costs and technological delays, corrosion may also have dramatic consequences for people and the surrounding environment when, for instance, corrosion causes failures of bridges, buildings, aircrafts, automobiles, and gas pipelines.

Dangerous situations do not only derive from corrosion failures. In production environments, for instance, workers need to be protected in their daily work. In this connection, new research into insulating coatings and intumescent coatings can help create a safer work environment.

'This year, we have conducted projects on insulation coatings which can ensure "safe-touch" properties for workers on chemical plants and reduce heat loss from pipes and process equipment,' says Søren Kiil, who has also in the past delivered important research into intumescent coatings that, for instance, can buy people precious time whenever a fire erupts – thus underlining the broad usability and not least the importance of coatings for our people, planet, and profits.

< Asger Lindholdt working on the raft that he designed together with a team of colleagues from CHEC. The raft had cylinders with different coatings and was submerged into the waters of Roskilde Bay for two fouling seasons, one year in total.

A sample of one of the bioplastics developed by Jon Trifol Guzman. This transparent material is made entirely of cellulose and it is a sustainable alternative to petroleum-based plastic.

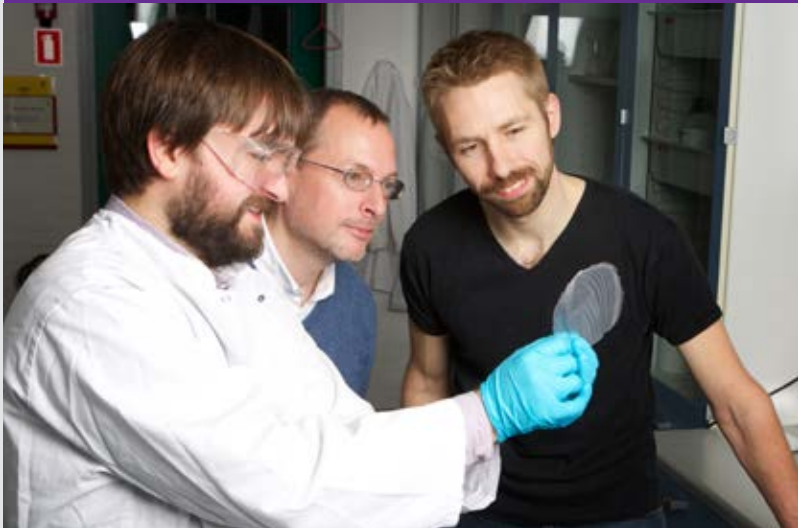
Facts about the PhD project

The project by Jon Trifol Guzman is entitled: 'Novel Clay/Nanocellulose Biocomposite Films and Coatings in the Context of New Packaging Materials' and was a project within the framework of the Marie Curie programme that was supervised by Peter Szabo, Anders Daugaard, and Ole Hassager.

The project is part of the interdisciplinary research training network, Marie Curie, which includes eight European universities – including the Danish Polymer Centre at DTU – as well as three research institutes and six enterprises.

The network received funding through the EU 7th Framework Programme. The Marie Curie PhD Fellows have developed a personal network, and the research groups have used the network to establish new projects such as the COST Action for active and intelligent packaging.

A new, more sustainable material developed by reinforcing commercial bioplastic using additives from plants such as nanocellulose and oregano extracts can solve the most common challenges of bioplastics such as brittleness, moderate barrier properties, and low heat resistance. The new material actively protects food from degradation.



Jon Trifol Guzman together with his supervisors Associate Professor Peter Szabo and Associate Professor Anders Daugaard. >

Combining nanocellulose and nanoclay to make the perfect sustainable plastic

There are plenty of arguments for investing in research into bioplastics. Especially polylactic acid (PLA) continues to show much promise for sustainable food packaging. PLA is both bio-based and biodegradable and is thus a good alternative to petrochemical-based plastics. Bioplastics made from PLA are already available in the market. Yet PLA in its pure form has important limitations, such as low thermal resistance, which makes thermoforming (fabrication of the product from the molten plastic) a challenge and limits its uses in high-temperature applications. Furthermore, without additives PLA does not provide an adequate barrier against oxygen and water in the surrounding environment, which leads to faster degradation of the food, and finally pure PLA is highly brittle. Therefore, much research is devoted to finding the right additives to PLA in order to extend its uses and make it stronger. This year, a PhD project by Jon Trifol Guzman showed interesting results that may solve these issues.

'The thermomechanical properties of PLA have already been proved to be enhanced with the addition of nanocellulose, but I wanted to find out what happens when you combine nanocellulose and nanoclay in a polymer matrix, so I extracted high-purity nanocellulose from sisal fibres by a novel, simple, and easily up-scalable process. Composites with this nanocellulose reinforced the PLA as expected, but what was particularly interesting was the dramatic synergistic effect that became evident from the combination,' explains the PhD.

Ten times faster production rate and a longer shelf-life

The combination not only made the PLA stronger, it also improved the possible production rate.

"When I investigated the hybrid composites further in terms of size and type of crystalline and amorphous domains of the polymer, I was able to explain the effect of the two fillers. What I found was that the combination not only resulted in better crystals, it also produced them ten times faster. You can imagine that this can make quite a difference in industry.'

The project also shed light on the key parameters of the controlled release of active components for use in packaging materials. In particular, the use of oregano extracts in combination with packaging materials is interesting, since oregano extracts are known to kill the bacteria that degrade the food, which means a controlled release of those compounds would potentially enhance the shelf-life of the food.

