International Master's Programme on Circular Economy (CIRCLE)

Course Descriptions, as of September 2018

a) European partners

University of Graz (Austria)

First study year

Baumgartner: Eco-Controlling, course, 4 ECTS
In this course the students will get an overview of the standards, tools and methods for eco-controlling, especially for analyzing ecological opportunities and threats for the firm, the strengths and weaknesses within the company, as well as for planning, controlling, and reporting on the eco-performance of the organisation. Here, methods like eco-balances, material flow analysis, environmental cost accounting and different approaches for environmental oriented evaluation will be discussed. Environmental/sustainability performance measurement will also be content of the course.

Kiesnere, Stern: Sustainability entrepreneurship, course, 4 ECTS
Based on the general idea of ecological, economic and social sustainability, this course focuses on the planning of sustainable entrepreneurial activities in a business start-up. The students learn about the entrepreneurial spirit and creation of the innovative products and services.
After explaining the theoretical and practical implications of creating a business start-up, the main focus of the course lies on generating a sustainable business idea within the project group, developing the business plan, giving, receiving and integrating the feedback, and practicing to sell the idea in the final sessions of the class.
Business plan includes potential market analysis, competitor analysis, financial plan, management plan and strategy concept, between others.
At the end of the course each project group has to present a business plan in front of a jury consisting of internal and external experts.

Brudermann, Crockett, Posch: Research Project Sustainability Management, tutorial, 6 ECTS
Content of this course are selected research activities that are closely linked to actual ongoing research projects at the Institute of Systems Sciences, Innovation and Sustainability Research. The key objective of this tutorial is the ability to apply selected methods and instruments of social research in teams into the sustainability management context, tailor-made for "real word" research projects.

Globocnik: Product and Service development, course, 4 ECTS
The course distinguishes between the creating of incremental product innovations and breakthrough product developments (radical product innovations). Based on case studies of new products and specific group projects, students will learn about basic state of the art approaches for product developments including the appropriate methodologies. Hereby, stakeholder analysis plays a crucial role for the investigation of the given preference profiles of existing and potential customer groups as well. Further, by focusing on the so called "fuzzy front end" students learn to deal with ill-defined markets and needs and to identify future opportunities by applying future oriented techniques such as the scenario technique and rapid prototyping. Strategic thoughts on how to transform those opportunities into sustainable marketable products are consequently also part of this course.

Aschemann: Environmental and technology assessment, course, 4 ECTS
The course "Environmental and Technology Assessment" focuses on key assessment tools regarding the environmental context with particular emphasis on their possibilities in terms of application and advancement.
Students should be able to understand the concept and the application range of methods and tools such as environmental impact assessment (EIA), strategic environmental assessment (SEA), technology assessment (TA), sustainability impact assessment (SIA), health impact assessment (HIA) and life cycle analysis (LCA), both in theory and in practice. Moreover, they should know strengths and weaknesses of the tools mentioned in order to get the ability to select the suitable tool for the problem given and to define its proper framework requirements. Finally, they should be aware of actual research issues regarding those instruments and the opportunities for their advancement and further development.

Gelbmann and Schmidt: Waste and Recycling, course, 4 ECTS
Waste management is a task that has to be accomplished by enterprises, both by those who produce waste and those who see to it. This course provides for both sides: giving an overview of different kinds of (solid) wastes that may accrue and the ways firms can deal with them, the legal bases that have to be accounted for (like devising corporate waste management

concepts or the regulations on packaging). If an enterprises devises proper strategies of waste separation and disposal, this can add to both, environmental protection and enterprise efficiency.

Aschemann: Fundamentals of Circular Economy and Industrial Ecology, seminar, 4 ECTS (first time in winter term 19/20)
The seminar presents fundamentals of "Circular Economy" and "Industrial Ecology". It will address its definition(s), ideology and principles, history and future directions. Moreover, its areas of application and main technical terms, methods and tools will be discussed, such as material flow accounting; substance flow analysis; life cycle assessment; footprint approaches; industrial metabolism; reuse/remanufacturing/recycling; cradle to cradle; blue economy; de-growth.

Kirchengast: Earth Climate System and Climate Change, lecture, 3 ECTS
The Earth climate system (basic terminology, components, phenomenology, balance principle); paleoclimate and history of climate; climate observation, types of elements, climate classification; physical climate mechanisms and geobiochemical cycles; climate modeling and prediction; anthropogenic climate change, global warming and change; climate change and economy. Dependent on level of knowledge and foci of interest of participants some room exists to account for this in weighting the depth of treatment of the different sub-topics above.

