December, 2020

International Master's Programme on Circular Economy (CIRCLE)
Course Descriptions (subject to change)

University	Course	Year	ECTS
University of Graz	Sustainability Controlling and Management	1	4
	Change Management and Learning for Sustainability	1	4
	Research Project Sustainability and Innovation Management	1	6
	Product and Service development	1	4
	Environmental and technology assessment	1	4
	Waste and Recycling	1	4
	Fundamentals of Circular Economy and Industrial Ecology	1	4
	Earth Climate System and Climate Change	1	3
	Strategic Sustainability Management	1	4
	Value Chain Management	1	4
	Selected Topics of Innovation Management	1	4
	Electives	1	15
	CIRCLE Summer school	1	3
	Environmental Decision-Making	2	4
	Sustainable Business Models	2	4
	Methods for inter- and transdisciplinary problem-solving	2	2
	Sustainable Innovation	2	4
	Research Project Sustainability and Innovation Management	2	6
	Ethical decision-making on climate change: An experimental approach	2	10
	Carbon removal technologies in the context of the European Green Deal	2	10
	Master's Thesis	2	30
Leiden University/ Delft University of Technology	Earth System Science and Analysis	1	5
	Society's Metabolism	1	5
	Analysing Physical Processes	1	5
	Transitions, Innovation and Governance	1	5
	System Design for Industrial Ecology	1	5
	Analysing Social Processes	1	5
	Industrial Ecology Project 1	1	10
	Circular Economy, specialisation module developed specifically for CIRCLE	1	5
	CIRCLE Summer School	1	3
	Electives	1	12
	Industrial Ecology Project 2	2	10
	Thesis Preparation Module	2	5
	Electives	2	15
	Thesis Research Project	2	30
Chalmers University	Science of environmental change	1	7.5
	Sustainable development	1	7.5
	Environmental systems analysis	1	7.5
	Technical change and the environment	1	7.5
	Environmental management	1	7.5
	Environmental policy instruments	1	7.5
	Environmental risk assessment	1	7.5
	Life cycle assessment	1	7.5
	Applied industrial ecology	1	7.5
	CIRCLE summer school	1	3
	Sustainable energy futures	2	7.5

	Circular economy	2	7.5
	Leadership for sustainability transitions	2	7.5
	Assessing sustainability	2	7.5
	Managing stakeholders for sustainable development	2	7.5
	Urban metabolism and resources	2	7.5
	Sustainable power production and transportation	2	7.5
	Industrial energy systems	2	7.5
	Sustainable electric power systems	2	7.5
	Sustainable transportation	2	7.5
	Product lifecycle management	2	7.5
	Master thesis	2	30

NTNU	Life Cycle Assessment	1	7.5
	Material flow analysis	1	7.5
	Climate change mitigation	1	7.5
	Solid Waste Technology and Resource Recovery	1	7.5
	Experts in teamwork	1	7.5
	Environmental and resource economics	1	7.5
	Understanding and quantifying environmental impacts on ecosystems	1	7.5
	Input-Output analysis	1	7.5
	Modeling of Built Environment Systems	1	7.5
	CIRCLE Summer School	1	3
	Industrial Ecology project	2	15
	Environmental management and corporate governance	2	7.5
	Critical review and communication of science	2	7.5
	Lifecycle performance of aluminium products	2	7.5
	Lifecycle performance of aluminium products	2	7.5
	Master Thesis	2	30

Curtin University Perth	Corporate Stewardship	2	7.5
	Organisational Strategies for Sustainability	2	7.5
	Sustainable Energy	2	7.5
	Environmental Systems	2	7.5
	Eco-efficiency	2	7.5
	Master Thesis: Sustainability Management Dissertation	2	30

Tsinghua University Beijing	Master Thesis	2	30

Waseda University Tokyo	Research Seminar on Industrial Ecology and Econometrics	2	5
	Hybrid Input-Output Analysis in Industrial Ecology	2	5
	Environmental Economics	2	5
	Methods in Applied Microeconometrics	2	5
	Health Economics	2	5
	Network Analysis	2	5
	Spatial Economics	2	5
	Master Thesis	2	30

A) EUROPEAN PARTNERS

University of Graz

First study year

Baumgartner, Arijit, Kettele: Sustainability Controlling and Management, course, 4 ECTS

In this course, 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.

