Courses content of the second semester at TalTech

Course title: Green Chemistry Metrics for Feedstocks to Biochemical Development

Key words	Green Chemistry metrics, biomass processing, bioproduct development
Aims	The aim of the course is to provide to the students the knowledge of the green technology metrics of biomass compositional analysis and biomass processing technologies for bioproduct development. The course is developed through the typical approaches and principles of the kinetics of pre-treatrment technologies for various biomass/feedstocks.
Content	**Lectures and Exercises** The potential for blends to reduce feedstock production costs using low cost formulation models and feedstock supply chain technoeconomic analysis. The core areas are : pretreatment technologies and compositional analysis of a wide range of feedstocks for bioproduct development including bioethanol, biobutanol, volatile fatty acid production, lactic acid production, PHA, PHB production, biogas production, and succinic acid production etc. The background to the principles of green chemistry, green engineering and sustainable manufacturing **Practical class** 1. Practicals on computational methods to determine green chemistry metrics 2. Laboratory experiments to determine green chemistry metrics, including biodegradation 3. Laboratory experiments for compositional analysis of the feedstocks. 4. Experiments on bioprocessing of feedstocks to relevant bioproduct formation.
ECTS	**6**
Skills for the Diploma supplement	Knowledge of sustainable and cleaner production routes; Knowledge of the principles of green chemistry and associated metrics; Capacity to implement multi-disciplinary approaches to design new sustainable routes for the product valorization
Learning outcomes and skills	<u>Knowledge and understanding</u> For a passing grade the student must • understand the principles and approaches of the Green chemistry metrics and pre-treatments technologies • apply the Green Chemistry metrics to the biomass valorisation • be familiar with Green Chemistry tools and software <u>Competences and skills</u> For a passing grade the student must • use green chemistry metric tools • critically evaluate the technologies of bioprocessing of biomass to bioproducts and feedstock compositional analysis

	Judgement and approach For a passing grade the student must • Demonstrate knowledge of the possible bioproducts (biochemicals, organic acids, biopolymer etc.) from feedstocks
Module Coordinator(s)	Yevgen Karpichev
Teaching staff	Yevgen Karpichev, Vijai K. Gupta (+TBD)
Language of instruction	English
Nb hours of lectures	32 h
Nb hours of practical work	24 h
Nb hours of tutorials	8 h
Nb hours of personal work	
Nb hours of other	
Length of the internship in weeks	
Bibliography recommended	1. R. Luque (2012) Green Chemistry, NovaScience Publishers, New York. 2. J.H. Clark, R. Luque, A.S. Matharu (2012) Green Chemistry, Biofuels and Biorefinery Annual Rev. Chem. Biomol. Eng. 2012, 3, 183-208 3. R. Luque, J. Campelo, J.H. Clark, (2010) Handbook of biofuels production: processes and Technologies, Woodhead Publishing, Cambridge, UK. 4. V.K. Gupta and M. Tuohy (2013). Biofuel Technologies, Recent Developments. Springer Science+Business Media, LLC, 233 Spring Street, New York, NY 10013, USA; ISBN 978-3-642-34518-0 5. Ashok Pandey Christian Larroche Steven Ricke Claude-Gilles Dussap (2011). Biofuels: Alternative Feedstocks and Conversion Processes, ISBN: 9780123851000 6. Vijai K. Gupta, Christian P. Kubicek, Jean-Guy Berrin, David W. Wilson, Marie Couturier, Alex Berlin, Edivaldo X.F. Filho, and Thaddeus Ezeji (2016). Fungal Enzymes for Bio-products from Sustainable and Waste Biomass. Trends in Biochemical Sciences, Cell Press, 41: 633_645 7. Haibo Xie and Nicholas Gathergood (2013) The Role of Green Chemistry in Biomass Processing and Conversion, John Wiley & Sons, Hoboken, New Jersey ISBN 978-0-470-64410-2
Prerequisites	
Teaching period (when)	Semester 2 of the Master
Place of teaching (where)	**TalTech**
Assessment	Defense of literature task/written report Final written exam (1.5 hour): /100

Course title: Sustainable and cleaner Production

Key words	
Aims	- To give an overview about the key issues of sustainable development. - To introduce the main environmental problems in industry in Estonia and abroad. - To introduce the main principles of green chemistry and technology. - To show the options for design of zero-discharge productions. - To introduce the sources of green energy and their application.

