Module Handbook

Master of Science

in

International Material Flow Management

(IMAT M.Sc.)

[Version October 2020]

Contents

Preamble

This ***Module Handbook*** (MH) presents the detailed technicalities of the study programme ***Master of Science in International Material Flow Management*** (IMAT M.Sc.) which was designed, developed and launched in 2004 by the Institute for Applied Material Flow Management (IfaS) of the Trier University of Applied Sciences (HT) based on the three key attributes of IMAT, *viz* innovativeness, interdisciplinarity, and internationality.

This advanced and leading-edge postgraduate programme for master-level qualification is in the domain of '*science'* and specifically focuses on the discipline of International Material Flow Management with emphasis on engineering economics. And, it was designed recognising the lacuna in the field of environmental and sustainability sciences. In addition to its main course offering —i.e. in-class lectures, IMAT M.Sc. students have also been given the unique opportunity to follow selected ***blended e-learning courses*** offered by the parallel IMAT engineering programme (IMAT M.Eng.) offered as a set of five dual-degree programmes (as of July 2020) by the global IMAT Network University (IMAT-NU) that includes nine partner universities on five continents[1].

Upon completing the course work in the first two semesters, the students are given two options; either to spend the third semester abroad —***Study Semester Abroad***— or to undertake a research-oriented internship that leads to the master thesis —that must be defended in a formal colloquium— and the subsequent award of the master qualification.

This award-winning IMAT M.Sc. programme has been recognised the world over as an education portfolio/programme which is attuned and better positioned to cater to the goal "***Education for Sustainable Development***". Staying true to its objectives, the IMAT M.Sc. produces competent and skilled young professionals —also known as ***Material Flow Managers***— to undertake the global challenges of Sustainable Development.

This Module Handbook intends to serve as a comprehensive guide to the courses offered at IMAT M.Sc. programme. One may obtain further insights and the latest information pertinent to the programme by visiting the IMAT website —***www.imat-master.com***.

[1] Global IMAT-NU partners:

- Environmental Campus Birkenfeld (ECB) of the Trier University of Applied Sciences, Germany
- Ritsumeikan Asia Pacific University (APU), Beppu, Japan
- National Taipei University of Technology (NTUT), Taipei, Taiwan
- Al Akhawayn University (AUI), Ifrane, Morocco
- Universidad Panamericana (UP_{Mex}), Aguascalientes, Mexico
- Universidade Positivo (UP_{Braz}), Curitiba, Brazil
- Universidade Lusófona, Lisbon, Portugal
- Sultan Qaboos University, Muscat, Oman
- Hindustan Institute of Technology and Science, Chennai, India

Study Plan IMAT M.Sc.

Visualized in the following table is the study plan including the modules, in-class learning hours (SWS[2]), credits (according to the European Credit Transfer System – ECTS), the workload and the weight of the modules (in percentage) that determines the final average grade (Grade Point Average - GPA).

	Modules No.	Modules / Subjects	SWS	ECTS	Workload	Module Weight / Total Grade (in %)
Semester 1	M1	Global Environmental Challenges and Green Business Opportunities	4	6	180	6,67
	M2	MFM Project Management and Financing	4	6	180	6,67
	M3	Research Management and Applied Material Flow Management	4	6	180	6,67
	M4	Economic Aspects of Sustainable Energy Systems	4	6	180	6,67
	M5	Regional Material Flow Management	4	6	180	6,67
Semester 2	M6	Sustainability Management in Industry	4	6	180	6,67
	M7	Circular Economy and Zero Emission Systems: Financing Strategies for Resilient Societies	4	6	180	6,67
	M8	Industrial Ecology and Industry 4.0	4	6	180	6,67
	M9	Economic Aspects of Integrated Water Resource Management	4	6	180	6,67
	M10	Elective **	4	6	180	6,67
Semester 3	M11	Internship / Study Semester Abroad *	20	30	900	0,00
Semester 4	M12	Master Thesis	(20)	(30)		
		Colloquium		*6*	180	6,67
		Thesis		*24*	720	26,67
	TOTAL		80	120	3600	100

NOTES: M= Module; SWH= Semester Week Hours; ECTS= European Credit Transfer System

M11*= Module with pass/fail grading
M10** is to be selected from the catalogue of electives for the course of study regulated in these regulations. This may include modules for which attendance is compulsory in accordance with §12(2) of these regulations as a prerequisite for achieving the learning objectives and passing the examination.

[2] SWS is the German abbreviation for Semesterwochenstunden, corresponding to Semester Week Hours/in-class hours

This programme has 12 modules, whereof modules 1 to 10 each carries 6 ECTS and a corresponding workload of 180 hours per module. Module 11 provides the students with the opportunity to deepen the theoretical knowledge by conducting an internship in companies, research organisations and (non) governmental entities with a duration of 16 weeks and (minimum) 20 semester week hours (SWH) per week. Alternatively, students have the choice to conduct a theoretical study semester at any university with an equivalent workload of 20 SWH per week and a duration of 16 weeks. The M11 is a pass/fail module, thus not included in the final grade. Thus, the total ECTS relevant for the grade point average (GPA) sums up to 90 ECTS.

