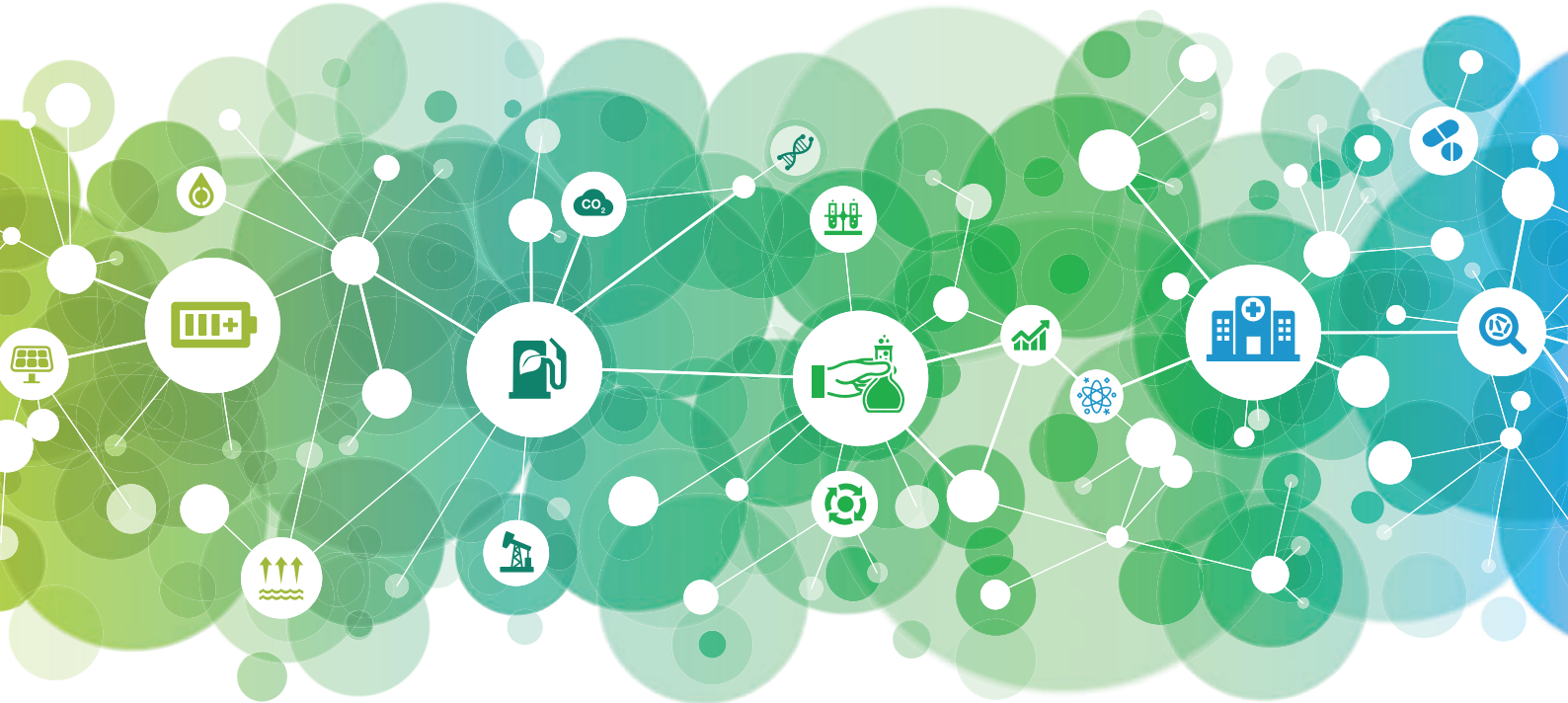
Centre for Sustainable Chemical Technologies

UNIVERSITY OF BATH



Centre for Sustainable Chemical Technologies

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WELCOME

When we opened the doors of the Centre for Sustainable Chemical Technologies in 2008, we immediately got to work assembling a range of people, equipment and research projects to address the major global challenge of sustainable development. Our mission is to advance research in the field of sustainable chemical technologies by bringing together expertise of multidisciplinary scientists and engineers. We do this by developing new molecules, materials and processes for sustainability, structured around four main themes: Energy and Water, Renewable Feedstocks and Biotechnology, Processes and Manufacturing, and Healthcare Technologies.

