MATERIAL FLOW ANALYSIS - TEP4285
Raw Materials Exploration and Sustainability

CONTACT INFORMATION

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COURSE CONTENT AND INTENDED LEARNING OUTCOMES (ILOs):

The course provides an introduction into the analysis, evaluation, and design of the anthropogenic metabolism on various scales (companies, cities, countries, world). The students will learn how to use MFA in order to anticipate changes in resource demand and emissions, to interpret these changes in terms of consequences for the environment, resource security, employment, or geopolitical conditions, and to identify opportunities for changing the system in a desired direction. The methodological elements of the course include: i) terminology, system definition, and indicator selection; ii) mathematical representation of systems; iii) mathematical representation of uncertainty, sensitivity analysis, and data reconciliation; iv) dynamic modeling; v) introduction to and application of various software for MFA modeling. The methodology lectures are supplemented by background lectures, which include practical examples of MFAs. In the exercises, the students will employ the tools and methodologies in practical examples related to the main human activities (to nourish, to clean, to transport and communicate, to reside and work). The lectures will contain interactive elements with short discussions.

Knowledge
The students will obtain knowledge about:
- the main challenges and strategies for the socio-economic metabolism related to the basic human activities (to nourish, to clean, to transport and communicate, to reside and work);
- the theory of the socio-economic metabolism and its examination in space and time through material flow analysis (MFA).

Skills
The students will be able:
- to explain the role of key substances and materials in today's societal metabolism and their potential interactions with the environment;
- to define MFA systems, and to describe a system as a mathematical model in order to test the impact of data uncertainties and to develop simple scenarios (forecasting, backcasting, analyzing implications of interventions);
- to point out and reflect on strengths, limitations, and specific areas of application of different MFAs

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(including other industrial ecology tools that build on them), and to interpret the results in terms of their policy implications (e.g., judge the effectiveness of different interventions).

General competence
The students will:
- familiarize with the use of system approaches for solving complex problems;
- become aware of the similarities and differences between MFA and other industrial ecology tools, the types of questions they can address, and their limitations;
- learn to effectively communicate complex information with practitioners (including visual representation).

Aligning with the EIT OLOs:

☑ EIT OLO 1 - Making value judgments and sustainability competencies
2= highly relevant to the course content – The course provides the student with the ability to use MFA in order to anticipate changes in resource demand and emissions, to interpret these changes in terms of consequences for the environment, resource security, employment, or geopolitical conditions, and to identify opportunities for changing the system in a sustainable direction.

☐ EIT OLO 2 - Entrepreneurship skills and competencies

☑ EIT OLO 3 - Creativity skills and competencies
2= highly relevant to the course content – The course focuses on systems thinking and quantitatively analysing the linkages between different parts of the economy. This encourages the students to think beyond traditional disciplinary boundaries, to determine systemic consequences of alternative interventions, and to identify novel solutions to problems.

☐ EIT OLO 4 - Innovation skills and competencies

☑ EIT OLO 5 - Research skills and competencies
2= highly relevant to the course content – The course provides the students with cutting-edge research tools (methodology lectures) and applications in various areas (background lectures). Subsequently, they are applying the tools on their own to new problems (exercises), where they work in groups of 2-3 students.

☑ EIT OLO 6 - Intellectual transforming skills and competencies
1= marginally relevant to the course content – The course exposes the students to some extent to practical experiences through excursions and guest lectures by industry representatives. These experiences are relevant for motivating the questions they are addressing in the exercises and for critically reflecting on the effectiveness of existing industrial strategies in different contexts.

☐ EIT OLO 7 - Leadership skills and competencies

ASSESSMENT METHODS AND GRADING SYSTEM

Different assessment methods will be used to evaluate the students: content-based, competence-based and impact-based assessments. Content-based assessment refers to assessment tasks that mainly ask the learner about facts. Competence-based assessment refers to assessment of intended learning outcomes that ask the learner to show ability to also use these facts. Impact-based assessments take the assessment of competencies one step further and ask the learner to use these competencies in a real-life situation to create a change or solve a challenge.

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Active participation during the course is key to stimulate the students and allow them to reflect on strengths, limitations, and specific areas of application of different MFAs. The exercises allow the evaluation of students based on their critical and creative thinking in terms of value judgment and sustainability assessment (EIT OLO 1 and EIT OLO 3), since they are tasked to apply the methods learned in different activities which involve human activities, from biofuels to cement and GHG emissions. The students are provided with only background information and are required to conduct their own literature research (EIT OLO 5) so to submit informed policy recommendations.

The final exam is split into two parts: exercises (evaluation of reports) and a written exam. Both parts aim to test all of the OLOs mentioned above, however, the written exam is better suited to evaluate the value judgement and sustainability competencies (OLO 1) and the creativity skills and competencies (OLO 3), the exercises are better suited to address the research and the intellectual transforming skills and competencies (OLOs 5 and 6).

ASSESSMENT METHOD	WEIGHT ON FINAL GRADE
Exercises (reports)	30%
Written exam	70%

COURSE SESSIONS

Part 1	**BACKGROUND**
Content	The background lectures and excursion provide an introduction into the socioeconomic metabolism with a focus on the four human activities: • To Nourish (food – carbon, nitrogen, phosphorus) • To Clean (waste management) • To Transport and Communicate (mobility, electronics, paper – aluminum, critical materials) • To Reside and Work (buildings – construction minerals, steel)
Readings	Recommended reading: Baccini and Brunner (2012): Metabolism of the Anthroposphere. MIT Press. Literature on the individual topics will be provided
Assignment	No assignments for this part. Active participation in discussions.

Part 2	**METHODOLOGY**

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Content	Methodology lectures provide the students with the tools necessary to conduct and interpret a material flow analysis. This includes: • System definition • Procedure • Mathematical description: quasi-stationary models • Uncertainty analysis (sensitivity analysis, error propagation, Monte Carlo simulation, data reconciliation) • Mathematical description: dynamic models • Lifetime estimation • Scenario development
Readings	Recommended reading: Brunner and Rechberger (2016): Handbook of Material Flow Analysis; CRC Press. Additional literature will be provided for each lecture topic.
Assignment	No assignments for this part. Active participation in discussions.

Part 3	**EXERCISES**
Content	In the exercises, the students learn to employ the methods (part 2) in different applications for all human activities (part 1). The exercises focus on the following topics: • Biofuels • Phosphorus cycle • Omega-3 fatty acids • Lead cycle • Cement and greenhouse gas emissions
Readings	No readings are provided here. The students will use the information provided in part 1 and 2, and conduct their own literature research.
Assignment	The students will get assignment texts for each exercise, which includes relevant background information.

Part 4	**FINAL EXAM**
Date - hours	Date and place will be announced at the beginning of the semester – h 09.00 – 13.00
Content	A written examination will take place in November/December. The duration is 4 hours. The topics of the text are related to the application of MFA in different contexts, with a focus on: • System definition • Mathematical modelling (only quasi-stationary cases) • Uncertainty analysis • Interpretation of given MFAs

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RaMES

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