Gelbmann: Strategic Sustainability Management, Course, 4 ECTS
Content of this course is corporate social responsibility. After this course students are able to understand the basics of strategic sustainability management, are able to develop, implement, and control concepts for strategic sustainability management and are able to devise and implement sustainability reports and other communications of sustainability performance reporting.

Aschemann: Value Chain Management, Course, 4 ECTS
In this course, essential basic concepts and principles of value chain management (VCM) will be taught, focusing on its relations to circular economy and industrial ecology. In order to deepen the students' VCM understanding, some case studies will be discussed, too. A guest talk and a field trip serve as practice-oriented contributions for this course.

Asada, Mair: Selected Topics of Sustainability and Innovation Management, Course, 4 ECTS
Bio-economy and associated terms like bio-based economy, circular economy or post-carbon economy are increasingly used and discussed. According to OECD (2006), the concept of bio-economy can be defined as "transforming life science knowledge into new, sustainable, eco-efficient and competitive products". To realize the vision of a bio-economy, innovation plays a crucial role in this process.
Bio-economic innovations aim at replacing fossil resources for energy, chemicals and materials with renewable and bio-based feed stocks. The concept of bio-refining (equivalent to petrochemical refining) is a basic concept bio-economic innovation. Bio-refining can be done with various kinds of bio-based raw materials applying different technical approaches such as chemical, biotechnological or even physical methods producing various products and energy.
In this course, students will discover the state of the art of bio-refining and investigate their influence on products and (economic) developments.

Electives
15 ECTS have to be chosen from the entire courses offer of the university and Graz University of Technology, which are in the context of circular economy. The CIRCLE summer school between first and second study year (worth 3 ECTS) should be taken at any case; also internships can be done (maximal 6 ECTS, equivalent to four weeks full-time employment).

Sum Graz first study year: 60 ECTS

Second study year

Brudermann: Environmental Decision-Making, Course, 4 ECTS
This course addresses decision making in an environmental context. The course will provide an overview on how humans make decisions by taking into account insights from psychology, behavioral/experimental economics, sociology game theory and neuro-economics.

Dully, Ulz: Integrated Management Systems, Course, 4 ECTS
The objective of the course lies in the switching of basic knowledge in management systems (including environmental management, quality management, systems for occupational health and safety, etc.) and in the training of management methods and instruments for the implementation of an integrated management system. A specific focus will be on environmental aspects of such management systems. Furthermore, important aspects of the common management standards (ISO 14001, EMAS, ISO 9001, OHSAS 18001, ...) are presented and discussed. Finally students should apply their acquired knowledge on different case studies.

Aschemann: Methods for inter- and transdisciplinary problem-solving, course, 2 ECTS
Content of this course is the introduction of selected important methods in order to contribute to inter- and transdisciplinary problem-solving. Moreover, further inter- and transdisciplinary methods and tools will be introduced and

their application in case studies will be discussed in order to enhance the students' knowledge and ability to apply and critically reflect on those methods in an inter- and transdisciplinary context.

Rauter: Sustainable Innovation, Course, 4 ECTS
The course aims at building up a systematic understanding of sustainable innovation processes which goes beyond particular product, service or process innovations. Sustainable innovations also require social, cultural or institutional innovations – in other words: system innovations – to create viable alternatives to existing structures and products and to be able to unleash their sustainability potential. Promoting more sustainable forms of production and consumption requires strategies at different levels: at the level of firms for creating more sustainable products and services, at the level of policy to create conditions for innovation systems for sustainability, and at the level of civil society to develop new practices of use and consumption and to articulate demand in a qualified way.
Selected topics are:
- Basics of innovation Management
- Transition Management and Innovation Systems
- Sustainable & Eco-Innovation
- Sustainable Open Innovation
- Business Models

Rauter Stern: Research Project innovation Management, turotial, 6 ECTS
Content of this course are selected research activities that are closely linked to ongoing research projects and research interests of the Institute of Systems Science, Innovation and Sustainability Research. Objective of this course is the ability to apply selected methods and instruments of social research in teams.