Stern: Change Management and Learning for Sustainability, 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.

Stern, Moreno, Crockett, Brudermann: Research Project Sustainability and Innovation 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 given problem context 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, 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

The seminar presents fundamentals of both Circular Economy and Industrial Ecology. It will address the definition(s), philosophy and principles, history and future directions of both fields mentioned. Moreover, their areas of application, main technical terms (such as industrial metabolism; industrial symbiosis; recycling; closing the loops etc.), methods and tools will be discussed, such as material flow accounting; life cycle assessment or footprint approaches. Additionally, case studies will be presented and discussed.

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, case studies will be discussed, too. Guest talks and a field trip serve as practice-oriented contributions for this course.

Moreno, Stern: Selected Topics of Innovation Management, Course, 4 ECTS

The effects of climate change could cause such changes and problems. However, differences in e.g. company size, sector and regional characteristics may have an influence in their capacity and way to innovate. The seminar is going to investigate the following questions:

- How are companies affected by climate change?
- What are they doing about it?
- What are the main factors determining enterprises innovation strategies and capacity to adapt to climate change?

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 neuroeconomics.

Rauter: Sustainable Business Models, Course, 4 ECTS
This course is focused on exploring literature and best-practice examples of different types of sustainable business models.

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.

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: (i) at the level of firms for creating more sustainable products and services; (ii) at the level of policy to create conditions for innovation systems for sustainability; (iii) and at the level of civil society to develop new practices of use and consumption and to articulate demand in a qualified way.

Stern, Moreno, Crockett, Brudermann: Research Project Sustainability and Innovation 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.

In "Interdisciplinary Practical Trainings" (IPs), 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.

Baumgartner, Arijit, Fleiß, Pölzler: Ethical decision-making on climate change: An experimental approach, IP, 10 ECTS

In the absence of any global climate governance regime, the pressure on business leaders to take ethically desirable action on climate change is constantly growing. Yet, we have very little understanding of how business leaders respond to the ethical demands associated with climate change. In the absence of such an understanding it is impossible to predict when and if such demands will be met.

In this IP, students in groups will conduct behavioral laboratory experiments to explore the mechanism of ethical decision-making in the context of climate change. The focus of the experiments will be on predicting moral judgments, which is widely held as fundamental to the ethical/unethical outcomes of organisational decision-making.

Students will learn about the normative theories of climate ethics, fundamentals of ethical decision-making in organisations and the technique of conducting behavioral lab experiments. They will also learn how to use statistical methods to assess the results of the lab experiments.

Schweitzer, Friedrich, Aschemann: Carbon removal technologies in the context of the European Green Deal, IP, 10 ECTS

With the European Green Deal, the EU has set itself the goal of growing into a fair and prosperous society in which no net greenhouse gas emissions will be released in 2050. In addition to renewable energies, low-emission technologies and a circular economy, carbon removal techniques should also be used to achieve the goals. In addition to the benefits, these techniques also involve risks, sometimes it lacks a framework for decision-making.

In the IP we will deal with carbon removal technologies (such as CCS or CCU) as well as with the legal basis and political framework for their use within the framework of the "European Green Deal". Finally, the students should slip into the roles of several EU countries and negotiate possible framework conditions for the use of carbon removal techniques in a simulation game. The teachers and guest lecturers will give an overview of the following subject area:

- The European Green Deal
- Scientific fundamentals of climate change and emission paths for the 1.5 ° goal
- Technical fundamentals of carbon removal technologies
- Economic, legal and social aspects of carbon removal technologies
- Political framework for carbon removal techniques

In various small groups, the students should deal intensively with the European Green Deal, carbon removal techniques, benefits and risks as well as with economic, social, legal and political aspects. In preparation for the simulation game, EU country-specific conditions and political framework conditions regarding the use of carbon removal techniques are being worked out in further small groups as part of the EU's Green Deal.

This knowledge is used in the simulation game and the students will negotiate in the role of relevant EU countries on framework conditions for the use of carbon removal techniques in Europe to achieve zero net greenhouse gas emissions in 2050.