M7 and M8 are blended e-learning modules conducted —via the worldwide web— by the IMAT-NU partner universities, and they are part of the curriculum of the IMAT M.Eng. programme. M10 is an elective module.

Description of the Modules

This section presents the details of all the modules of the IMAT M.Sc. programme. These technicalities span from the outline of the learning objectives to the offered ECTS, the weightage of grades, workload, the assessment methods, etc.

Module 1 [M1]: Global Environmental Challenges & Green Business Opportunities		
Duration	1 semester	
Study Semester	1st semester	
Frequency	Annual (Winter semester)	
Recommended Prerequisites	Basic comprehension of ecosystems	
Classification	☒ Required Course ☐ Compulsory Elective Course	
Credit Points	6	
Weight of Grade	(6/90) 6.67%	
Contact Hours	4 SWH/60 h	
Self-Study	120 h	
Total Workload	180 h	
Language	English	
Mode of Delivery & Didactics	Lectures, group work and discussions, case studies	
Professor in-charge	Prof. Dr. Peter Heck	
Teaching Personnel	Prof. Dr. Peter Heck; Mr. Ranahansa Dasanayake	
Requirement for the Award of ECTS Points	Passed module examination(s) and passing the interim assessment(s)	
Methods of Evaluation (%)= allocation	☒ Written exam (50) ☐ Viva voce ☐ Colloquium ☒ Project presentation (20)	☐ Class participation ☒ Term paper or essay (30) ☐ Practical exam ☐ Laboratory performance

1. Learning Objectives

The students have a comprehensive understanding of the systemic interactions of ecosystems. They understand the laws of thermodynamics and their functionality and criticality in natural ecosystems and manmade complex systems. The students are also able to distinguish between the natural and manmade systems and their dynamics. They are able to identify and describe the material and energy flows in ecosystems and are able to show the interactions between natural systems and manmade systems. They are also able to analyse the global environmental challenges arising out of human interaction with the ecosystems and can identify the green business opportunities within as a consequence of applying the state-of-the-art remedial measures.

2. Module Content

This module offers students an in-depth learning opportunity about the system interaction of ecosystems in order to understand that issues such as inefficiencies and waste/emission problems are non-existent in functioning ecosystems but inherent to man-made systems. A spectrum of diverse and interrelated topics presents the fundamentals of the complex concepts as follows.

2.1) Global environmental challenges/issues

Discusses manmade problems in ecosystems as well as solutions to these issues based on Zero Emission (ZE) and Material Flow Management (MFM) concepts. The key issues discussed include:

- Water problems (water pollution, water scarcity, flooding)
- Waste problems (industrial, household, agricultural wastes)
- Energy issues
- Issues of resources and sinks
- Agriculture and food security issues
- Various other current issues such as global warming, ocean pollution, landscape degradation and the loss of biodiversity.

2.2) Introduction to ecosystem theory

Provides clarification of the key terms, concepts and the models of the environment (e.g. species, predators, symbiosis, population, biosphere, biotope, biodiversity and resilience in an ecosystem, environmental gradients, limiting factors, potency, biotopes, niches, ecosystem equilibrium, carrying capacity, ecological footprint).

2.3) Material flows in ecosystems

Provides a comprehensive overview of the pertinent matter and energy flows in ecosystems, such as carbon cycle, phosphorous cycle, nitrogen cycle, water cycle, food chain, etc. and also introduces the terms, concepts and models of photoautotrophic, heterotrophic, decomposers.

2.4) Waste and wastewater in ecosystems

Provides insights into how recycling happens in the ecosystems (e.g. detritus recycling) compared to that of manmade systems. Provides an understanding of the organic loads in water in ecosystems and compare and contrast that with the manmade systems. Discusses the natural/bio-based treatment of water pollution, use of bio-indicators for water quality, importance and application of indicters such as BOD and COD, etc.

2.5) Soil development and function

Discusses the physical, biological and chemical aspects of soil, soil degradation, and sustainable aspects of soil management such as in the case of black soil (*Terra Preta*).

2.6) Energy in ecosystems

Provides in-depth knowledge on the application of the 1^{st} and 2^{nd} laws of thermodynamics in ecosystems. Topics covered include the law of conservation of energy, entropy, exergy, energy supply and energy balance of natural ecosystems, energy flow in the food chain/web, etc.

2.7) Aspects of CE and related terms

Provides insights into clean technology, efficiency and sufficiency strategies, decentralised versus central supply of utility and disposal of waste/emissions, product and process integrated environmental protection.

2.8) Economic aspects of CE

Discusses ecological economics, the steady-state theory, etc.

2.9) An introduction to international policy models

Provides an in-depth understanding of the key elements such as Sustainable Society, 3R Society, CE, Recycling Economy, Material Flow Society, Zero Emission Communities, etc.