A 95-99% biodegradable plastic

The additives in bioplastics are often criticized for not being degradable. However, according the new findings, the amount of additives can be reduced quite a bit. By adding a very small amount of the two additives – actually just 1% nanocellulose and 1% nanoclay – you can greatly improve the bioplastic properties. Depending on the conditions, the improvement on barrier properties was up to 90%–and at industrial level this could be even higher, since the faster crystallization usually seen during industrial processing was not taken into account. Also, the new material was proven to have a significantly improved thermal resistance of up to 80 °C.

'Of course, nanoclay is not biodegradable, but on the other hand it is basically soil, and in such small amounts the bioplastic will still be at least 95-99% biodegradable. That means the industry is now very close to having a sustainable and useful food packaging', says Jon Trifol Guzman.

Future perspectives of DPC

According to the new Head of DPC, Associate Professor Anne Ladegaard Skov, the PhD project is a good example of the direction in which the research at DPC is going.

'In a world that seems to be running into consumption overdrive, sustainable materials are currently of high priority in the polymer society where researchers are racing against time to provide bio-based, biodegradable, and bio-sustainable products for companies and customers worldwide. DPC takes an active role in this development as partners in two EU projects and one national project where focus has been on the material development as well as material characterization. DPC holds all facilities for this and is therefore a natural partner,' says Anne Ladegaard Skov.

EDUCATION

Photo: Educator of the Year, Jakob Munkholt Christensen with students
Assistant Professor Jakob Munkholt Christensen was titled 'Educator of the Year' at the DTU Annual Party on 8 May 2015. Jakob Munkholt Christensen teaches 'Unit Operations of Chemical Engineering and Biotechnology' for two BEng programmes and 'Progress in Research' and 'SDC Summer School in Unit Operations' for the MSc programme in Chemical and Biochemical Engineering at the Sino-Danish Center (SDC) in Beijing. ©Mikal Schlosser.

Programmes at DTU Chemical and Biochemical Engineering

The department participates in two 3½ year Bachelor of Engineering programmes in Chemical and Biochemical Engineering and Chemistry and Business Economy, a three-year Bachelor of Science programme in Chemistry and Technology, three two-year Master of Science programmes in Applied Chemistry, Chemical and Biochemical Engineering, which includes an Honours programme, and Petroleum Engineering, and finally a Sino-Danish Master of Engineering programme in Chemical and Biochemical Engineering.

Our students work both theoretically and experimentally with the core disciplines in chemical engineering such as unit operations, transport phenomena, reaction engineering, mathematical modelling, and thermodynamics. They are taught by faculty specializing in these areas with applications in energy conversion, enzyme technology and biotechnology, polymers, computer modelling, process and product design.

COURSES 1 SEPTEMBER 2014 - 31 AUGUST 2015

PHD COURSES

28901	Advanced Computer Aided Modelling
28902	Process & Tools Integration
28904	Soft Matter Physics
28905	Advanced Topics in Process Systems Engineering
28908	Rheology of complex fluids
28909	Thermodynamics Models, Fundamentals and Computational Aspects
28915	Petroleum Reservoir Fluids, Properties and Production
28917	Statistical Thermodynamics for Chemical Engineering
28923	Uncertainty and Sensitivity Analysis of Numerical Models
28924	Process Engineering Laboratory
28926	Fundamentals and Industrial applications
28927	Advanced Topics in Process Technology
28928	Electrolyte Solution Thermodynamics
28930	Advances in Chemical and Biochemical Engineering
28931	Biorefinery and Sustainability

SINO-DANISH CENTER (SDC) COURSES

88700	Industrial Reaction Engineering
88701	Transport Processes
88702	BioProcess Engineering
88703	Laboratory Experiments
88704	Progress in Research
88705	Process Design - Principles & Methods
88707	Energy and Sustainability
88708	Green Chemical Engineering
88713	SDC Green Challenge
88714	SDC Summer School in Unit Operations
88715	Biorefinery

COURSES

MSC, BSC AND BENG COURSES

Below, course numbers and names are shown for 2015, with the number of students attending shown in brackets. Courses for Bachelor of Engineering are marked with a **(B)**. The other courses are Bachelor of Science courses, Master of Science courses or common courses.

SPRING SEMESTER

28001 Introduction to Chemistry and Chemical Engineering (49)
28012 Chemical and Biochemical Process Engineering (70) **(B)**
28016 Mathematical models for chemical and biochemical systems (61) **(B)**
28017 Chemical and Biochemical Process Engineering (22) **(B)**
28020 Introduction to Chemical and Biochemical Engineering (70)
28022 Unit Operations of Chemical Engineering and Biotechnology (68) **(B)**
28025 Bio Process Technology (71)
28121 Chemical Unit Operations Laboratory (22)
28122 Chemical Unit Operations Laboratory – three-week Summer University Laboratory (8)
28124 Summer course in chemical process and plant design (25)
28157 Process Design (11) **(B)**
28160 Mathematical models for chemical systems (35)
28212 Polymer Chemistry (19)
28214 Polymer Synthesis and Characterization (13)
28221 Chemical Engineering Thermodynamics (28)
28231 Laboratory in Chemical and Biochemical Engineering (28)
28270 Industrial Ecology (11)
28322 Chemical Engineering Thermodynamics (31) **(B)**
28342 Chemical Reaction Engineering (24) **(B)**
28345 Chemical Reaction Engineering (35)
28350 Process Design: Principles and Methods (42)
28352 Chemical Process Control (12) **(B)**
28415 Oil and Gas Production (51)
28423 Phase Equilibria for Separation Processes (24)
28434 Membrane Technology (43)
28443 Industrial Reaction Engineering (23)
28451 Optimizing Plantwide Control (17)
28850 Quality by Design (QbD): Integration of product and process development (37)
28852 Risk Assessment in Chemical Industry (39)
28855 Good Manufactoring Practice (60)
28864 Introduction to Matlab Programming (28)
28871 Production of Biofuels (14)
28885 Technology and Economy of Oil and Gas Production (44) **(B)**
28891 Research Immersion (1)