We bring together academic expertise in collaboration with a network of industrial partners to carry out research, training and outreach in sustainable chemical technologies. We attract the best PhD candidates from across the country and around the world to join our EPSRC Centre for Doctoral Training. Our excellent track record of graduated students demonstrates their continued commitment and application of new technologies in industry and academia.

The Centre has rapidly become an important hub for sustainability in the UK. In the coming years, as we grow, we will continue to advance our knowledge in this field and develop our model in which creative researchers can approach major problems in a nurturing, intellectually challenging and productive environment. I hope this brochure gives you a flavour of some of our activities and culture and I encourage you to take advantage of the many opportunities and resources we have available for joint research projects, collaborations and training.

Professor Matthew Davidson
Director
M.G.Davidson@bath.ac.uk

Centre for
Sustainable
Chemical Technologies

ABOUT US

Scientists and engineers **working together with industry** for a sustainable future

The Centre for Sustainable Chemical Technology (CSCT) is a unique, multidisciplinary university research Centre with a strong record of training and graduating PhD students. We develop new molecules, materials, processes and systems from the lab right through to industrial application, with an emphasis on practical sustainability. Our scientists and engineers work together with industry to meet the needs of current and future generations.

We are funded by the British Government (Engineering & Physical Sciences Research Council) as a Centre for Doctoral Training, which has enabled us to develop a full programme of training and development opportunities not usually available to PhD candidates. Our students are graduates of science and engineering disciplines (Biology & Biochemistry, Chemistry, Chemical Engineering, Electrical Engineering, Mathematics, Mechanical Engineering, Pharmacy & Pharmacology and Physics) with a strong interest in sustainable technologies.

Funded by

EPSRC

Established

2008

07 International Partners

23 Industrial Partners

94 Academics Involved

118 PhD students

"The CSCT is an internationally recognised Centre of excellence in both research and training, providing students with a vibrant and supportive interdisciplinary research environment."

Professor Tim Mays, Co-Director

Our Management Team (From left to right):

Co-Director, Professor Tim Mays - T.J.Mays@bath.ac.uk

Training Director, Dr Janet Scott - J.L.Scott@bath.ac.uk

Centre Manager, Dr Marc Hutchby - M.Hutchby@bath.ac.uk

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OUR RESEARCH

With leading academic research groups in many relevant areas, and state-of-the-art facilities, we carry out research that crosses traditional boundaries between chemical science and engineering. All our research projects are multidisciplinary in nature, to deliver new and sustainable chemical technologies for the future.

Energy and water
Solar cells, Fuel cells & batteries, Sustainable water supply, Water cycle & human health

Renewable Feedstocks & Biotechnology
Biofuels, Biopolymers, CO_2 utilisation, Platform chemicals

Processes & Manufacturing
Reaction engineering, Sustainable integrated processes, Process intensification, Flow chemistry

Healthcare Technologies
Synthetic methodology for pharmaceuticals, Rapid sensing in hospital environments, Infection detection, Diagnostic nanomedicines

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CASE STUDY

Developing new green energy materials

We are exploring and developing new materials for the next generation of green energy devices, including solar cells, lithium batteries, thermoelectrics and fuel cells. Materials performance lies at the heart of the development of green energy technologies, and computational methods now play a vital role in modelling and predicting the atomic-scale properties of novel materials.

One area of research, in collaboration with the 5 Yr EPSRC Programme Grant Energy Materials: Computational Solutions is to understand the ionic and electronic transportation within hybrid halide perovskite solar cells, the fastest-advancing solar technology to date. Through this knowledge and in collaboration with experimental groups in the CSCT and elsewhere we can begin to predict and design new molecular architectures, essential to make these devices a daily reality.