2.10) Case studies with potential solutions/sustainable approaches

Discusses specific case studies from a diversity of domains and provide real-life applications/practical examples from around the world. The students also get the opportunity to present country-specific situations (ideally from their home countries), perspectives, and strategies towards achieving sustainable development associated with the focal concepts discussed throughout the module.

3. Required Reading

1. Bingham N., Blowers A., Belshaw C. (2003). *Contested Environments.* Wiley. Harris, Francis (Ed.): Global environmental issues, Wiley.

2. Spiro T.G., Stigliani W.M. (2003). *Chemistry of the Environment* (2nd edition), Tsinghua University Press.

3. Marsh W.M., Grossa Jr. J. (2005). *Environmental Geography: Science, Land Use, and Earth Systems.* Wiley.

4. Cox C.B., Moore P.D. (2000). *Biogeography. An ecological and evolutionary approach*, (6th ed.), Oxford.

5. Ristinen R. R., Kraushaar J. (2006). *Energy and the Environment* (2nd ed.). Wiley.

6. Niele F. (2005). *Energy. Engine of Evolution, Shell Global Solutions.* Elsevier.

7. Worldwatch Institute: State of the World yearly publications.

8. Manning R. (2000). *Food's Frontier. The next Green Revolution.* University of California Press.

9. Caufield C. (1991). *In the Rainforest – Report from a Strange, Beautiful, Imperiled World*, University of Chicago Press.

10. EPA (2003). *Beyond RCA. Waste and Materials Management in the Year 2020.* Washington.

11. Task Force of Circular Economy and Cleaner Production (2003). *Strategy and Mechanism Study for Promotion of Circular Economy and Cleaner Production in China.* Beijing.

12. Bringezu S., Schütz H. (2001). *Total Material Requirement of the European Union.* Copenhagen.

13. Luks F., Hammer M. (2003). *Material Flow Analysis, Discourse Analysis and the Rhetorics of (Ecological) Economics.* Bonn.

14. Wagner L. A. (2002). *Materials in the Economy – Material Flows, Scarcity, and the Environment.* US Geological Survey Circular 1221, Denver.

15. OECD (2000). *Special Session on Material Flow Accounting.* Paris.

16. OECD (2002). *Sustainable Development. Indicators to Measure Decoupling of Environmental Pressure from Economic Growth.* Paris.

Module 2 [M2]: MFM Project Management & Financing		
Duration	1 semester	
Study Semester	1st semester	
Frequency	Annual (Winter semester)	
Recommended Prerequisites	None	
Classification	☒ Required Course ☐ Compulsory Elective Course	
Credit Points	6	
Weight of Grade	(6/90) 6.67%	
Contact Hours	4 SWH/60 h	
Self-Study	90 h	
Total Workload	150 h	
Language	English	
Mode of Delivery & Didactics	Lectures, group work and discussions, case studies, seminar, project workshop	
Professor in-charge	Prof. Dr. Christian Bleis	
Teaching Personnel	Prof. Dr. Christian Bleis; invited lecturers of specific expertise on speciality topics	
Requirement for the Award of ECTS Points	All two elements of the grade assessment must be passed individually.	
Methods of Evaluation (%)= allocation	☐ Written exam ☐ Viva voce ☐ Colloquium ☒ Project presentation(s) (50)	☐ Class participation ☒ Term paper or essay (50) ☐ Practical exam ☐ Laboratory performance

1. Learning Objectives

Students have acquired an in-depth understanding of the (financial) feasibility of projects, especially based on financial analytics and key performance indicators. Therefore, they possess a sound understanding of creating and analysing financial statements, profit and loss accounts as well as balance sheets. They are able to identify strengths, weaknesses and potentials of projects and able to create business plans with adequate financing instruments. In addition to the micro-analytical financial feasibility check, the students are able to model regional added value potentials of circular economy projects at industrial, regional and national levels bringing in macro-perspective —financial— on project performance evaluation.

The students are also competent in connecting their theoretical knowledge to new and practical cases and able to identify problems in economic systems and solving them independently.

2. Module Content

In terms of value orientation, this course focuses on financial analysis as an instrument for assessing and reconciling green business investment projects on the basis of microeconomic modelling and regional added value forecasts. Accordingly, the course consists of five major parts. They are:

2.1) Accounting & controlling

Includes the terms and the basics of cost accounting and controlling in companies/institutions, and provides know-how in reading and interpreting a balance sheet, financial statement and profit-and-loss-account.

2.2) Investment calculations & project/business valuation

Provides an introduction to financial mathematics such as internal rate of return (IRR), return on investment (RoI), net present value (NPV), real options, etc. and, also presents the basics of the valuation of projects, e.g. Capital Asset Pricing Model, Discounted Cash Flow Calculation (DCFC), etc. as well as other value-asset and market approaches.

2.3) Finance & investment

Includes an introduction to and an evaluation of financial performance indicators to interpret and measure profitability, solvency, liquidity and stability of businesses.