Aschemann, Mayer, Meyer; Aschemann, Baumgartner, Perstel, Ulz, Zettl: Interdisciplinary practical training (IP), 10 ECTS
The topic of the course is changing every semester. A maximum of 20 students will work together with a team of lecturers during the whole semester on a specific and practical interdisciplinary project issue. For study year 2017/18, the following five topics are offered:

a) This IP offers aspects of a multidisciplinary analysis and an ethical-ecological assessment of enterprises. For this IP the practice partner is "BHDT Best High Pressure & Drilling Technology" in Kapfenberg/Styria. Students have to apply the assessment methodology correctly and to reflect on it. This methodology consists of the elements interpretation framework, measurement tools and data collection. Methodologies used are, inter alia, GRI, FSSD and SDGs.

b) The challenges of climate change in a municipality/region are very diverse and depend strongly on local conditions. So, for example, a tourist region has to deal with other challenges as an agricultural region or a town in the suburban area. As an example for the different types of regions in Styria, approaches and measures are to be defined and assessed within the IP. Different aspects, such as the cost-benefit of measures, spatial planning aspects and energy-relevant aspects are to be considered. The aim is that the IP will be used to identify and assess ways for municipalities and regions to adapt to climate change with different preconditions and requirements. The students thus make a significant contribution to the implementation of the country's climate change adaptation strategy.

c) In this IP, we will try to capture different value orientations and associated beliefs – in short: worldviews – in order to understand different perspectives on sustainable development and engage you as a student personally into the search for it. As we will see in this course, the sustainability problem can be understood as an overemphasis of, and subsequent degeneration, of one-sided worldviews. In our attempt to structure this mixed problem of objective/subjective knowledge, we take the concept of 'worldviews' as our starting point and we address global challenges such as: population growth, poverty and food security, energy and resource use, ecosystem stability, and urbanisation. Each time when dealing with such an issue, we will look at the respective worldviews and the stances that different sciences take onto the problems.

d) This IP is looking at how supply chains can optimize the sustainability performance of a product from an environmental, social and governance/managerial perspective. Students will be provided with basic knowledge on supply chains, sustainability issues in supply chains and supply chain stakeholders to be able to conduct an in-depth supply chain analysis related to the product of their choice, e.g., in the clothes, food, or electronic sectors. This in-depth analysis consists in mapping the supply chain members and non-supply chain stakeholders looking at what companies are currently doing to provide environmental and social-friendly products and defining what should be improved, e.g., how the supply chain could be better organized, or which regulations shall be adapted. The lecture will use real case examples based on the lecturers' experience in projects such as SustainHub to provide the students with a good understanding of the environmental, social, and managerial aspects related to the manufacture of a product. Due to the global characteristics of most supply chains today, this analysis requires to take into consideration different socioeconomic contexts, for which examples will also be provided to students in the introductory lectures. Students will then work on their research topic in interdisciplinary groups of 3-4

people and will have the possibility to use supply chain mapping tools (e.g. Sourcemap) and analyse supply chain databases (e.g., Trucost), to work on their research project.

e) In the course of a simulation game, students shall play the role of the big players in international climate negotiations and find consensus through discussion. The basis for these discussions (which parties are willing to agree to which admissions) shall be compiled by the students themselves. These contain, e.g., national climate protection measures, the Paris Agreement, the NDCs as well as methods for the reduction and avoidance of greenhouse gas emissions (e.g. increased use of biofuels, CCS – carbon capture and storage, socio-economic measures).
In preparation for this game, the lecturers will give an overview on Austrian, European and international climate politics, as well as scientific background of climate change.
Invited guest lectures:
Procedures of international climate negotiations (Mag. Jakob Lenz, BMLFUW, negotiator of the Austrian delegation since 2009)
Furthermore planned: Expert of the Wegener Center, Climate protection co-ordinator of Styria

Sum Graz third semester: 30 ECTS

Fourth semester:
Master Thesis, 26 ECTS plus Master Examination, 2 ECTS, plus Master Seminar, 2 ECTS (Sum: 30 ECTS)

Sum Graz fourth semester: 30 ECTS

Leiden University, Delft University of Technology (The Netherlands)

First year, 60 ECTS
These courses are compulsory for first year MScIE students, and can be taken as electives by MIND+ students that spend their second year in the Leiden/Delft program.

G. Korevaar, R. Kleijn & J. Quist: General Introduction to Industrial Ecology, 6 ECTS
Students are introduced to the basic concepts of industrial ecology: the technosphere-biosphere analogy, the principles of life-cycle thinking, eco-design, stakeholder investigation, and organizational aspects of industrial clustering.