Industrial Partners

Johnson Matthey | SHARP

CSCT students involved

- Lee Burton, cohort 2010
- Adam Jackson, cohort 2011
- Stephen Wood, cohort 2011
- Jessica Bristow, cohort 2012
- Dan Davies, cohort 2014

Outputs

Acc. Chem. Res., **2016**, 49, 528
Chem. Soc. Rev., **2016**, 10.1039/c5cs00841g
J. Phys. Chem. Lett., **2016**, 7, 1083
Nat. Commun., **2015**, 6, 7497
Nat. Commun., **2015**, 6, 7124
J. Phys. Chem. C, **2015**, 119, 15935
J. Am. Chem. Soc., **2015**, 137, 9136
Phys. Rev. B, **2015**, 91, 144107

"Developing new sustainable materials holds the key to cheaper and more efficient solar cells for homes and rechargeable batteries for electric cars."
Professor Saiful Islam

New insights into the atomic level operation of energy materials could unlock the door to new families of compounds with a step change in efficiency and performance.

"This work is a collaboration between Chemistry and Chemical Engineering, where we are tackling one of the biggest problems of the 21st century. Our catalysts show significant promise and we are now working on methods to improve them even further."

Dr Matthew Jones

The conversion of CO_2 to valuable hydrocarbons could be the key to reducing atmospheric greenhouse gas emissions. It represents an attractive alternative, from a financial point of view, for large emitters compared to geological storage of carbon.

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Industrial Partners

sasol reaching new frontiers

CSCT students involved

- Daniel Minett, cohort 2009
- Robert Chapman, cohort 2012
- Emma Sackville, cohort 2013
- Michael Joyes, cohort 2014
- Andrew Hall, cohort 2014

Outputs

Chem. Commun., **2013**, 49, 11683
ChemSusChem **2015**, 8, 4064
ChemPlusChem **2013**, 78, 1536
Catal. Sci. Technol., **2014**, 4, 3351
Catal. Sci. Technol., **2013**, 3, 115
Patent: WO 2014076487 A1

CASE STUDY

Converting carbon dioxide into valuable hydrocarbons

We are developing low-cost, abundant and industrially compatible catalysts to directly convert a waste product, carbon dioxide, into valuable hydrocarbons. This highly desirable process will not only provide us with a source of renewable hydrocarbons but will also provide an incentive to large CO_2 emitters to support the necessary carbon costs in the first place.

By working across Chemistry and Chemical Engineering our work has been able to rapidly progress beyond first principles. Specifically we have developed a novel way of decorating carbon nanotubes with iron nanoparticles to directly convert CO_2 into hydrocarbons with enhanced yield and selectivity. Not only has this led to numerous specialised and general publications but a successfully filled international patent directly resulted in a new industrially funded collaboration.

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CASE STUDY

Flow Chemistry - combining expertise in novel chemical transformations with innovative reactor design

Flow chemistry provides a valuable alternative to reactions run in a simple vessel. Typically, a catalyst is immobilised on a solid support and the reactants flow through a channel and are converted into products in a continuous operation. This has allowed elegant collaborative work to be done by teams involving Chemists and Chemical Engineers, combining expertise in novel chemical transformations with innovative reactor design.

Flow expertise within the CSCT has recently concentrated on real time reaction monitoring via flow NMR studies providing a direct insight into the pathway a reaction follows to produce a certain chemical mixture. This knowledge is key to optimising product yields whilst reducing energy consumption and minimising waste. Success in this area has seen the publication of a practical guide to this versatile and powerful tool along with a joint University of Bath/ EPSRC equipment grant to establish a world-leading, £1.3 million state-of-the-art analytical facility within the CSCT.

Industrial Partners

AstraZeneca, CatSci Innovation in Catalysis, Bruker, S-PACT, Johnson Matthey, gsk

CSCT students involved

- William Reynolds, cohort 2009
- Bill Cunningham, cohort 2013
- Jon Chouler, cohort 2013
- Andrew Hall, cohort 2014

Outputs

Catal. Sci. Technol., **2016**,10.1039/C6CY01754A
Catal. Sci. Technol., **2014**, 4, 948
Catal. Sci. Technol., **2013**, 3, 85
Tetrahedron Lett., **2011**, 33, 4253
Chem. Eng. Res. Des., **2010**, 4, 1533
Green Chem., **2010**, 12, 1687

"We have had successful collaborative ventures in the area of flow chemistry where the scale has been from nanochannel and microchannel reactors through to larger scale reactors capable of producing several grams of product per minute."