2.4) Business plan design

This segment covers aspects of the key attributes of and content of business plans, managerial budgeting and prediction of business potentials, market and competitor analysis, and case studies in business plan design.

2.5) Prediction of (regional) added value

Presents insight into the investors' perspective to societal "value", (macro-economic) methods and tools to "determine" the additional values of ZE/CE projects throughout all value chains and life cycles.

2.6) Project planning and project management

The segment provides insight into the structuring, planning, execution and control of a project (temporary endeavours) including the definition of objectives, deliverables and milestones. Students learn to reduce complex tasks into comprehensive, measurable work packages and assign budget and resources. Students learn to apply basic project planning and management tools in their own research projects.

3. Required Reading

There are no required textbooks considering the course's broad nature and scope. However, the students are advised to peruse general books on financial analysis and project management (e.g. Project Management Institute. (2004). *A guide to the project management body of knowledge (PMBOK guide)*. Newtown Square, Pa: Project Management Institute.) All other required learning material such as cases are provided throughout the course.

Module 3 [M3]: Research Management & Applied Material Flow Management		
Duration	1 semester	
Study Semester	1st semester	
Frequency	Annual (Winter semester)	
Recommended Prerequisites	None	
Classification	☒ Required Course ☐ Compulsory Elective Course	
Credit Points	6	
Weight of Grade	(6/90) 6.67%	
Contact Hours	4 SWH/60 h	
Self-Study	120 h	
Total Workload	180 h	
Language	English	
Mode of Delivery & Didactics	Lectures, group work and discussions, case studies	
Professor in-charge	Dr. Michael Knaus & local IMAT-NU coordinators	
Teaching Personnel	Dr. Michael Knaus & local IMAT-NU coordinators	
Requirement for the Award of ECTS Points	The two elements of the grade assessment must be passed individually.	
Methods of Evaluation (%)= allocation	☐ Written exam ☐ Viva voce ☐ Colloquium ☒ Project presentation (50)	☐ Class participation ☒ Term paper or essay (50) ☐ Practical exam ☐ Laboratory performance

1. Learning Objectives

Students have a profound understanding of the field of the *scientific method*, scientific work, academic/technical writing, dissemination/communication of research results, etc. They are able and competent in synthesising a thesis and also able to present the key ideas/findings to an audience, concisely. They are equipped with the skills to undertake a comprehensive review of literature, able to search academic databases using the latest tools, competent in data mining, and able to read and understand scientific papers published in peer-reviewed journals. They have the required comprehension and the skills in analytical thinking and able to undertake scientific communication at different levels required in academia and the public communications domains.

2. Module Content

This is a refresher course on the principles of the *scientific method*, academic writing and communications. A key objective is to help students plan/prepare for their research undertaking and the subsequent synthesis of the master thesis. As a requirement of this module, the students will continuously and in a stepwise manner work on their research and their master thesis. Regular webinars will also be conducted as the need be to include all students from the IMAT-NU partner universities. IMAT-NU faculty that includes well published and reputed professors will coach the students in this endeavour throughout the course. A third of the module includes theoretical work whereas the remainder is dedicated to hands-on praxis of technical/academic writing and other forms of communications. Accordingly, this module contains:

2.1) Undertaking scientific research

Provides an introduction to/a refresher on the *scientific method*, applicable tools, latest trends, formulating research queries/hypothesis, etc.

2.2) Structuring the thesis/Academic writing

Discusses how to survey of literature, relevant tools and databases, the structure of a master's thesis and related technicalities, the language of technical/academic writing, etc.

2.3) Communications

Presents the aspects of both oral—targeting the colloquium—and other forms of communication—academic papers for peer-reviewed journals, conferences, etc.—of scientific findings.

3. Required Reading

There are no required textbooks to peruse. However, the students are advised to familiarise themselves with the process of academic/technical writing by associating peer-reviewed publications. All other required learning material is provided throughout the course.

Module 4 [M4]: Economic Aspects of Sustainable Energy Systems		
Duration	1 semester	
Study Semester	1st semester	
Frequency	Annual (Winter semester)	
Recommended Prerequisites	None	
Classification	☒ Required Course ☐ Compulsory Optional Subject	
Credit Points	6	
Weight of Grade	(6/90) 6.67%	
Contact Hours	4 SWS/60 h	
Self-Study	120 h	
Total Workload	180 h	
Language	English	
Mode of Delivery & Didactics	Lectures, group work and discussions, exercises	
Professor in-charge	TBC	
Teaching Personnel	TBC	
Requirement for the Award of ECTS Points	All three elements of the grade assessment must be passed individually.	
Methods of Evaluation (%)= allocation	☒ Written exam (50) ☐ Oral exam ☐ Laboratory performance ☒ Project presentation (25)	☐ Portfolio ☒ Term paper or essay (25) ☐ Practical exam ☐ Colloquium

1. Learning Objectives

The students comprehend the basic engineering foundation in energy-relevant issues (e.g. thermodynamics, electrodynamics and efficiencies) and have a basic technical understanding of important renewable energy (REN) technologies and storage options.