Sum Graz third semester: 30 ECTS

Fourth semester:

Master Thesis (27 ECTS), plus Master Examination (1 ECTS), plus Master Seminar (2 ECTS)

Sum Graz fourth semester: 30 ECTS

Leiden University, Delft University of Technology (The Netherlands)

First year, 60 ECTS

The seven courses below are compulsory for first year MSc IE students, and can be taken as electives by CIRCLE students that spend their second year in the Leiden/Delft program. In the second semester of the first year, there is space for 15 ECTS on electives for first year Leiden/Delft CIRCLE students.

J. Mogollon & L. Scherer: Earth System Science and Analysis, 5 ECTS

How does the earth system work, and how have natural cycles developed over time and space? This course is meant to introduce students to planet Earth and its resources, as viewed from a system's perspective, as a guiding analogy for sustainable systems. The course will present the evolution of Earth's four spheres (biosphere, geosphere, hydrosphere, and atmosphere) over 4.5 billion years. These developments will highlight the importance of the carbon, nutrient, and water cycles for life on our planet. This section will follow an interdisciplinary look at the causes and potential impacts of natural changes of the Earth System.

S. Cucurachi: Society's Metabolism, 5 ECTS

The course explores what role humans play in altering the natural functioning of Earth and it prepares students to evaluate the impact of society's metabolism on the earth system functioning. This course will introduce students to the Anthropocene, including the various pressures that society's metabolism exerts on the natural system and its cycles. The main themes addressed in this course include the Anthropocene, Economics of the Anthropocene, Resources and scenarios, Energy analysis, Water, Food System, Societal challenges and governance. An additional focus of this course is an introduction to various communication techniques and the opportunity to apply these skills in project work.

M. Hu & R. Kleijn: Analysing Physical Processes, 5 ECTS

The course provides knowledge of the core tools used in the area of Industrial Ecology, their philosophy and their position in the field. Students are trained in the applicability of these tools by working on case studies with the aid of specific software-tools (MFA/SFA, LCA, IOA).

J. Quist & T. Hoppe: Transitions, Innovation and Governance, 5 ECTS

The course provides an overview of sustainable innovation, sustainability transitions, in particular socio-technical transitions and their governance. The starting point of the course is that sustainable innovation, transitions and their governance are required to bring about sustainable development and transitions to sustainability. Innovation is considered as both technical and non-technical novelty that can be brought successfully to the market, can improve business practices, or can lead to major changes in user practices in society. Sustainable innovation is related to concepts like social innovation, eco-innovation and responsible innovation. It is shown that innovation can take place at various scales from product and technology to system level society and when taking place at a system level it will lead to societal transitions, which are needed to move towards sustainability. Adequate governance, governance strategies and policies are needed to facilitate sustainable innovation and sustainability transitions.

A. Ramirez: System Design for Industrial Ecology, 5 ECTS

A core element of industrial ecology is that it requires to look at a problem from a system perspective. This course aims to provide insights necessary to understand and apply the core concepts of system design in the field of Industrial Ecology. The course will introduce the core concepts of system thinking (such as interconnectedness, synthesis, feedback loops, causality) and students will work on their application in small case studies.

A. Ghorbani: Methods: Analysing Social Processes, 5 ECTS

The course explains the process of scientific research in the social sciences and introduces the main methods used in the field. It helps students in theorizing and thinking like a researcher, which are often prerequisites of empirical and modelling research. The course covers the whole process

of research from building hypotheses and collecting data, to modelling and simulation and analysis of data. Topics include: case study research, surveys, questionnaires, mixed-methods, modelling and simulation.

U. Hackauf & G. Korevaar: Industrial Ecology Project 1, 10 ECTS
In the course, urban environments and industrial systems are being approached from an ecosystem perspective, with the focus on three important flows: energy, water, construction materials and resources. Analyzing these flows reveals the complexity of urban and industrial environments. The flow systems are related in multiple ways. An intervention to improve one flow can have a negative impact on another flow. Spatial interventions hold potentials for synergies or the possibility to find the synergy between an industrial cluster and an urban area nearby. The final outcome of the course is an improved, integrated and implemented sustainable urban development or sustainable industrial development.

E. van der Voet & G. Korevaar: Circular Economy, specialisation module developed specifically for CIRCLE, 5 ECTS
This course has been developed as an elective of the domestic MSc IE, 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 (registered in the form of an Industrial Ecology Capita Selecta).

Electives, 12 ECTS

Second year, 60 ECTS
The Industrial Ecology Project 2, the Thesis Preparation Module and the Thesis Research Project are compulsory parts of the second year. In the first semester of the second year, there is space for 15 ECTS on electives.