Professor Jonathan Williams

In addition to gaining a deeper understanding of how existing processes occur, we will be developing new catalysts, molecules that enable complex chemical reactions, which play a vital role in addressing major global challenges such as sustainable energy, mitigation of greenhouse gases, destroying atmospheric and water pollutants and transforming food and crop waste into valuable products.

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ABOUT THE CDT

The Centre for Doctoral Training (CDT) in Sustainable Chemical Technologies brings together a thriving community of over 60 PhD students who conduct high quality, challenging, truly interdisciplinary research directed jointly by academic staff from across the University of Bath in collaboration with our international and industrial partners.

Why study with us?

- Practical & relevant research
- Interdisciplinary research
- Industrial and international collaboration
- Flexible project choice
- Supportive peer group
- Broad technical and transferable skills training
- Intellectually challenging and positive environment
- Full and part studentship funding available
- Additional internship and travel funding available
- Support for international students

How to Apply

Online application system:
www.bath.ac.uk/csct/cdt

Interviews start from November each year. Applications are always open but competitive.

"What attracted me to join the CDT was the opportunity to work on an interdisciplinary PhD project with a clear focus on industrial impact and the chance to undertake a three month placement to further develop my skills."
Dominic Ferdani, cohort 2014

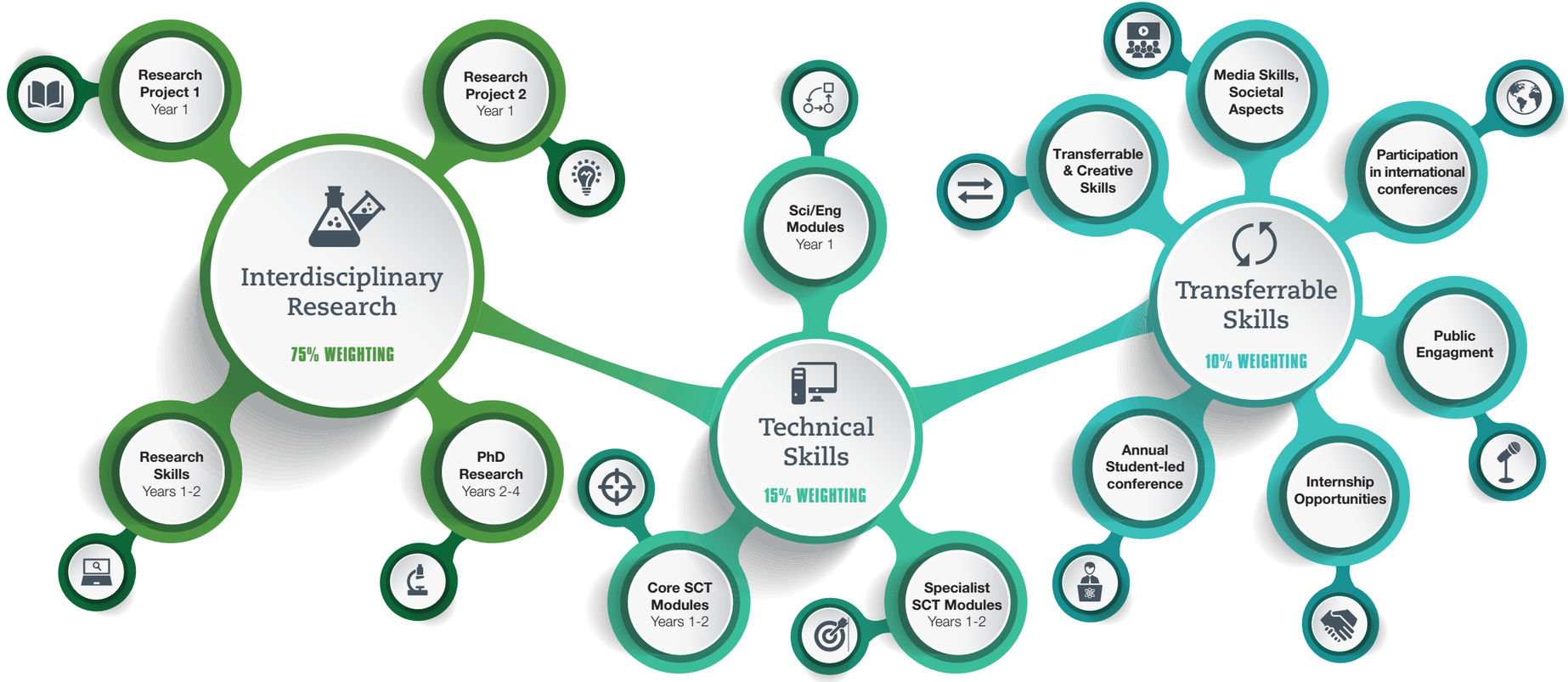
Centre for Sustainable Chemical Technologies