They understand actual and future design challenges and strategies for 100% REN supply systems as well as the qualitative difference between the conventional and regenerative supply of energy in terms of long-term continuity, economy and ecology based on methodological knowledge on energy life cycle assessment and energy balances throughout the various life stages from resource extraction towards final use energy.

The students also have an overview of future-oriented Smart Grid design requirements and components and understand cross-sectoral synergies (power-to-heat, power-to-gas, power-to-mobility).

2. Module Content

The course provides engineering background information on current renewable energy and energy storage technologies and the future-oriented sector-coupling options. Therefore, the transmission of basic engineering knowledge and equations to rudimentary design renewable energy systems are focused. Students are provided with an overview of essential economic and ecological questions and methods to predict the potentials and regional added value of renewables on industrial, regional and national levels.

This module also enables students to develop the knowledge and skills to understand, articulate, create and critique 100% REN systems, and develop their own renewable energy projects including potential analysis and business planning aspects.

In addition, students understand the basic engineering formulas, methods and practices of cross-sectoral energy efficiency technologies such as compressed air, cooling, steam and pump systems. The details of the key areas covered in the course are as follows.

2.1) Basic engineering principles of energy systems

Provides the basics of energy (physics) and electricity: units, mechanics, (electrodynamics), basic principles of the "First and Second Law of Thermodynamics" (internal energy, enthalpy, entropy, emergy, exergy). Provides the energy-related definitions: from primary energy to end-use energy and from end-use energy to useful energy and also discusses the basics of electric power systems: features and structure of power (supply, transmission and distribution) systems as well as design and operation of power systems and grids (operating reserve, voltage and frequency stability). Also, provides some insights into the electricity demand characteristics and Demand Side Management options.

2.2) In-depth analysis of REN (Wind, Solar, Hydro, Biomass, Geothermal Heat)

Discusses the basic physical principles of different REN, the analysis of current technology options, level of innovation and mode of operation, the economic aspects of renewable energy on a micro and macro-economic level and the impacts of RE on industrial/regional/national Zero-Emission concepts and case studies.

2.3) Systematic approach to 100% REN

Presents the concepts of calculatory and physical energy autonomy, energy-mix, seasonal/geographical balance, grid operation and management, requirements for storage systems, etc.

Also discusses the storage systems, physical capabilities and optimization strategies for storage infrastructure on a macro-economic level, identification and use of processes with inherent storage capabilities (water tower, desalination, mechanization, heating/cooling), aspects of *beyond counting kWhs*: intended excess production of REN —a paradigm shift in grid operation from supply shortfall to abundance of energy, and power-to-gas, power-to-mobility, power-to-heat systems.

2.4) Market drivers and barriers of REN

Presents the aspects of economic drivers and market/legal incentives of REN (feed-in tariffs, subsidies, power purchase agreement, investment and financing, etc), grid parity and cost of energy (services) of different RENs, international legal and institutional frameworks for REN [quotas for renewable supply, ratification of (inter-) national agreements (e.g. Kyoto-Protocol), grid access and feed-in codes, etc.].

2.5) Energy system design: future challenges & strategies

Provides an understanding of the future-oriented smart grids and their design requirements and components, including metering, demand response, virtual power plants, dynamic pricing, demand-side management, network integration, etc. and also presents the methods of analysis of risks to the smart grids and discuss protective measures to ensure the system integrity and supply reliability.

3. Required Reading

1.) Feynman, Richard P., Robert B. Leighton, and Matthew L. Sands. *The Feynman Lectures on Physics*. Reading, Mass: Addison-Wesley Pub. Co, 1963.

2.) Tipler, P. A., Mosca, G., (2007). *Physics for Scientists and Engineers*. W. H. Freemann.

Course-related links/Internet Resources

The general required readings are supplemented by suitable publications of relevant international institutions such as IRENA, IPCC, etc. Some examples of supplemental literature recommendations are:

1.) https://www.ipcc.ch/report/renewable-energy-sources-and-climate-change-mitigation/

2.) https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_chapter7.pdf

3.) https://www.irena.org/publications/2020/Jun/Renewable-Power-Costs-in-2019

4.) https://www.irena.org/publications/2020/May/Tracking-SDG7-The-Energy-Progress-Report-2020

5.) https://www.irena.org/publications/2020/Apr/Global-Renewables-Outlook-2020

6.) https://www.irena.org/publications/2020/Mar/Electricity-Storage-Valuation-Framework-2020

7.) https://www.irena.org/publications/2020/Jan/Advancing-renewables-in-developing-countries