Courses given in co-operation with other departments:

26316 Analysis and Chromatography (40)
27944 Biotechnology and process design (34) **(B)**
41683 Materials Science (44) **(B)**

FALL SEMESTER

28012 Chemical and Biochemical Process Engineering (79) **(B)**
28016 Mathematical models for chemical and biochemical systems (45) **(B)**
28022 Unit Operations of Chemical Engineering and Biotechnology (44) **(B)**
28121 Chemical Unit Operations Laboratory (35)
28140 Introduction to Chemical Reaction Engineering (42)
28150 Introduction to Process Control (39)
28157 Process and product design (11) **(B)**
28213 Polymer Technology (38)
28233 Recovery and Purification of Biological Products (50)
28242 Chemical Kinetics and Catalysis (44)
28244 Combustion and High Temperature Process (56)
28246 Applied Enzyme Technology and Kinetics (54)
28247 Advanced Enzyme Technology (21)
28272 Engineering and Environmental Sustainability (21)
28310 Chemical and Biochemical Product Design (55)
28315 Colloid and Surface Chemistry (70)
28316 Laboratory Course in Colloid and Surface Chemistry (13)
28322 Chemical Engineering Thermodynamics (33) **(B)**
28342 Chemical Reaction Engineering (13) **(B)**
28352 Chemical Process Control (18) **(B)**
28361 Chemical Engineering Model Analysis (37)
28420 Separation Processes (44)
28515 Enhanced Oil Recovery (41)
28530 Transport Processes (54)
28811 Polymers in Processes and Products (12)
28831 Computational fluid dynamics in chemical engineering (12)
28845 Chemical Reaction Engineering Laboratory (24)
28864 Introduction to Matlab Programming (26)
28870 Energy and Sustainability (91)
28872 Biorefinery (26)

Courses given in co-operation with other departments:

23522 Rheology of food and biological materials (8)
26010 Introductory Project in Chemistry (62)
27004 Health, Diseases and Technology (59)
27944 Biotechnology and process design (11) **(B)**
41657 Materials Science for Chemists (46)
41683 Materials Science (22) **(B)**

BACHELOR OF ENGINEERING DEGREES

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

Abatzis, Jimmie	SmartWater Flooding
Abdulrahman, Tareq	Scale up of Pharmaceutical Ethanol Production
Arp, Nadia Hedegaard	Modeling of SLE for salts in mixed solvents
Bjerregaard, Matias Falk	Crystallization of $AlC1_3.6H_2O$ in acidic leaching of Anorthosite
Bülow-Nielsen, Martin	Comparison of three electrolyte models for the carbon capture with aqueous ammonia
Foelsby, Jonas Richard	Modeling of the Thermal Conductivity of Salt Solutions
Gahozo, Maria Ange	Sulphur dioxide removal from marine exhaust
Ghazvini, Mohammad Shabani	Sensitivity Analysis of Production of Pharma Grade Ethanol
Kadir, Zryan A	Improvement of the Production Sanitation in Hollow Fibers Ultrafiltration System
Knudsen, Rikke Kirstine	The influence of additives on the thermal properties of PLA
Larsen, Michael Roland	Acidic Leaching of Anorthosite
Leth-Møller, Søren	Selenium removal from wast Water - an experimental study
Munyambuga, Zack Ezechiel, and Merve Ocal	Experimental and Numerical Study of the Behaviour of Enzyme Catalyzed Reactions in a Microreactor
Rasmussen, Tanja Nørgaard	Sugar crystallization, experimental examination and implementation of inhibition
Schreiber, Jes Peter	Barrier coatings for fiber based packaging
Taleb, Moujahid Jawad Ali	Conversion of refuse derived fuels (RDFs) under calciner conditions
Westh, Andreas Gudmundsson	Preparation and Testing of 3d Printable Formulations with Controllable Mechanical Properties
Özbölük, Yasemin	Analysis of Fouling in Hollow - Fiber