E. van der Laaqn & E. Cuppen: Closed loop supply chains, 6 ECTS
This course discusses how product reuse and recycling ('closing the loop') can contribute to business value creation and the reduction of environmental footprints at the same time. It furthermore discusses barriers and opportunities for the development of circular systems.

H. Hansen & A. Ghorbani: Renewable Energy Systems, 6 ECTS
This course provides an introduction to technical and societal aspects of renewable energy. Different types of renewable energy sources are treated and their application in buildings, industry and transport, as well as the societal context of these technologies.

L. Scherer: Fundamentals of Systems, Data, Models and Computational Thinking, 6 ECTS
In this course, you will learn to use the programming language Python for scientific work, especially for analysing and visualising datasets that are relevant for Industrial Ecology.

R. Kleijn, M. Hu: Analytical methodologies and tools, 6 ECTS
This course provides knowledge of the most important analytical tools in the area of Industrial Ecology, their philosophy and their position in the field: LCA, MFA, IOA and others, by lectures and practical applications of software tools.

E. van Bueren, U. Hackauf: Urban environments and infrastructures, 6 ECTS
Students will learn about four themes in urban areas which significantly influence the sustainability performance of urban areas: transport, energy, water and construction materials. In addition, they will understand why technical solutions for sustainable urban areas are difficult to implement.

J. Quist, L. Kamp: Sustainable Innovation and Social Change, 6 ECTS
The course combines technical innovations with markets and stakeholders and addresses system innovation and transition concepts and theories. Students learn about backcasting, stakeholder dialogues and transition management and how these relate to emerging industrial ecology niches.

S. Cuchurachi, M. Hu: System Earth, 6 ECTS

The course explores major global sustainability issues related to the use of resources at the global level. All are so-called 'wicked problems': they are complex, there are many actors involved, there is a high urgency and the consequences are enormous.

G. Koervaar: Design of Sustainable Technological Systems, 6 ECTS

In this course an introduction will be given on principles and methodologies of sustainable design. Emphasis is on important environmental and safety issues of sustainable engineering. Design for eco-industrial parks and industrial symbiosis are the major topics in bringing all aspects together.

E. van der Voet, G. Korevaar: Circular Economy, specialization module to be developed specifically for CIRCLE, 6 ECTS

This course is to be developed as an elective of the domestic MScIE, but compulsory for first year CIRCLE students. Second year CIRCLE students can take this course as an elective. This joint Leiden-Delft course teaches basic concepts, methods, tools and indicators related to the circular economy.

CIRCLE Summer School, 3 ECTS

The summer school is administratively included in the Leiden-Delft curriculum as a 3 ECTS compulsory course, for CIRCLE students only.

Second year, 60 ECTS

The Interdisciplinary Project Groups, the Thesis Preparation and the Master Thesis are compulsory parts of the second year. The specialization modules can be taken as electives by all CIRCLE students, also by those that spend their first year in the Leiden/Delft program. In addition to the courses mentioned below, there is a multitude of courses in Leiden and especially Delft that students can choose as electives. It is also possible to do a Capita Selecta, which is an individual course for example containing a book exam or a small piece of research. Capita selecta exist for 2, 3, 4, 5 and 6 ECTS. In the future, more program-internal specialization modules will be developed, to accommodate the growing number of students.

Interdisciplinary Project Groups, compulsory course, 12ECTS

In this course, the students do a group project on a real-industrial ecology problem. By problem-oriented education, the students are trained to cooperate with various disciplines and come up with industrial/practical solutions.

J. Guinée: LCA practice and reporting, specialization module, 9 ECTS

This course aims at teaching students the method of Life Cycle Assessment, and to provide sufficient scientific basis and practical skills to perform an attributional life cycle assessment study independently.

J. Dias Rodrigues: Environmental Input-Output Analysis, specialization module, 6 ECTS

In this course you will learn Environmental Input-Output Analysis (EIOA), a standard methodology which models the propagation of environmental pressures across supply chains, stemming from consumer behavior and policy options, across multiple spatial and sectoral scales.

M. van 't Zelfde & E. van der Voet: GIS and urban mining, specialization module, 4 ECTS

This course teaches the basics of GIS analysis. Students will apply their newly acquired skills to a case of urban mining. Using ARCGIS in combination with the Dutch database on addresses and buildings, a spatially explicit database can be built on the urban mine in a specific city.