Module 5 [M5]: Regional Material Flow Management (rMFM)		
Duration	1 semester	
Study Semester	1st semester	
Frequency	Annual (Winter semester)	
Recommended Prerequisites	None	
Classification	☒ Required Course ☐ Compulsory Elective Course	
Credit Points	6	
Weight of Grade	(6/90) 6.67%	
Contact Hours	4 SWH/60 h	
Self-Study	120 h	
Total Workload	180 h	
Language	English	
Mode of Delivery & Didactics	Lectures, group work and discussions, case studies	
Professor in-charge	Prof. Dr. Peter Heck	
Teaching Personnel	Prof. Dr. Peter Heck; Mr. Ranahansa Dasanayake	
Requirement for the Award of ECTS Points	All three elements of the grade assessment must be passed individually.	
Methods of Evaluation (%)= allocation	☒ Written exam (30) ☐ Viva voce ☐ Colloquium ☒ Project presentation (40)	☐ Class participation ☒ Scientific paper (30) ☐ Practical exam ☐ Laboratory performance

1. Learning Objectives

The students have the ability to analyse regions from cultural, economic, historic, political and administrative points of view where, in doing so, they are capable to deploy the method of Material Flow Analysis. They also have a thorough understanding of the different forms of value creation in regions along the social, economic, and ecological dimensions. They understand how regions communicate internally and externally and know-how regions are governed.

Furthermore, they have a first-hand overview/exposure of the key Zero Emission technologies to implement in regional Zero Emission strategies. The students also have the competence in using microeconomic tools to evaluate the regional added value (RAV) potentials and compute the business and development opportunities. They are able to analyse regional MFM projects and identify the weaknesses and potentials for improvement. Students are capable of developing systemic change management strategies for regions while factoring in stakeholder management, networking, and knowledge management. The students have the knowledge and competence on how to use the MFM tools to develop and subsequently implement MFM master plans in international contexts and to deploy this knowledge in their own countries/regions to design and undertake regional MFM projects during the master thesis semester and after the completion of their master qualifications.

2. Module Content

1) Introduction to regional MFM and urban metabolism processes

Provides an introduction to the regional MFM tool kit, the definition of regions and system boundaries —including cultural, historical, political, administrative— and the aspects of regionalization and globalization, etc. Also improves the understanding of the new strategies for regions in a globalised economy.

2) Regional key person analysis (i.e. Stakeholder Analysis)

Provides knowledge on the process of analysing key persons, ranking systems of the stakeholders —according to their importance/criticality— for change management in the region.

3) Regional stakeholder management

Discusses the evaluation methods of the stakes of key persons in a system, check their potential influence for new technologies, and how to identify losers and winners of a system change.

4) Regional Material Flow Analysis (rMFA)

Provides insights into the analysis of the most important/critical material and energy streams in a system such as waste, water, wastewater, energy, agriculture, tourism, traffic, mobility, etc. Also provides in-depth knowledge on how to turn questions and data into project information, and how to communicate system change, etc. and also the aspects of modelling material streams in a system. Also discusses the process of analysing regional development processes including the drivers, pull and push dynamics, barriers and obstacles of regional changes, etc.

5) New regional MFM based management strategies

In-depth exploration of new management strategies and technologies for regional energy production and distribution management, management strategies and technologies for regional waste management, management strategies and technologies for regional water management, management strategies and technologies for regional transportation management, etc.

6) Local added value strategies on a regional scale

Presents new business models for regional investments and provides an introduction to economic modelling of regional MFM projects. In addition, the aspects of carbon management, carbon trading and carbon finance, green financing (e.g. contracting, cooperatives, etc.) and fundraising strategies for MFM Master Plan development are discussed.

7) Student assessment and presentation of international best practice examples on regional MFM projects

Students analyse an international case study (or studies) employing their recently acquired knowledge on rMFM and critically assess the project/projects and present, in a seminar-style forum, their findings.

3. Required Reading

Brunner, P.H., Rechberger, H. (2004). *Practical Handbook of Material Flow Analysis*. Lewis Publications.

Various IfaS study/project reports on global rMFM undertakings

Recent publications on the subject of rMFM/MFM from selected international journals (Journal of Industrial Ecology, Journal of Cleaner Production, Sustainability, etc.)

Selected BMU publications on technological topics related to rMFM

Module 6 [M6]: Sustainability Management in Industry		
Duration	1 semester	
Study Semester	2nd semester	
Frequency	Annual (Summer semester)	
Recommended Prerequisites	None	
Classification	☒ Required Course ☐ Compulsory Elective Course	
Credit Points	6	
Weight of Grade	(6/90) 6.67%	
Contact Hours	4 SWH/60 h	
Self-Study	120 h	
Total Workload	180 h	
Language	English	
Mode of Delivery & Didactics	Lectures, group work and discussions, case studies	
Professor in-charge	Prof. Dr. Klaus Helling	
Teaching Personnel	Prof. Dr. Klaus Helling; selected international guest lecturers	
Requirement for the Award of ECTS Points	The two elements of the grade assessment must be passed individually.	
Methods of Evaluation (%)= allocation	☒ Written exam (40) ☐ Viva voce ☐ Colloquium ☐ Project presentation	☐ Class participation ☒ Scientific paper with oral presentation (60) ☐ Practical exam ☐ Laboratory performance