MASTER OF SCIENCE DEGREES

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

Aarsheim, Vegard Eriksen	The effect of antiagglomerants on hydrate formation in real systems
Afzal, Mamuna	Experimental Study of Enzyme Applicability for Enhanced Oil Recovery
Ahkami, Mehrdad	Smart waterflooding of petroleum reservoirs: verifying the models with experimental data
Ahlmann-Ohlsen, Elisabeth	Enzymatic degradation of tattoo inks
Akhtar, Anam	Characterization of polymer properties as a function of E-beam irradiation dosage
Al Baiati, Ammar Saheb Jaafar	Diffusion Modeling
Almoor, Karim	Thermodynamic Modeling of CO2 Capture Process Based on Amine Mixture
Amiri, Zohreh	Anticorrosive coatings and interlayer adhesion loss
Amundsen, Aleksander Fjaerestad	MEOR: Modeling and numerical simulations
Andersen, Casper Ørsø	Chitosan encapsulation of enzymes for detergents
Andersen, Hans Erik Samuel	HCN synthesis with bimetallic alloys
Andersen, Patrick Alexander Schjøtt	Computational Fluid Dynamic Modeling of a Novel Rotating Flow Cell
Andersen, Simon Koefoed	Kinetics for carbon formation in prereforming
Ásgeirsson, Thorvaldur Tolli	Modeling gas separation in polymer membranes
Bach, Christian	Modeling of Crystal Dissolution in Downstream Processes of Enzymatic Proteins
Balzarotti, Riccardo Angelo Carlo	Pretreatment of Sugarcane Bagasse – Ensiling and Hydrothermal Pretreatment
Beljaev, Peter	Continuous purification of protein
Benicek, Jakub	Application of emulsion-forming enzymes for enhanced oil recovery
Bjerregaard, Rikke	Synthesis and Test of Alternative Diesel Oxidation Catalysts
Bøttcher, Andreas Emil Ege	Preparation of High Capacitance PDMS Elastomers
Carrasco Vidiella, Joan	Enzymatic biodiesel processing
Christensen, Steen Müller	Performance of combined diesel particulate filter and SCR
Colom, Juan-Manuel	Vanadium catalyzed oxidation of SO_2 to SO_3

MASTER OF SCIENCE DEGREES

Daugbjerg, Jesper Thorgils	New Production Methods for Intermediates used for the API Malitracene Hydrochloride
Flensborg, Julie Pauline	Microbial enhanced oil recovery
Fjellerup, Kasper	Sustainable process networks for carbon dioxide conversion
Floc H, Tanguy Martin Benjamin	Rheological Properties of Pressure Sensitive Adhesives
Gustafsson, Rune Scheldon	Development of a Laboratory model for the hGH recovery process
Gørløv, Agnete	Modelling Investigation of Steady State and Transient Fixed Bed Operation in Hydroprocessing Reactors
Hammershøi, Peter Kristen	Evaluation of CU-Chabazite and Fe-Chabazite Zeolite Catalysts for Selective Catalytic Reduction of Nitrogen Oxides with ammonia
Hansen, Morten	Phase Transition Analysis and Optimization of Natural Gas using Equation of States
Hansen, Tobias Anker	Development of a Predictive Version of the CPA Equation of State for Applications in the Chemical Industry
Hessel, Christian Evald	CPFD simulations of gas-solid in a non-reacting pilot-scale calciner
Hoang, Cathrine Le Thao Nhi	HC1 emissions from Cement Plants
Hofer, Andreas Torup	High Temperature Methane Steam Reforming Kinetics
Holm, Martin Soon Ho	Efficiency and Emission Optimization of Biomass CHP Gas Engines
Holm-Petersen, Jakob	Integration of an enzymatic reaction with NF to enhance separation between xylose and glucose
Ishøy, Jonas	Aerosol Dynamics in Sulfuric Acid Condensers
Jensen, Morten Walk	Pilot Scale Experimental Studies and Simulation of Dynamic Mode CO_2 Capture
Jørgensen, Mathias	Kinetic Model for the TIGAS process
Jørgensen, Stine Louise	Characterization of Pretreatment Liquor Oligosaccharides
Kaperonis, Apostolos	Continuous Process – Set up Design Space for a Purification Process
Koltveit, Alexander	Investigating Kinetic Hydrate Inhibition and Biodegradability of Synthetic Green Inhibitors
Kourmpetis, Dimitrios	Computer modelling of microbial enhanced oil recovery
Køhler, Pernille Staal	Investigation of the robustness of cells by examination of the effect of the physiological state when changing the process parameters
Larsen, Morten Jesper Greisen	Simulation of rate-based distillation
Lejre, Kasper Hartvig	Thermal dissociation of H_2SO_4
Lewandoski, Lotte Skotte	Evaluation of high pressure behaviour of elastomeric plugs
Li, Ning	Blade coatings for wind turbines
Lopez, Pau Cabañeros	Model-based process optimization multivariable analysis
Mahler, Peter Runge	Industrial coatings at extreme conditions
Matziaris, Konstantinos	Enzymatic biomass hydrolysate processing
Mazlom, Naka Ali Akla	Investigation of the Influence from Compounds in Inbicon Bioliquid on Fermentation
Meissner, Murray Peter	Continuous iso-butanol synthesis by *Escherichia* coli JCL260
Mejdahl, Lasse	Waste-to-chemicals – Process Integration
Mørk, Kasper Skov	High–performance Coating Solutions for Handling Difficulties in the Cement Industry
Nielsen, Anders	Promoting Pelleted and Mycelial Morphology in Filamentous Fermentation Broth
Nielsen, Anders Damgaard	Characterisation and valorisation of industrial lignin products
Nielsen, Henrik Lund	Rate Based Model Development and Simulation of CO_2 Absorption and Desorption Columns using Piperazine Promoted Potassium
Novakova, Kristyna	Laser Welding of Polymers
Nygaard, Camilla Wolff	Gasification of sewage sludge in a TwoStage gasifier
Nørregaard, Lasse	Methods for purification of fisetin
Nørregård, Rasmus	Model based monitoring of biochemical batch processes
Pedersen, Morten Nedergaard	Alternative fuels burner
Pichler, Andreas	Measurement and modelling of mass transfer in the presence of substrate gradients
Prag, Christian Vilhelm	Production of Natural Methane Hydrate by CO_2 Hydrate Swapping
Raun, Kristian Viegaard	Upscaling of a catalytic process for production of methyl lactate
Rodrigues, Diogo	Microbial Community Optimization for Electricity Generation in Microbial Fuel Cells
Silva, Diogo	Pretreatment of hamp fibers for enzyme treatment
Stummann, Magnus Zingler	Desulphurization of FCC naphta with emphasis on the removal of thiols
Sørensen, Mikael Refshammer	Processing of Rare Earth Element ore: Thermodynamic Modeling and Simulation
Tendrup, Mette Natasha	Computer-Aided Process Flowsheet Design
Unnarsdóttir, Unnur Margrét	Production of natural gas from hydrates by swapping with CO_2 and flue gas
Vest, Mads Gotha	Polymers for Skin Friendly Adhesives
Vilby, Tobias	Separation of Kanamycin B from Tobramycin by boronate Affinity Chromatography
Wiebe, Maria Meldgaard	Sustainable Process Design Through Process Intensification
Yang, Jifeng	Advanced Modeling of Bioreactors
Yue, Yingchao	Insulation coatings for steel structures