E. van der Voet, S. Cuchurachi, B. Sprecher: Advanced MFA, specialization module, 6 ECTS

MFA methodology is discussed and applied to a practical case. Students are taught how to conduct an MFA case study, specifying three approaches: accounting, static modelling and dynamic modelling. For the dynamic MFA, the Vensim software will be used.

Master Thesis Preparation, 6 ECTS

This course aims at preparing a research proposal for the MSc thesis research and is compulsory for second year CIRCLE students.

Master Thesis, 30 ECTS

Chalmers University Gothenburg (Sweden)

First study year, 60 ECTS

Science of environmental change, compulsory course, 7.5 ECTS
The course includes basic natural science knowledge for the understanding of different central environmental and resource problems. A special focus is on problems coupled to different substance and materials flows. The course is also aiming at increasing the knowledge on the industrial societies' turnover of energy and materials and its connection to various natural systems and processes and the emergence and mitigation of environmental problems.

Waste management, elective, 7.5 ECTS
The purpose of this course is to train the students in different waste management techniques. A special emphasis will be on techniques for transformation of waste materials into products that can be beneficially utilized. The ultimate goal should, of course, be that no waste is formed in industry or society. But in the foreseeable future, activities in the industry and society will produce waste. An important step towards a sustainable society is a proper waste management with the goal of utilizing the waste material in best possible way.

Sustainable development, compulsory course, 7.5 ECTS
The aim is to give students the opportunity to acquire a systems perspective on society of today, and based on this develop their insights into restrictions and possibilities that follow from the need to transform the industrial society to conform to a sustainable development. Besides attaining knowledge of the concept of sustainable development, including different perspectives on this concept, students will learn about the consequences of societal resource use, and about strategies for changing this use into a more sustainable direction.

Environmental systems analysis, compulsory course, 7.5 ECTS
The aim of is to give knowledge regarding number of environmental systems analysis tools such as Environmental Risk Assessment, Life Cycle Assessment, Environmental Impact Assessment, and Materials Flow Analysis. The course also aims at understanding of the relationship between different environmental systems analysis tools.

Environmental management, compulsory course, 7.5 ECTS
The course aims at an understanding of the factors driving and shaping the management of environmental efforts in industry. In addition, the course aims at giving an overview of different strategies and methods in environmental management.

Environmental policy instruments, compulsory course, 7.5 ECTS
This course is intended to give an overview of applied environmental economics with particular emphasis on the design of policies in the area of environmental and natural resource management.

Life cycle assessment, compulsory course, 7.5 ECTS
The course aims at providing an understanding of methods to assess the environmental impact of products in a life cycle perspective. The course gives the theoretical background for Life Cycle Assessment as a method, skills to use the method and knowledge about its application areas and limitations.

Circular economy, compulsory course, 7.5 ECTS
This is a project course. The aim is that students should gain knowledge and skills about some analytical tools and methods applied to accomplish circular economy.

Third semester, 30 ECTS

Sustainable energy futures, compulsory course, 7.5 ECTS
The course should give the student knowledge of the general development of the energy system (past development and outlook for the future), its environmental and resource impacts, as well as tools to analyze these developments. The overall aim of this course is to address the following questions:

- How will climate change policies reshape the world energy system over the next century?
- What role may play increased energy efficiency, renewables, fossil fuel and nuclear power, in the near and long term future if the climate challenge is to be met?
- In which sectors limited energy resources are most efficiently used, e.g., should biomass be used for transportation fuels or for heat production?
- Which climate policies are needed for a cost-effective solution to the climate challenge?

The aim is to illustrate these issues by drawing upon recent research in the area, and based upon this to discuss and problematize existing visions for a sustainable energy future.

Sustainable power production and transportation, elective, 7.5 ECTS
The course aims to provide the students with advanced and state-of-the-art developments in wind power, photo voltages, wave power and hybrid electric vehicles, dwelling both on the theoretical fundaments as well as building a good practical and experimental basis. The goal of the course is also to give the students a deep knowledge about the modelling, design and control of the electric system for hydro, wind, wave, and solar power. The electric system in electric or hybrid-electric vehicles will also be treated. The understanding of the grid interaction of these power sources and consumables is also an important goal.