1. Learning Objectives

The students have a good comprehension of the characteristics of industrial MFM and how it has emerged. They have the knowledge and competence to undertake evidence-based analysis of businesses/industries and demonstrate the cases for eco-efficiency. Furthermore, they are able to use Life-Cycle-Analysis (LCA) as a sustainability assessment tool in industrial MFM. The students have a thorough understanding of the requirements of Management Systems (e.g. ISO 14001, ISO 50001) and the GRI requirements for sustainability reporting and know the benefits of sustainability reporting for companies. The students are able to critically reflect upon the technical content of sustainability reports and capable of understanding the evidence of Corporate Social Responsibility.

Furthermore, the students have a thorough understanding of the current trends in consumer behaviour and its implications/impacts on global sustainability. Accordingly, the need for sustainable development and both short-term and long-term sustainability goals (SDGs). The students are also able to identify the importance and the contribution of industrial sustainability management towards achieving these international goals.

2. Module Content

2.1) Definition of industrial material flow management (iMFM), related terms, and the scopes

Discusses the aims and forms of industrial MFM, sustainability management, supply chain management, environmental management, cleaner production (CP), etc.

2.2) Principles and key elements of resource and energy efficiency in industry

Provides insights into the concepts and practices such as design for environment, producer responsibility, re-engineering processes, revalorization of by-products, product redesign, rethink markets, etc. and undertake a thorough analysis of case studies on resource and energy efficiency in international industrial sectors provided as webinars by faculty members of the IMAT partner universities and international experts.

2.3) Introduction to relevant ISO-based management systems

Provides detailed discussions on the principles, requirements and guidelines for the quantification and reporting of the environmental impacts (14001) towards carbon footprint of products (14067:2018) towards energy management (50001) consistent with International Standards on life cycle assessment (LCA) (ISO 14040 and ISO 14044).

2.4) Sustainability trends

Provides insights into the SDGs, carbon-neutral production and consumption, sustainability branding and trends, industrial trends/strategies for achieving sustainability and SDGs, etc.

2.5) Overview of sustainability management and reporting initiatives and the strategies in the industry

Presents the Corporate Social Responsibility (ISO 26001) and discusses the CSR versus Green Washing. Also discusses the carbon footprint and other footprints. Provides case studies on CSR and CF.

2.6) Analysis of the global reporting initiative (GRI)

Discusses GRI principles required in the GRI report to ensure the report quality. Includes the technicalities such as GRI standard disclosures: strategy, company profile and stakeholder engagement; GRI economic indicators—including the definitions and examples; GRI environmental and social indicators—including the definitions and examples. Provides a series of case studies on GRI to improve comprehension of practical applications.

3. Required Reading

Helling, K., (2006). *Principles of Industrial Material Management.* Birkenfeld

Guidelines of ISO 14001; ISO 14040; ISO 26000; EMAS III

Wagner, B., Enzler, S. (2006). *Material Flow Management – Improving Cost Efficiency and Environmental Performance.* Heidelberg

WBCSD, (2006). *The Eco-Efficiency Learning Module*.

GRI-Standards for Sustainability Reporting

Course-related links/Internet Resources

The general required readings are supplemented by suitable publications of relevant international institutions. Some examples of supplemental literature recommendations are:

1. Cleaner Production Germany

https://www.cleaner-production.de/index.php/de/ 2. The International Organization for Standardization https://www.iso.org/home.html 3. World Business Council for Sustainable Development https://www.wbcsd.org 5. Global Reporting Initiative https://www.globalreporting.org/Pages/default.aspx Further readings and case study materials will be provided.

Module 9 [M9]: Economic Aspects of Integrated Water Resource Management		
Duration	1 semester	
Study Semester	2nd semester	
Frequency	Annual (Summer semester)	
Recommended Prerequisites	Basic comprehension of ecosystem management (M1) & the basic aspects of natural science (e-M5)	
Classification	☒ Required Course ☐ Compulsory Elective Course	
Credit Points	6	
Weight of Grade	(6/90) 6.67%	
Contact Hours	4 SWH/60 h	
Self-Study	120 h	
Total Workload	180 h	
Language	English	
Mode of Delivery & Didactics	Lectures, group work, excursions and discussions, case studies	
Professor in-charge	TBC	
Teaching Personnel	TBC	
Requirement for the Award of ECTS Points	The two elements of the grade assessment must be passed individually.	
Methods of Evaluation (%)= allocation	☒ Written exam (50) ☐ Viva voce ☐ Colloquium ☐ Project presentation	☐ Class participation ☒ Scientific paper with oral presentation (50) ☐ Practical exam ☐ Laboratory performance

1. Learning Objectives

Students have a good understanding of the technical and economic aspects of integrated water resource management (IWRM), which is an important prerequisite for the implementation of regional Zero Emission strategies and managing the global challenges of water and sanitation.