THE FACULTY **2015**

SCIENTIFIC

Jens Abildskov
Associate Professor

Jakob Munkholt Christensen
Assistant Professor

Karsten H. Clement
Professor (Docent)

Kim Dam-Johansen
Professor,
Head of Dept.

Anders Egede Daugaard
Associate Professor

Philip Fosbøll
Associate Professor

Rafiqul Gani
Professor

Hariklia N. Gavala
Associate Professor

Krist V. B. Gernaey
Professor

Peter Glarborg
Professor

Ole Hassager
Professor

Jakob Kjøbsted Huusom
Associate Professor

Anker D. Jensen
Professor

Søren Kiil
Associate Professor

Georgios M. Kontogeorgis
Professor

Ulrich Krühne
Associate Professor

Xiandong Liang
Assistant Professor

Anne Meyer
Professor

Anna E. Lantz
Associate Professor

Manuel Pinelo
Associate Professor

Alexander A. Shapiro
Associate Professor

Gürkan Sin
Associate Professor

Loannis V. Skiadas
Associate Professor

Anne Ladegaard Skov
Associate Professor

Nicolas Von Solms
Associate Professor

Peter Szabo
Associate Professor

Kaj Thomsen
Associate Professor

Stig Wedel
Associate Professor

John Woodley
Professor

Hao Wu
Assistant Professor

Hanne Østergård
Research Specialist

ADMINISTRATIVE AND OPERATIVE

Gitte Brandt
Head of Secretariat

Ivan Hundebøl
Special Consultant,
PILOT PLANT

Lars Kiørboe
Head of PILOT PLANT

EMIRITUS

Søren Hvilsted
Professor
(Research manager)

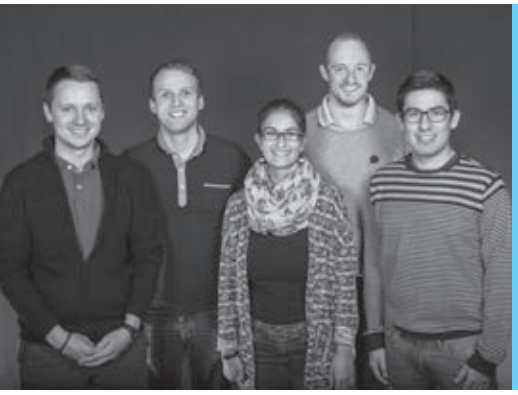
Gunnar Jonsson
Associate Professor
Emeritus

Sten Bay Jørgensen
Professor Emeritus

Michael L. Michelsen
Professor Emeritus
(Docent)

John Villadsen
Professor Emeritus

KT STUDENTS



Our student organisation, KTStudents, represents all students in the courses at the department. Its goal is to improve the study environment for students through social and professional activities.

< From the left: Kasper Israelsen, Kasper L. Berendt, Dorothee L. Kurz, Joachim Thrane, and Jorge A. Sevilla Moreno (missing from the picture are Casper Lundquist and Andreea Toderascu)

Company presentations

Companies within the chemical and biochemical areas are invited to present their daily work and challenges. The company presentations give the students a better understanding of their potential future jobs, an opportunity to network and thereby a way for the students to attain projects, internships or student jobs.

Company visits

The students are given the opportunity to visit companies within the chemical and biochemical fields. The tours around the production plants give the students insight into large-scale industry and the surrounding working environment.

Social events

Through social events, students get to socialize and network with other students. These activities especially strengthen the network between international and Danish students.

Liaison between the department and the students

In addition to providing knowledge about what a career in the chemical engineering industry entails, KTStudents also aims to help the academic development of chemical engineering students by acting as a liaison between the department and the students. We aim to expose students to research undertaken at DTU Chemical and Biochemical Engineering to generate awareness about the research centres and to facilitate a direction for BSc, MSc or PhD thesis topics.