Industrial Ecology Project 2, 10 ECTS
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.

Thesis Preparation Module, 5 ECTS
This course aims at preparing a research proposal for the MSc thesis research and is compulsory for second year CIRCLE students.

Electives, 15 ECTS

Thesis Research Project, 30 ECTS

Specialisation modules
The specialisation modules can be taken as electives by all CIRCLE students, also by those that spend their first year in the Leiden/Delft program (if fitted within their programme). In addition to the courses mentioned below, there is a multitude of courses in Leiden and especially in 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 exists for 2, 3, 4, 5 and 6 ECTS.

J. Guinée: LCA Practice & Reporting, specialisation module, 10 ECTS, semester 1
Life cycle assessment (LCA) is a science- and evidence-based method for quantifying the environmental burdens and impacts related to the whole life cycle of a product or service system. 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.

R. Wang: Environmental Input-Output Analysis, specialisation module, 5 ECTS, semester 2
In this course you will learn Environmental Input-Output Analysis (EIOA), a standard methodology which models environmental interventions associated with production and consumption of products, across multiple spatial and sectoral scales.

M. van 't Zelfde & E. van der Voet: GIS: Spatial Analysis in Urban Regions, specialisation module, 5 ECTS, semester 2
This course teaches the basics of GIS analysis. Students will apply their newly acquired skills to a case of urban mining. Using GIS software 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. Cucurachi: Material Flow Analysis, specialisation module, 5 ECTS, semester 2
This course teaches students the method(s) of Material Flow Analysis (MFA). Students learn the basic methodology, the methodological debates and the latest methodological developments regarding systems definition, quantification, modelling and the interpretation of the results. They learn how to use MFA by applying it in a case study, using different software tools.

L. Scherer: Advanced Data Analysis with Python, specialisation module, 5 ECTS, semester 1
To be developed

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.

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.

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.

Environmental management, compulsory elective course, i.e. 4 in a list of 10 stated courses are required for the degree, 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 elective course, i.e. 4 in a list of 10 stated courses are required for the degree, 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.

Environmental risk assessment, compulsory elective course, i.e. 4 in a list of 10 stated courses are required for the degree, 7.5 ECTS
The aim of the course is for the students to become knowledgeable about environmental risks and be able to apply environmental risk assessment. This course provides a broad introduction to environmental risks and environmental risk assessment that covers:
· Historical and contemporary environmental risks
· Existential risks
· Conceptual models in risk assessment
· Risk ranking
· Probabilistic risk assessment
· Risk assessment of chemicals
· Uncertainty analysis
· Social science perspectives on risk

Life cycle assessment, compulsory elective course, i.e. 4 in a list of 10 stated courses are required for the degree, 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.

Applied industrial ecology, compulsory elective course, i.e. 4 in a list of 10 stated courses are required for the degree, 7.5 ECTS
The aim of the course is that students should gain knowledge and skills about some analytical tools and methods applied in Industrial Ecology to support them to assess critical aspects of sustainability, focus on environmental impacts and resource constraints, and to suggest measures towards sustainable development. The focus is on technical systems and life cycles of resources and products.

Third semester, 30 ECTS

Sustainable energy futures, compulsory elective, 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.

Circular economy, compulsory elective, 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.

Leadership for sustainability transitions, compulsory elective, 7.5 ECTS

The aim of 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.

Assessing sustainability, compulsory 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.

Managing stakeholders for sustainable development, compulsory 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.

Urban metabolism and resources, elective, 7.5 ECTS

The aim of the course is for students to understand functioning of cities in terms of their technical systems, including water and transportation infrastructures, urban resource use and waste production as well as exchange between the cities and the environment. The obtained skills will enable students to assess cities resource consumption and environmental impact, critically examine urban technical systems and propose the necessary measures to achieve the Sustainable

Development Goals and to meet challenges of global urbanization, resource scarcity and environmental degradation.

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.

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.

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.

Product lifecycle management (PLM), elective, 7.5 ECTS
The purpose of the course of is to provide an overview of how IT tools are used to create and manage products throughout their lifecycles, from identification of customers need to product retirement. In particular, the course focuses on the advanced use of CAD and PDM systems to rationalize the product development process.