Content	Society, economy, environment. Prospectives of survival of human society. Sustainable development and sustainable technology. Legislation. Tasks of engineers. Industry in Estonia and abroad (production of pulp, paper, cement, glass, biodiesel, MTBE, oil shale industry etc.). Environmental problems in industry. Principles of green chemistry, new catalysts. Life Cycle Assessment (LCA) as a tool for identification of more environmentally friendly products and processes. Best available technology (BAT). Separation and destruction processes. New methods of gaseous effluents and wastewater treatment. Examples of zero-discharge industrial processes. Energy, units, power, exergy. Fossil fuels as a source of energy. Energy and climate change. Heat machines. Carnot cycle and efficiency. Electricity production at thermal power plants and combistations. Sources of green energy (sun, wind, waterfalls, waves etc.). Energy of biomass. Electrochemistry and fuel cells. Nuclear and thermofusion energy, prospectives and dangers. Energy saving in industry and residental houses. Carbon dioxide sequestration and storage
ECTS	**6**
Skills	For a passing grade the student must: be able to define the key issues of sustainable development; - is familiar with the main environmental problems in industry in Estonia and abroad; - is familiar with the main principles of green chemistry and technology and is able to apply them; - is able to design the zero-discharge industrial processes; - is familiar with the sources of green energy and their application; - is able to clarify written form and discuss in English the problems concerning the sustainable production; - is willing to actively participate in the civil society and demonstrates tolerance towards diversity of attitudes and values.
Module Coordinator(s)	Niina Dulova
Teaching staff	
Language of instruction	English
Nb hours of lectures	3 (weekly hours)
Nb hours of practical work	1 (weekly hours)
Nb hours of tutorials	
Nb hours of personal work	4 (weekly hours)
Nb hours of other	
Length of the internship in weeks	
Bibliography recommended	-Tapas K. Das. Toward Zero Discharge. J.Wiley & Sons, 2005. - Sustainable Development in Practice. Case Studies for Engineers and Scientists. Eds. A.Azapagic et al. J.Wiley & Sons, 2004. - R.Ristinen, J.J.Kraushaar. Energy and the Environmen
Prerequisites	
Teaching period (when)	Semester 2 of the Master
Place of teaching (where)	**TalTech**
Assessment	Two written interim exams, Two tests on topics of practical training and a presentation. Final mark is the weighed sum of the scores acquired for different components: 0.3*(1st interim exam mark) + 0.3*(2nd interim exam mark) + 0.1*(1st test mark) + 0.1*(2nd test mark) + 0.2*(presentation mark).

Course title: Biopolymers: basics, introduction and applications

Key words	
Aims	To give an overview of biopolymers, their chemical structures, properties and functions. To discuss the main applications of biopolymers and bio-based materials, including their chemistry and their highly diverged applications.
Content	Biopolymers are polymers produced by living organisms. There are three main classes of biopolymers based on the differing monomeric units used and the structure of the biopolymer formed: polynucleotides, which are composed of nucleotide monomers; polypeptides and proteins, which are polymers of amino acids; and polysaccharides, which are polymeric carbohydrate structures. In addition there are bio-based polymeric materials which are man-made polymers basing to renewable feedstocks. The course introduces all these materials from the view point of practical material science. The main industrial applications and some new innovations in the field of commodity and engineering plastics will be reviewed.
ECTS	6
Skills	The students will know the main biopolymer types, their origin and functions. They will have an idea of the relationships of chemical structure and properties of biopolymers and an image of their industrial applications
Module Coordinator(s)	Elvira Tarasova
Teaching staff	
Language of instruction	English
Nb hours of lectures	1 (weekly hours)
Nb hours of practical work	1 (weekly hours)
Nb hours of tutorials	2 (weekly hours)
Nb hours of personal work	4 (weekly hours)
Nb hours of other	
Length of the internship in weeks	
Bibliography recommended	Book: Biopolymers: New Materials for Sustainable Films and Coatings David Plackett (Editor) ISBN: 978-0-470-68341-5
Prerequisites	
Teaching period (when)	Semester 2 of the Master
Place of teaching (where)	TalTech
Assessment	Audiovisual presentation, 30% of the final credit; Tests, 2x10=20% of the final credit; Final test 50% of the final credit