GUESTS

NAME	TITLE	FROM
Ryoichi Nakayma	PhD student	Nihon University, Japan
Maria Teresa Lopez-Arenas	Professor	University sao Carlos University, Brazil
Alfonso Mauricio Sales-Cruz	Professor	Universidad Autonoma Metropolitana Unidad Cuasimalpa, Mexico
Tobias Orlander	PhD student	Universidad Autonoma Metropolitana Unidad Cuasimalpa, Mecico
Fabio Battini	PhD student	Huazhong University of Science and Technology, China
Sun Hyung Kim	Postdoc	Pisa UNI, Italy
Ana Teresa de Melo Machado Simoes Carvalho	MSc student	Korea Uni - Korea
Mafalda Costa Artur Dias	MSc student	Universidade de Lisboa, Portugal
Estelle Sonia Roas Garanhao	MSc student	Universidade de Lisboa, Portugal
David Chaiko	MSc student	UTL Uni, Portugal
Elena Fritzler	MSc student	Sharif University, Iran
Moises Alberto Gonzalez-Conteras	MSc student	TU - Munich, Germany
Omar Anaya-Reza	MSc student	Universidad Autónoma Metropolitana-Cuajimalpa, Mexico
Pau Cabañeros Lopez	PhD student	Universidad Autónoma Metropolitana-Cuajimalpa, Mexico
Bianca Grabner	MSc student	Graz UNI, Austria
Alberto Orsi	MSc student	Politecnico di Milano, Italy

NAME	TITLE	FROM
Viviana Vichi	MSc student	Politecnico di Milano, Italy
Edouard Moine	MSc student	Politecnico di Milano, Italy
Shuai Yang	PhD student	Girona University, Spain
Camille Marcarie	PhD student	University of Chinese Academy of Sciences, China
Thomas Cognet	MSc student	ENSIACET, France
Stephane Hoerner	MSc student	ENSIACET, France
Circui Lyu	PhD student	Chineese Academy of Sciences, China
Xun Liao	PhD student	EPFL, Schwizerland
Yujun Wang	Professor	Tsinghua University, China
Thanh Thien Nguyen	Professor	Tsinghau University, China
Salvadora Ortega Requena	PhD student	Universidad Antonoma De Madrid, Spain
Weeranut Prasertsri	MSc student	PPC Thailand
Kaesinee Petchkaekul	MSc student	PPC Thailand
Denghui Wang	PhD student	Xiàn Jiaotong Universitet, China
Yang Wang	PhD student	North China Electric Power University, China
Angel Corcoles Garcia	PhD student	Sanofi-Aventis, Germany
Xiaolong Li	PhD student	Guest PhD - Institut Technology Sepuluh Nopember, Indonesia
Shi Huang	PhD student	Qingdao Institute, China

PUBLICATIONS

Photo: Rafiqul Gani discusses his research at the BASF Science Symposium
DTU Chemical Engineering strives for excellence in research. That includes recruiting excellent researchers – one of them is Professor Rafiqul Gani for whom 2015 started out well, as he was appointed Doctor Honoris Causa at the University of Pannonia. Then, on 9 March, Gani was invited to give a lecture at the science symposium organized by BASF as part of their 150-year anniversary celebrations, and on 1 April he gave an invited lecture at the Sinopec Engineering Incorporation (SEI) in Beijing. He was then re-elected as President of the European Federation of Chemical Engineering on 25 October, and on 6 November he received his third Doctor Honoris Causa degree, this time from the University of Babeș-Bolyai. He concluded 2015 by receiving the AIChE Computing in Chemical Engineering Award on 10 November. © BASF SE.

WoS publications
1 JANUARY - 1 DECEMBER 2015

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Abu, Rohana; Woodley, John M. / **Application of Enzyme Coupling Reactions to Shift Thermodynamically Limited Biocatalytic Reactions.** Chemcatchem, Vol. 7, No. 19, 2015, p. 3094-3105.

Alberti, Michael; Weber, Roman; Mancini, Marco; Fateev, Alexander; Clausen, Sønnik / **Validation of HITEMP-2010 for carbon dioxide and water vapour at high temperatures and atmospheric pressures in 450-7600cm^{-1} spectral range.** Journal of Quantitative Spectroscopy & Radiative Transfer, Vol. 157, 2015, p. 14-33.

Alexeev, Artem; Shapiro, Alexander; Thomsen, Kaj / **Modeling of Dissolution Effects on Waterflooding.** Transport in Porous Media, Vol. 106, No. 3, 2015, p. 545-562.

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Barton, Emma J.; Yurchenko, Sergei N.; Tennyson, Jonathan; Clausen, Sønnik; Fateev, Alexander / **High-resolution absorption measurements of NH_3 at high temperatures: 500-2100cm^{-1}.** Journal of Quantitative Spectroscopy & Radiative Transfer, Vol. 167, 2015, p. 126-134.

Bensah, Edem Cudjoe; Kemausuor, Francis; Miezah, Kodwo; Kádár, Zsófia; Mensah, Moses / **African perspective on cellulosic ethanol production.** Renewable and Sustainable Energy Reviews, Vol. 49, 2015.

Boiocchi, Riccardo; Mauricio Iglesias, Miguel; Vangsgaard, Anna Katrine; Gernaey, Krist; Sin, Gürkan / **Aeration control by monitoring the microbiological activity using fuzzy logic diagnosis and control. Application to a complete autotrophic nitrogen removal reactor.** Journal of Process Control, Vol. 30, 2015, p. 22-33.