THE STRUCTURE OF OUR PROGRAMME

The four-year Integrated PhD in Sustainable Chemical Technologies comprises two small research projects, technical training and transferable skills training in year one, followed by a main PhD project and advanced training courses in years two to four.

All students in the Centre receive foundation training to supplement their undergraduate knowledge, as well as training in sustainable chemical technologies and transferable skills.

"It's more than just a PhD."
Emma Sackville, cohort 2013



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OUR PROGRAMME IN NUMBERS

Applications to join CSCT

124/137
Offers accepted

137/719
Offers made/Applications

Gender balance

46/54%

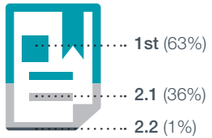
Applications from all over the world

57%
Home

14%
EU

29%
Rest of World

Degree classification



Applications by subject studied for degree

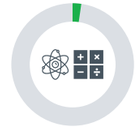
53%
Chemistry

22%
Chem Eng

12%
Other

9%
Medicine/Bio

2%
Natural Science



2%
Physics/Maths

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Citations & Publications

49%
Publications in Top 10 most cited worldwide

85%
Publications in Top 10 Journals

24%
Publications are international collaborations

130+
Publications in Top 10 most cited worldwide

4047
Scopus views

815+
Citations

Grants

£34.1M
funding awarded

Awards

30
Poster prizes at conferences

14
National Public Engagment Awards

Graduates leaving to pursue careers in

60%
Industry

23%
Academia

10%
Research Management

7%
Teaching

Published December 2016

WHORROD FELLOWS

Our Whorrod Research Fellowships were made possible by a £1m donation from entrepreneur and University of Bath graduate Roger Whorrod and his wife Sue Whorrod.

Roger Whorrod

"Sue and I were delighted to invest in early career researchers to develop their research ideas into strong programmes, particularly with the emphasis on sustainable development. We are very pleased that that the fellowships have been and continue to be a complete success producing work of the highest standard."

Professor Aron Walsh

"The Whorrod fellowship has helped to launch my independent research career. Since joining the CSCT my group has expanded to 15 researchers and we are tackling some of the most challenging issues in the development of new materials for energy generation and storage."

Dr Marta Coma

"My research falls in the area of environmental biotechnology, specifically in the treatment and valorisation of waste streams to produce renewable (sustainable) chemicals. The multidisciplinary nature of the CSCT provides a more integrated approach for my work."

Dr Antoine Buchard

"Having worked both in academia and in industry, the CSCT was the natural place for me to start my independent research career. Our research group investigates the synthesis of novel degradable plastics from renewable resources such as carbon dioxide and sugars from biomass or foodwaste."

Dr Chris Chuck

"Working for the CSCT has given me the opportunity, industrial links and resources to develop truly sustainable technologies to reduce our impact on the environment. For example we have developed a yeast substitute for palm oil, that we are now taking to the industrial pilot scale."

Dr Ulrich Hintermair

"The CSCT provides the perfect environment for our work which deals with applied homogeneous catalysis for sustainable manufacturing and renewable energy conversion. The Centre produces highly skilled students performing world-class research, and the strong industrial links provide pathways for immediate real-world impact of our work."