Industrial energy systems, elective, 7.5 ECTS
The aim is to train students to use process integration methods and tools necessary for identifying and designing efficient energy system solutions for the process industry that contribute to sustainable development. Technical systems encountered in the course include heat exchanger networks, boilers, heat pumps, combined heat and power systems, and thermal separation units. Besides technical and economic issues, the course also covers the role of industrial process energy systems for meeting greenhouse gas emissions reduction targets. The course also introduces a method to identify the cost-optimal mix of different process heating technologies to satisfy a given process steam demand and for analysing how future energy policy instruments will influence this optimal solution.

Technical change and the environment, compulsory course, 7.5 ECTS
The course aims at putting technology into context. It aims at making the student aware of the interdependence between technical change, societal development, and the natural environment, in order to be able to take part in knowledgeable discussions on how technical change may help or hinder our ability to deal with environmental problems and resource limitations in the coming decades. The course provides knowledge of historical developments and current trends and introduces the student to different theoretical frameworks that can be used to analyse change.

Fuel cells - function and materials, elective, 7.5 ECTS
The course aims at giving a fundamental understanding of the function and materials of fuel cells, materials properties and components. What is needed to make the technique commercially available will be discussed.

Sustainable electric power systems, elective, 7.5 ECTS
The overall aim is that the student will show an understanding of the function of an electricity delivering system and what possibilities and limitation that such system has.

Assessing sustainability, elective, 7.5 ECTS
The course introduces basic concepts of sustainability and approaches for its assessment in connection to environmental measurements. The course also introduces important connections between sustainable development and environmental problems and their mitigation.

Sustainable transportation, elective, 7.5 ECTS
This course studies technological measures and political initiatives to reduce the environmental impacts of the transport sector. Alternative fuels and innovative vehicle technology, which are a necessity if a sustainable transport sector is to be achieved, are likely to have significant negative side effects and challenges, e.g. competition to food production, resource availability and land-use impacts. The aim of the course is to provide an understanding of the character and scale of the problem and the challenges of potential solutions.

Environmentally adapted product development, elective 7.5 ECTS
The course aims to provide understanding of the complex context of product development with consideration of ecological aspects, a comprehensive overview of current applicable possibilities and related manufacturing processes. Search for and evaluation of alternative solutions for environmental adaptation are practised. The course is based on a life-cycle perspective and deals with the product development, manufacturing, product use and disposal.

Managing stakeholders for sustainable development, elective, 7.5 ECTS
The course aims to provide students with an understanding of how to build constructive relationships with diverse stakeholders in practical contexts. Students gain practical skills and theoretical knowledge of both how to handle and manage the needs and interests of diverse stakeholders and of how to integrate stakeholders - varying types of expertise in relation to sustainability development projects. Stakeholders include local and central government authorities, intergovernmental organisations, industry, university, research institutes, insurance companies, NGOs and regular citizens. The course focuses on the types of cross-disciplinary knowledge and skills required to take leadership on sustainability projects and interact with stakeholders in each of these contexts.

Leadership for sustainability transitions, elective, 7.5 ECTS
The aim of the this course, which also is a preparatory course for Challenge Lab, is to provide students with theoretical perspectives, methods and tools that are useful for challenge-driven sustainability transitions in knowledge clusters. This includes knowledge about multi-level complex dynamic systems, sustainability principles and back-casting, as well as knowledge about design thinking and tools for self-leadership and multi-stakeholder interaction. Based on this knowledge

the students will interact with relevant stakeholders from academia, private- and public sector in a systems design process to identify project ideas that can be elaborated on in the Challenge Lab.

Fourth semester, 30 ECTS
Master Thesis, 30 ECTS

Norwegian University of Science and Technology, NTNU (Norway)

First year, 30 ECTS

Life Cycle Assessment (LCA), 7.5 ECTS, compulsory
Teaches the student the concepts, framework and application of LCA for evaluating the environmental performance of products and systems.

Material flow analysis, 7.5 ECTS, compulsory
Aim is to provide an introduction into the analysis, and design of the anthropogenic metabolism on various scales. Changes in resource demands and material uses can thus be anticipated and consequences for the environment assessed.

Climate change mitigation, 7.5 ECTS, compulsory
The course teaches students about the greenhouse effect including geochemical cycles of greenhouse gases, possible implications of climate change, the adaptation possibilities to it and associated costs.
Solid Waste Technology and Resource Recovery, 7.5 ECTS, compulsory
The course teaches theory, strategies and solutions for solid waste management and recycling and resource recovery from waste systems. Students shall be able to adopt a systems perspective in assessment of solutions and systems for solid waste management, and communicate in good ways with specialists and decision makers.