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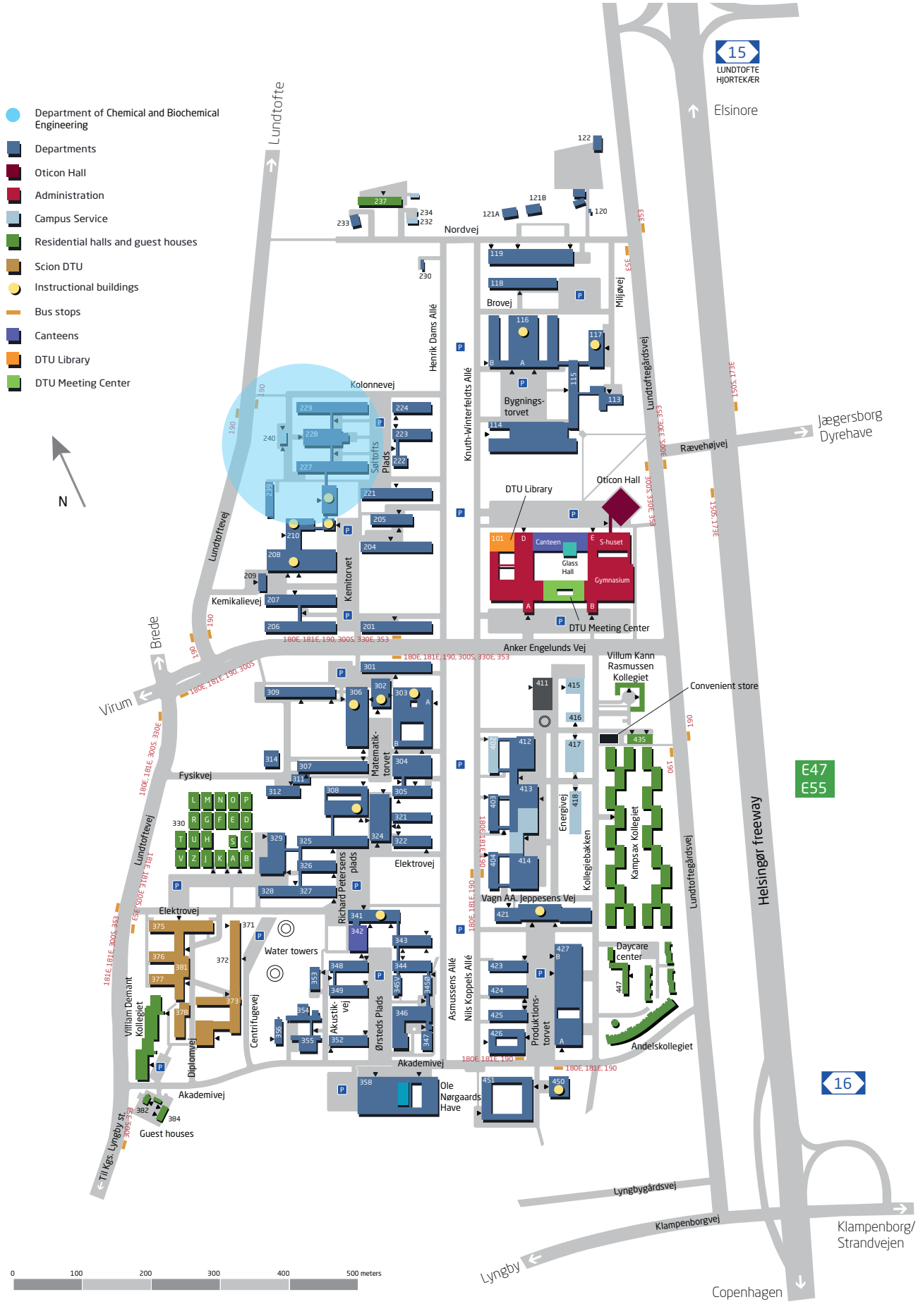
Photo: PhD students between towers of Graduate Schools Yearbooks
Anders Nørregaard, Parto Ludovica Hengeller and Soheila Ghafarneja pose among the many Graduate Schools Yearbooks in which their current work is represented. The Graduate Schools Yearbook contains abstracts from current PhD projects at DTU Chemical Engineering. The book is free of charge and can be downloaded at **www.kt.dtu.dk** or ordered in print by sending an e-mail to: **informationen@kt.dtu.dk**.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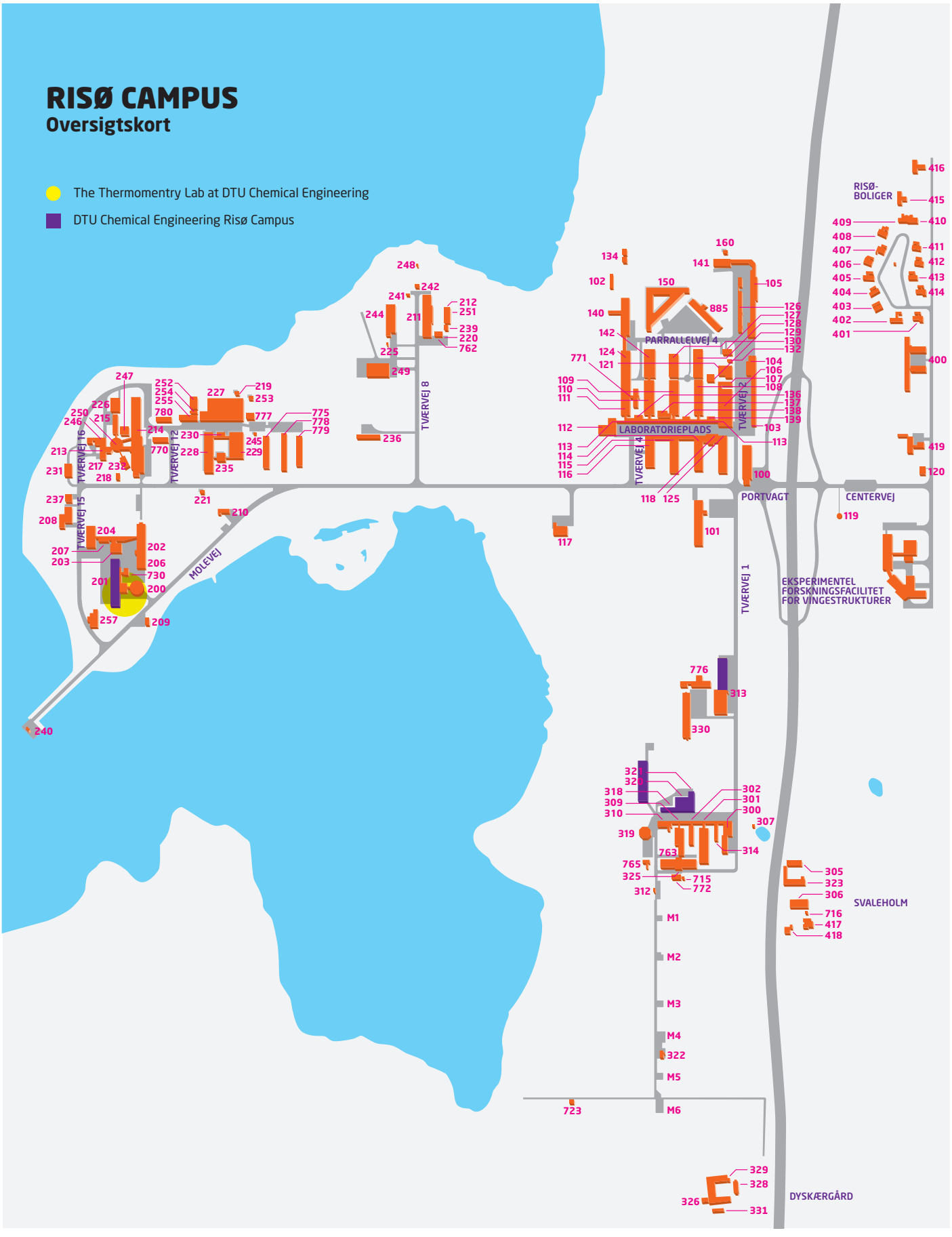