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CASE STUDY

Developing sustainable routes to medicine and food

Our research has developed new and sustainable routes to small organic molecules, essential for the pharmaceutical and agrochemical industries. For example, catalytic meta C-H functionalisation has allowed us to synthesise difficult to access drug like cores that previously would have taken multiple transformations and generated large amounts of waste.

Research in our labs has also seen the development of catalytic transformations using abundant, low cost and non-toxic metals. We have recently synthesised three pharmaceuticals using copper catalysis to construct the key drug cores, proving that sustainable catalysts can effectively replace the heavily used yet dwindling Platinum Group metals.

Industrial Partners

CatSci Innovation in Catalysis · NOVARTIS · gsk

CSCT students involved

- William Reynolds, cohort 2009
- William Mahy, cohort 2011
- Andrew Paterson, cohort 2012
- Callum Heron, cohort 2014

Outputs

ACS Catal., **2016**, 6, 5220
Cat. Sci. Tech., **2016**, 6, 7068
ACS Cent. Sci., **2015**, 1, 418
Angew. Chem. Int. Ed., **2015**, 54, 10944
Chem. Commun., **2015**, 51, 12807
Org. Lett., **2014**, 16, 5020
J. Am. Chem. Soc., **2011**, 133, 19298

"Historically the development of novel routes to small organic molecules has been performed without regard to sustainability. As a result, these processes can generate large amounts of chemical waste and use expensive, rare metals. By placing sustainability at the Centre of our methodology development we are able to design from first principles, atom-economical, low waste and abundant metal based catalytic transformations."

Professor Chris Frost

In close collaboration with our pharmaceutical and agrochemical partners, our research will bring us our essential medicines and food while reducing the impact on the environment.

> *"New ways of making, using and recycling plastics will have a major impact on global sustainability. By identifying and developing plastics from renewable sources we will not only reduce our dependence on petrochemicals but have the opportunity to build in desirable properties such as heat resistance and biodegradability."*
>
> Professor Matthew Davidson

Scientists and engineers in the CSCT, working together with industry partners are developing new renewable materials, benign catalysts and cleaner processes needed for the advanced polymeric materials of tomorrow.

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Industrial Partners

NNFCC The Bioeconomy Consultants

sasol

Corbion purac

Johnson Matthey

CSCT students involved

- George Gregory, cohort 2012
- Sarah Kirk, cohort 2012
- Paul McKeown, cohort 2012
- Helena Quilter, cohort 2013
- Michael Joyes, cohort 2014
- Kasia Smug, cohort 2014
- Strachan McCormick, cohort 2015

Outputs

Patent: WO 2014177543 A1

Chem. Commun., **2016**, 52, 10431
Marcomolecules, **2016**, 49, 7165
Dalton Trans., **2016**, 45, 5374
Chem. Sci., **2015**, 6, 5034
Angew. Chem. Int. Ed., **2014**, 53, 13858

CASE STUDY

Developing new sustainable plastics

We are developing new, sustainable catalysts, processes and building blocks for polymers such as polyesters (such as PET and polylactide), polyurethanes (PU) and polycarbonates (PC) which are used as commodity plastics and for high value biomedical applications.

In collaboration with industrial partners, we have developed and patented heavy-metal replacement catalysts for PET and PU that minimise the use of antimony and mercury in industrial processes. We have designed a series of very robust tin-free catalysts for the controlled synthesis of polylactide some of which are currently being tested for industrial applications and we are currently developing new catalysts and processes for incorporation of CO_2 into a new generation of sustainable, renewable plastics.

This work has led to a £2.6 million EPSRC project on sustainable chemical feedstocks, patented catalyst technology and fundamental knowledge of Group 4 metal catalysis that is being exploited by UK companies.

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CASE STUDY

The water cycle and human health

The presence of pharmaceutical drugs and personal care products in the aquatic environment has wide ranging environmental effects, from feminisation of fish to antimicrobial resistance. We are working closely with our industrial partners to develop methods utilising high resolution mass spectrometry capable of high accuracy measurements for quantitative, targeted and qualitative non-targeted simultaneous screening, essential to identify unknown compounds in the water. We apply these methods to test water treatment processes such as engineered natural wetlands and algal beds and to verify environmental and human health impacts.