Experts in teamwork, 7.5 ECTS, compulsory
Students from different academic backgrounds work together on an interdisciplinary project. This enables them to apply their academic competences and learn teamwork skills, which is essential for later on.

Environmental and resource economics, 7.5 ECTS, elective
The course teaches how economic theories are used to discuss environmental problems. Methods for environmental accounting and valuation, int. environmental agreements and the theory on optimal management are part of the course.

Understanding and quantifying environmental impacts on ecosystems, 7.5 ECTS, elective
The aim is to understand dominant problems for biodiversity and ecosystems and gain knowledge on different approaches for quantifying damages and values of biodiversity/ecosystems, such as LCA, footprinting or valuation of ecosyst. services.

Input-Output analysis, 7.5 ECTS, elective
The course provides knowledge about environmentally extended input-output models (EIO), national accounts and environmental extensions and application of EIO models at different scales.

Modeling of Built Environment Systems, 7.5 ECTS, elective
Knowledge is provided to formulate key problems related to selected built environment systems, to describe the tools used to analyse these problems, including a legal and socio-economic context.

Third semester, 30 ECTS

Industrial Ecology project, 15 ECTS, compulsory
The student conducts an own, small research project, addressing the systems analysis of environmental issues from a technical, economic and industrial perspective. The student makes use of tools such as MFA, LCA, input-output analysis or related techniques.

Environmental management and corporate governance, 7.5 ECTS, elective
The course teaches knowledge, understanding and skills to support sustainability, better environmental management and industrial practice under the vision of sustainable development and corporate social responsibility, and connections between environmental and social responsibility in global value chains.

Critical review and communication of science, 7.5 ECTS, elective
Seminar course to learn how to critically review information from the scientific literature. The student learns how to clearly present results in oral and written (reports, papers) form.

Lifecycle performance of aluminium products, 7.5 ECTS, elective
The course teaches the basic tools for sustainable innovation and product development of aluminium products, covering the aluminium value chain from ore to product end-of-life. The course covers circular economy and environmental impacts from aluminium production and recycling, economic perspectives and business models.

Revision of the basic tools, 7.5 ECTS, elective
Choice of one course of the first year for students that did not spend their first year in Trondheim. This gives them the opportunity to catch up with tools and concepts they may not be familiar with yet, depending on the background and where they spent their first year.

Fourth semester, 30 ECTS
Master's thesis, 30 ECTS

b) Associated Partners (outside Europe)

Curtin University Perth (Australia)

Third semester, 30 ECTS

Corporate Stewardship (MGMT6047), 7.5 ECTS
This unit reviews the role of corporate stewardship in setting the goals for company sustainability management. The unit gives students an understanding of the main operating elements in corporate stewardship, the role of the governing board in directing and providing leadership in corporate stewardship and the important role of stakeholder and shareholder engagement in both delivering and guiding corporate stewardship activities.

Organisational Strategies for Sustainability (MGMT6046), 7.5 ECTS
This unit examines the role of strategically planning a company's sustainability activities, the role of strategy in the development and delivery of the sustainability plan and the inherent benefits of organisational training and development in achieving a sustainability plan.

Sustainable Energy (PPRE6006), 7.5 ECTS
This unit reviews the use, value, technology and challenges faced by sustainable energy options in a world still dominated by fossil fuel. It examines the definition of what is sustainable energy and how it is crucial to sustainable consumption and production futures.

Environmental Systems (ENST6003) (Recycling systems), 7.5 ECTS
This unit reviews environmental management systems, their use, benefits and development in helping to achieve more eco-efficient production systems. The unit looks at the challenges of recycling and waste management and the importance of closed loop production systems in providing more sustainable production systems in the future.

Eco-efficiency (ENGR6000) (Remanufacturing systems), 7.5 ECTS
This unit examines the concept of eco-efficiency, its importance as a measurement/indicator of sustainability performance and as a benchmark in comparing alternative technologies and production systems.

Fourth semester, 30 ECTS (Master thesis)

Sustainability Management Dissertation (ENST6001) (Recycling and Remanufacturing), 30 ECTS
This intensive research project will focus on recycling and remanufacturing production and service opportunities. It will examine in detail in a project based research paper a specific waste technology or waste system and its inherent sustainability benefits.