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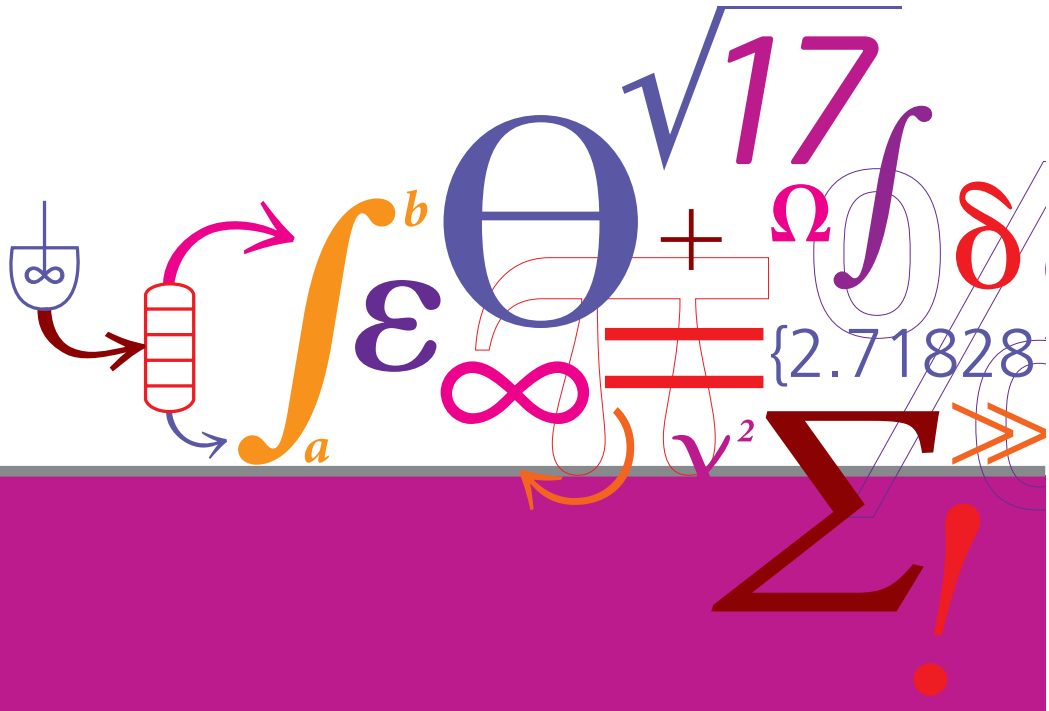

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