Our analytical capabilities are also at the forefront of a Pan-European inter-disciplinary and cross-sectoral research programme (£4.2m SEWPROF ITN) which aims to provide an integrated approach towards public health monitoring at a community level based on innovative wastewater-based epidemiology techniques.

Industrial Partners

Essex Water, a YTL company

CSCT students involved

- Shawn Rood, cohort 2014
- Daniel Scott, cohort 2015
- Caitlin Taylor, cohort 2015
- Vicky De Groof, cohort 2016
- Natalie Sims, cohort 2016
- Garyfalia Zoumpouli, cohort 2016

Outputs

BMC Public Health, **2016**, 16, 1035.
Environ. Sci. Technol., **2016**, 50, 9469
Environ. Sci. Technol., **2016**, 50, 3781
Sci. Rep., **2016**, 6, 21024
Environ. Pollut., **2016**, 215, 154
Anal. Chim. Acta., **2015**, 882, 112

"By developing analytical techniques and subsequent treatment technologies in collaboration with industry and the water utilities, we can meaningfully tackle the fundamental issues surrounding sustainable water."

Dr Barbara Kasprzyk-Hordern

Only by working closely with industry can we move away from controlled laboratory environments and develop more accurate water treatment and analytical techniques suited to the conditions experienced within the natural environment.

PUBLIC ENGAGEMENT

"Learning about how our work and research relates to industry and society was eye opening. The Public Engagement activities really help to put the work done at the Centre into perspective and develop communication skills which are crucial for success."

Michael Joyes, cohort 2014

For more information:

csct-public-engagement@bath.ac.uk

blogs.bath.ac.uk/csct/category/public-engagement

Centre for Sustainable Chemical Technologies

INDUSTRIAL & INTERNATIONAL PARTNERS

A wide range of multinational industries and international institutions are closely involved in the Centre, demonstrating the importance of sustainable chemical technologies.

Our partners greatly value the enhanced postgraduate training offered by our doctoral programme. Participation in the Centre includes partnership in PhD research projects, strategic advice, hosting of internships, participation in training and involvement in our industrial forum.

> *"I've been a fan of the CSCT right from its beginning. I've loved the work that the Centre has done. The whole idea of sustainable technologies and bringing together different capabilities are absolutely essential if we're going to build something that has impact."*
>
> Steve Martin, ZuvaSyntha

Key:
Location of Internship placement

INTERNSHIPS

All students have the opportunity to undertake up to three months of internship during their research to enhance their PhD.

As part of our Global Innovation Initiative (GII) collaboration, Jamie spent 2 months at University of Campinas (UNICAMP) in São Paulo, Brazil, where he got the opportunity to use cutting-edge instruments to characterise cellulose-based materials and dip his hands into computational modelling for the first time.

Jamie's PhD project investigates opportunities for novel, sustainable ingredients for formulated products and tissue engineering scaffolds. His goal is for his research to be used for biomedical applications.

> *"One day I want to be able to use tissue engineering to find ways to treat serious injuries that athletes come across and put them back up on their own feet. Without this collaboration, I would have never had this unique life-changing opportunity to learn from the best and gain numerous life skills."*
>
> Jamie Courtenay, cohort 2014

> *"It's very important for our students to build international networks as early in their careers as possible. The more experience they have outside the UK, the better equipped they are to deal with the global science economy."*
>
> Dr Janet Scott, Training Director

OUR GRADUATES

Our Alumni programme has seen our graduates move on to industrial employment or further research across the globe. The graduates are invited back to reconnect with the current members of the Centre and share valuable insights into their career choices.

Graduates leaving to pursue careers in

60% Industry

23% Academia

10% Research Management

7% Teaching

Employment

100% of graduates are in employment

Returnng Alumni

12 Alumni returned to deliver talks

What they say

"The extra training given in the CSCT on science communication, public engagement and sustainability has been fundamental in my career so far. I definitely wouldn't be where I am today without that knowledge."