Course title: Biorefinery Systems

Key words	Biorefinery, Green Chemistry, cost-efficiency; Bioconversion of biomass; **Bioproducts developments**

Aims	The course will provide an overview to the students on green chemistry strategies for biomass to bioproducts developments as biorefinery applications. We aim to provide highlights on all relevant biorefinery based production technologies for the bioprocessing of feedstocks and biowaste into valuable products such as biomaterials, bio-chemicals and biofuels, describing the merits and shortcomings of each, including cost-efficiency
Content	**Lectures and Exercises** Basis for the analysis and design of bioreactors and biotechnological processes; recent developments on biomass to bioproducts biorefineries based on green chemical strategies. Course content includes topics on- enzyme development from microbial cell factories; heterogeneous catalytic reactors system; enzymatic bioconversion of biomass; kinetics, operations and innovative process design; and thermal, chemical, biochemical recycling technologies for processing of biomass, process mapping for renewables to bio-chemicals and biopolymers Through group exercises focused on developing the ability to work in teams and deal with the resolution of real problems related to biorefinery
ECTS	**6**
Skills for the Diploma supplement	**S**kills in process and materials engineering applied to biomass production and conversion into biobased products
Skills	<u>Knowledge and understanding</u> For a passing grade the student must • understand the principles of • be familiar with the main steps of bioconversion methods • learn about biochemical characteristics involved in biorefinery applications <u>Competences and skills</u> For a passing grade the student must • understand concepts of the bioproduct based on the bioconversion of biomass; • possible bioprocessing for particular biomass feedstock, and developing core concepts of the subject <u>Judgement and approach</u> For a passing grade the student must • critically analysing of biorefinery applications • performing technical analyses
Module Coordinator(s)	Yevgen Karpichev
Teaching staff	Vijai Gupta ; Tiit Lukk
Language of instruction	English
Nb hours of lectures	48 h

Nb hours of practical work	8 h
Nb hours of tutorials	8 h
Nb hours of personal work	
Nb hours of other	
Length of the internship in weeks	
Bibliography recommended	1. C.S.K. Lin, L. Pfaltzgraff, L. Herrero-Davila, E.B. Mubofu, S. Abderrahim, J.H. Clark, A. Koutinas, N. Kopsahelis, K. Stamatelou, F. Dickson, S. Thankappan, Z. Mohamed, R. Brocklesby, R. Luque, (2013) Food waste as a valuable resource for the production of chemicals, materials and fuels. Current situation and global perspective .Energy Environ. Sci, 6, 426-464 2. J.H. Clark, R. Luque, A.S. Matharu (2012) Green Chemistry, Biofuels and Biore□nery Annual Rev. Chem. Biomol. Eng. 2012, 3, 183-208 3. R. Luque, J. Campelo, J.H. Clark, (2010) Handbook of biofuels production: processes and Technologies, Woodhead Publishing, Cambridge, UK. 4. V.K. Gupta and M. Tuohy (2013). Biofuel Technologies – Recent Developments. Springer Science+Business Media, LLC, 233 Spring Street, New York, NY 10013, USA; ISBN 978-3-642-34518-0 5. V.K. Gupta and M. Tuohy (2013). Book Series: Biofuel and Biore□nery. Springer Science+Business Media, LLC, 233 Spring Street, New York, NY 10013, USA; http://www.springer.com/series/11833 6. V.K. Gupta, M. Tuohy, C. P. Kubieck, J.N. Saddler and Feng Xu (2014). Bioenergy Research: Applications & Advances. Elsevier Science Publishers, The Netherlands. ISBN: 9780444595614.
Prerequisites	
Teaching period (when)	Semester 2 of the Master
Place of teaching (where)	**TalTech**
Assessment	Final written exam (1.5 hour): /100