Tsinghua University Beijing (China)

Fourth semester, 30 ECTS

Master Thesis, 30 ECTS

Waseda University Tokyo (Japan)

Third semester, 30 ECTS

Of the six courses listed below, (i) and (ii) are compulsory. Four courses out of (iii)–(vi) and other courses available at Graduate School of Economics have to be selected (sum: 30 ECTS).

(i) Research Seminar on Industrial Ecology and Econometrics (2 units = 5 ECTS)
Instructor: Shinichiro Nakamura and Yasushi Kondo
This joint seminar provides a unique opportunity for students of Industrial Ecology and Econometrics to be exposed to the frontier of research in the area of Industrial Ecology with particular methodological emphasis on Input-Output Analysis (IOA). The topics of application will include LCA, MFA, and LCC with special attention being paid to the issues related to waste management and recycling in a broad sense. The students will obtain enough knowledge in the current state of discipline that will enable them to identify interesting topics of research and the methodological tool required.

(ii) Hybrid input-output analysis in Industrial Ecology (2 units = 5 ECTS)
Instructor: Shinichiro Nakamura
Industrial Ecology (IE) is an emerging discipline focusing on the interactions between economy and environment based on a holistic view with emphasis on quantification and practical application in both private and public sectors. Input-Output Analysis (IOA), while originally developed in economics, has become one of the most widely used tools in IE. This course is aimed at making students familiar with the basics of IOA and its application in various areas of IE. Topics to be dealt with will include life cycle assessment (LCA), material flow analysis (MFA), life cycle costing (LCC), carbon- and water foot printing, waste management and recycling.

(iii) Industrial Ecology (2 units = 5 ECTS)
Instructor: Shinichiro Nakamura
Industrial Ecology is an emerging discipline focusing on the interactions between economy and environment based on a holistic view with emphasis on quantification and practical application in both private and public sectors. It is aimed at identifying possible strategies and policies toward the realization of a sustainable economy where a high quality of living can be achieved at the global level without compromising environmental issues. This course is aimed at making students familiar with the basic ideas and tools of Industrial Ecology. Topics to be dealt with will include LCA, MFA, LCC, carbon- and water footprint, and input-output analysis.

(iv) Econometrics I (2 units = 5 ECTS)
Instructor: Yasushi Kondo
This course introduces econometric methods and their application, in accordance with the textbook: J.M. Wooldridge, *Introductory Econometrics: A Modern Approach*, 6th edition, Cengage Learning, 2016. Basic use of econometric software, EViews and Stata, are introduced as well. In order for students to carry out their empirical projects, i.e., applied econometric studies, becoming able to choose appropriate methods based on sound understanding of econometric theory is an important goal of this course. The requisite background materials are basic mathematical tools, and fundamentals of probability and statistics presented in Appendices A to C of the textbook. Topics covered in Appendices C.3 and C.4 are not prerequisites and will be explained in this course.

(v) Environmental Economics (2 units = 5 ECTS)
Instructor: Toshihide Arimura
This course uses microeconomics and econometrics to analyze environmental issues. Topics include market-based regulations, valuing the environment, air pollution, global warming, waste management, international trade, and tradeoffs between environmental quality and economic growth. Coverage of the topics will balance textbook applications of environmental economics with analysis of environmental policy. Instruction will consist of a mix of lectures, class discussion and presentation. Analytical models will be used throughout the course. Students should be comfortable with basic economic models of optimization (utility and profit maximization). Calculus and basic knowledge on econometrics will be required. Students are expected to understand the graduate level of environmental economics based on microeconomics and econometrics.

(vi) Asian Economy (2 units = 5 ECTS)
Instructor: Yasuyuki Todo
This course will cover sources of and obstacles to economic growth and development in Asian economies, focusing on the role of internationalization of firms, industrial clusters, institutions (including political institutions), social networks, and

rural development. In each topic, we will first review theory and empirical evidence from growth theory, international economics, development economics, economic geography, economics of institutions, or network science and then examine Asian experiences. Therefore, basic understanding of microeconomics (including game theory) and econometrics at the undergraduate level is required. Particular attention will be paid to Japan, South Korea, China, and Southeast Asia, although South Asia and Sub-Saharan Africa will also be covered whenever possible.

Fourth semester, 30 ECTS

Master Thesis, 30 ECTS