Fourth semester, 30 ECTS
Master Thesis, 30 ECTS

Norwegian University of Science and Technology, NTNU (Norway)
First year, 30 ECTS

First semester (fall semester), with three compulsory and one elective course

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, suggested elective
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.
Second semester (spring semester), with one compulsory course. Students must choose 3 out of the listed four electives.

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, policy or industrial perspective.

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)–(vii) 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: KONDO, Yasushi, and NAKAMURA, Shinichiro
This research seminar covers recent topics in industrial ecology and circular economy, with an emphasis on input-output economics/input-output analysis (IOA). The topics include life-cycle assessment, footprint analysis, material flow analysis, and supply chain analysis. Special attention will be paid to issues related to waste management and 3R (reduce, reuse, and recycling) in a broad sense.
The research seminar is designed for second- and third-semester master students in econometrics or industrial ecology who are interested in circular economy. The main objectives of the research seminar are to provide the opportunity for students to obtain exposure to the frontier of research in industrial ecology and circular economy, and to assist students in choosing their master thesis topics or preparing their theses.

(ii) Hybrid Input-Output Analysis in Industrial Ecology (2 units = 5 ECTS)
Instructor: NAKAMURA, Shinichiro
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) Environmental Economics (2 units = 5 ECTS)

Instructor: ARIMURA, Toshihide

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.

(iv) Methods in Applied Microeconometrics (2 units = 5 ECTS)

Instructor: DEJARNETTE, Patrick

This course is designed to introduce students to common methods employed in Applied Microeconometrics, as well as some of the dangers or risks faced when employing them. Although we employ many techniques from statistics, applied microeconometrics is somewhat unique in the problems it faces when trying to establish causality; especially in the presence of humans who each have their own preferences and behaviors.

Rather than proving asymptotic results, this course focuses on the problems you might face given finite data and how to best confront them. As an applied class, this course will also cover how to implement these methods using statistical software (specifically “Stata” software). The course concludes with an individual project implementing these methods.

(v) Health Economics (2 units = 5 ECTS)

Instructor: NOGUCHI, Haruko

This is a graduate level course in health economics, in particular, focusing on demand for health, health care, and health insurance. This course will also be relevant to students who are interested into empirical microeconomic research. The main objectives of this course are obtaining theoretical and empirical tools and frameworks to analyze health-care related issues.

Course Schedule: (1) Introduction, (2–3) Healthcare system in Japan, (4) Health and healthcare: Inter-country comparisons, (5) Grossman model I: Health production and optimal heath, (6) Grossman model II: Optimal demand for healthcare, (7) Market failure in healthcare market, (8–10) Empirical analyses on healthcare demand, (11–12) Empirical analyses on healthcare supply, (13–14) Long-term care system in Japan, (15) Final examination.

(vi) Network Analysis (2 units = 5 ECTS)

Instructor: SOHN, Yunkyu

Most political and economic phenomena emerge from interactions between multiple actors. Network theory, which has been developed for centuries in mathematics, statistics, and physics, provides a quantitative framework to understand complex patterns of interactions.

This class is designed to introduce the basic framework and measures of network analysis. Students will first learn how to derive descriptive measures of network analysis using pencil and paper. Then, they will acquire skills for conducting basic network analysis using the programming language R. A list of network datasets available online and a list of academic articles that can be used as model papers for research reports will be provided.

Almost all of the contents covered in this class only require high school level mathematical knowledge. Knowledge in linear algebra, calculus, discrete mathematics, and statistics, however, yields deeper understanding of the subject. It is assumed that the students have no prior experience in a programming language.

(vii) Spatial Economics (2 units = 5 ECTS)

Instructor: SAITO, Yukiko

This course aims to provide a theoretical and empirical way of thinking about how geographical distance and space have an impact on economic activities. Spatial Economics is a combined field of international economics and economic geography. I will explain traditional theories for both fields and how they evolved over time and harmonized together inspired by empirical facts. This theoretical framework makes you understand mechanism behind inter-industry trade and intra-industry trade, an impact of trade cost reduction such as trade liberalization and development of transportation infrastructure, geographical pattern of economic activities, and agglomeration effect on economic growth. Finally, new literature is introduced and evidence-based policy is discussed based on theoretical and empirical analysis. Students are required to present previous literature and discuss based on the presentations.

Fourth semester, 30 ECTS

Master Thesis, 30 ECTS