Course title: Life Cycle Analysis of Green Technologies (

Key words	LCA, Green Chemistry; Green technology
Aims	The goal of the course is to provide students with detailed information on the modelling and optimization of life cycle analysis (LCA) of greener technologies
Content	**Lectures and Exercises** The environmental impact of biorefinery processes must be assessed through life cycle assessment model to evaluate the environmental significance of green technologies. Biomass to bioenergy programs needs to be subjected to detailed life cycle analysis (LCA), where all the considerations are evaluated. LCA can also help derisk biomass to bioenergy possesses. In this course, we provide topics on life cycle assessment of biofuels, bioproduct and biochemical production technologies; environmental impact analysis; process modelling and integration analysis, current R&D policies and regulations in biorefineries

	and future prospects; overview about waste management directives in EU and waste acts in EU; and product and material lifecycle assessment software
ECTS	6
Skills for the Diploma supplement	Environmental impact analysis; Life-cycle assessment of biorefinery processes
Skills	Knowledge and understanding For a passing grade the student must • estimate the environmental impact of biorefinery processes • be familiar with life cycle analysis tools • acquire the best EU practices on LCA • know the EU regulations on LCA Competences and skills For a passing grade the student must • use life cycle analysis to evaluate the environmental significance of green technologies and ensure the best possible technological solution • be able to apply life-cycle assessment to bio-based value-chains Judgement and approach For a passing grade the student must • know the LCA risk analysis biomass to bioenergy possesses • evaluate environmental impact analysis; process modelling and integration analysis, current EU policies and regulations in biorefineries
Module Coordinator(s)	Yevgen Karpichev
Teaching staff	Yevgen Karpichev; (+TBA)
Language of instruction	English
Nb hours of lectures	48 h
Nb hours of practical work	
Nb hours of tutorials	16
Nb hours of personal work	
Nb hours of other	
Length of the internship in weeks	
Bibliography recommended	1. C.S.K. Lin, L. Pfaltzgraff, L. Herrero-Davila, E.B. Mubofu, S. Abderrahim, J.H. Clark, A. Koutinas, N. Kopsahelis, K. Stamatelou, F. Dickson, S. Thankappan, Z. Mohamed, R. Brocklesby, R. Luque, (2013) Food waste as a valuable resource for the production of chemicals, materials and fuels. Current situation and global perspective .Energy Environ. Sci, 6, 426-464 2. J.H. Clark, R. Luque, A.S. Matharu (2012)Green Chemistry, Biofuels and Biore□nery Annual Rev. Chem. Biomol. Eng. 2012, 3, 183-208

	3. R. Luque, J. Campelo, J.H. Clark, (2010) Handbook of biofuels production: processes and Technologies, Woodhead Publishing, Cambridge, UK. 4. V.K. Gupta and M. Tuohy (2013). Biofuel Technologies – Recent Developments. Springer Science+Business Media, LLC, 233 Spring Street, New York, NY 10013, USA; ISBN 978-3-642-34518-0 5. V.K. Gupta and M. Tuohy (2013). Book Series: Biofuel and Biore□nery. Springer Science+Business Media, LLC, 233 Spring Street, New York, NY 10013, USA; http://www.springer.com/series/11833 6. V.K. Gupta, M. Tuohy, C. P. Kubieck, J.N. Saddler and Feng Xu (2014). Bioenergy Research: Applications & Advances. Elsevier Science Publishers, The Netherlands. ISBN: 9780444595614.
Prerequisites	
Teaching period (when)	Semester 2 of the Master
Place of teaching (where)	**TalTech**
Assessment	Defense of literature task/written report Final written exam (1.5 hour): /100