Dr Simon Bishopp, Researcher at **Shell**, Amsterdam

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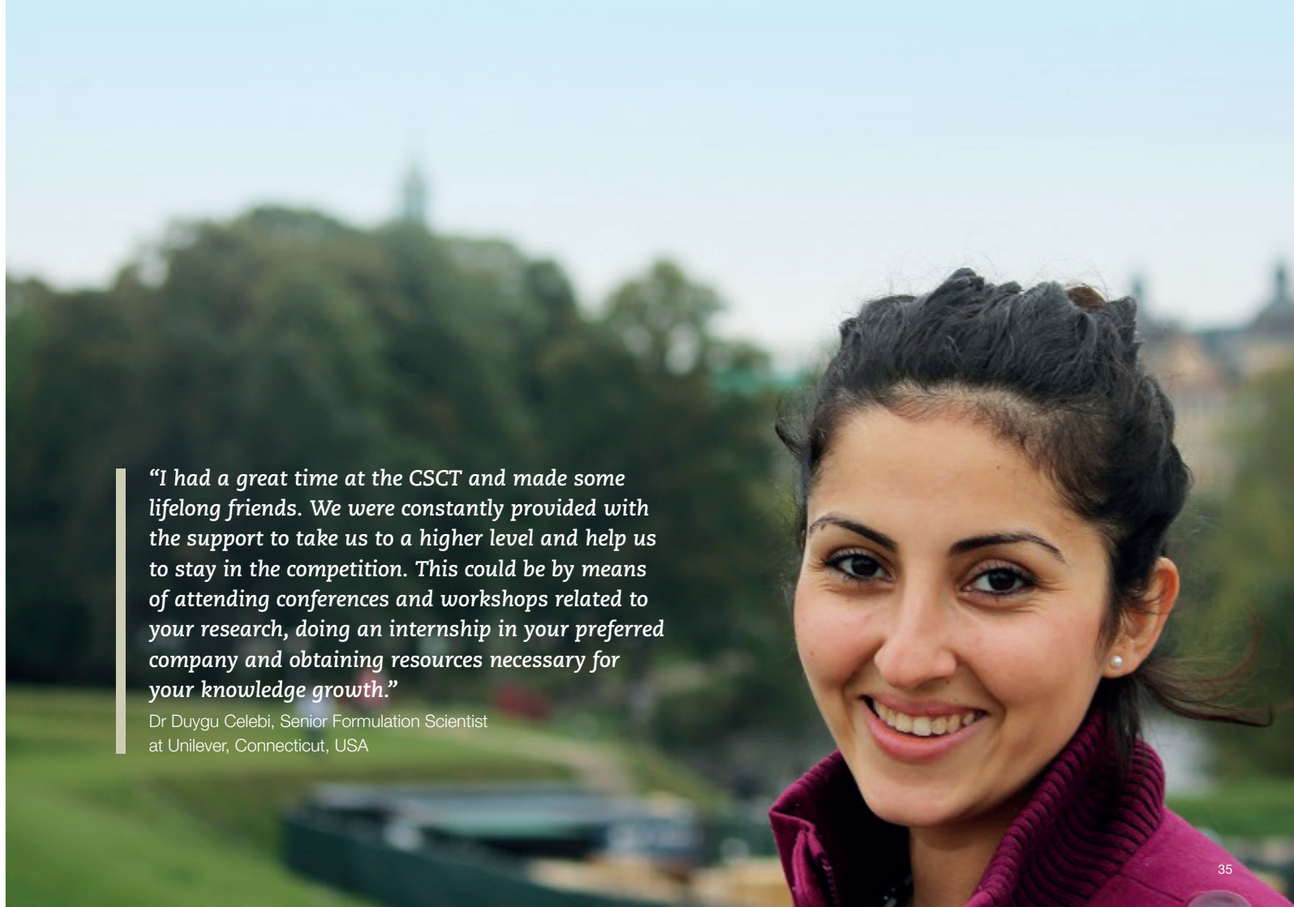

"I had a great time at the CSCT and made some lifelong friends. We were constantly provided with the support to take us to a higher level and help us to stay in the competition. This could be by means of attending conferences and workshops related to your research, doing an internship in your preferred company and obtaining resources necessary for your knowledge growth."

Dr Duygu Celebi, Senior Formulation Scientist at Unilever, Connecticut, USA

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