The students also possess basic knowledge in water science, aquatic ecology and the hydrological cycle combined with an understanding of the dynamic relationship between human and natural systems, in particular the interconnections between water, soil, energy, regional development and sustainability. The students understand the economic aspects as well as the basic technical principles and design aspects of water sanitation engineering infrastructure focusing on drinking water supply and treatment, sewerage and wastewater treatment, etc. They are also knowledgeable in new technology concept for nutrient recovery from wastewater, water reuse and energy-efficient (energy autarky) wastewater treatment. Students have a general understanding of technical aspects of the urban water infrastructure.

Students are able to apply the economic valuation tools to determine the levelized cost of water services (LCoWS) and perform economic viability checks on different water resource (efficiency) projects.

2. Module Content

1) Introduction to the hydrologic cycle and global water problems

Provides insights into the aspects such as the proportion of freshwater, seawater, global water volumes, global appropriation of freshwater, etc. Discusses the water cycle including the aspects of precipitation, infiltration, runoff, evapotranspiration and their computation/equations and measurement methods.

Provides an introduction to the sustainability principles of water resource management, the international water-related policies, case study on the history of water protection and water policies in Germany, and also provides an introduction to the Millennium Water Targets, the global issue of water scarcity and water pollution, etc.

2) Introduction to water supply and wastewater systems

Discusses the economic and technical aspects of drinking water, the historical development, economics and technical aspects of wastewater treatment, and the technical aspects of water treatment technologies, water reuse and wastewater avoidance strategies.

3) Principles of economic valuation of (waste)water management services

Provides an understanding of the basic economical and managerial aspects of water treatment technologies, the basic economic and managerial aspects of water reuse and wastewater avoidance strategies.

4) Case studies in sustainable water resource management
Provides detailed/in-depth case studies on appropriate technologies for water treatment in developed and developing countries.

3. Required Reading

Module-specific reading material will be provided throughout the course.

Following titles are recommended for further insights:

Springer Water book series; The Economics of Water (2021) in particular: https://link.springer.com/search?facet-series=%2213419%22&facet-content-type=%22Book%22

Module 11: Internship/Study Semester Abroad		
Duration	1 semester	
Study Semester	3rd semester	
Frequency	Annual (Winter semester)	
Recommended Prerequisites	Must have completed all preceding coursework.	
Classification	☒ Required Course ☐ Compulsory Elective Course	
Credit Points	30	
Weight of Grade	0% (Pass/Fail)	
Contact Hours	20 SWS/300 h	
Self-Study	Depends on the requirements of the partner university or the provider/host of the internship.	
Total Workload	900 h	
Language	English	
Mode of Delivery & Didactics	Lectures, case studies, practical & research work/scientific investigations, etc.	
Professor in-charge	Current IMAT Programme Coordinator	
Teaching Personnel	Lecturers according the selected topics	
Requirement for the Award of ECTS Points	For the internship option, students must provide a research report on their internship semester abroad highlighting the achieved objective/learning outcomes. The report should be of the length of 5,000 words. For the *study abroad* option, students must complete the objective codified in the learning agreement. Credit points are awarded in accordance with the regulations for the practical study phase and the semester abroad as well as accompanying internships for practice-oriented theses for the Bachelor and Master programmes in the department Environmental Business/Environmental Law.	
Methods of Evaluation (%)= allocation	☐ Written exam(s) (100) ☐ Viva voce ☐ Colloquium ☐ Project presentation	☐ Class participation ☒ Internship report (100) ☐ Practical exam ☐ Laboratory performance

1. Learning Objectives Module 11 provides the choice to conduct a practical internship and/or study semester abroad (or a combination thereof). Hence, students have the opportunity to deepen the theoretical knowledge in a practical internship phase by conducting an internship in companies, research organisations and (non) governmental entities with a duration of 16 weeks and (min) 20 semester week hours (SWH) per week. Alternatively, students have the choice to conduct a theoretical study semester at any university with an equivalent workload of 20 SWH per week and a duration of 16 weeks. Option Internship: The students possess the required level of practical understanding and able to apply the theoretical knowledge to a given situation in the domains of MFM, ZE, CE, ISWRM, SD and SRM. They are able to work in both public and private sectors of business orientation (i.e. a company) or a research institute, or a legislative body, etc. successfully. Option Study Semester Abroad: Students deepen their theoretical knowledge based on the unique teaching focal point of the selected exchange university. Prior to the study semester, the ECB programme coordinator, as well as the local contact point of the selected exchange university are defining the learning agreement which includes the definition of classes to attend with their respective learning objectives, module content and methods of grade evaluation.
2. Module Content The content of the internship/study semester abroad should be in accordance with the thematic areas of the IMAT programme.
3. Required Reading N/A

Blended e-learning modules

The following modules, M7 and M8, are collaboratively offered by the IMAT-NU as ***blended e-learning modules.***

These modules are designed and developed to highlight the status, applications, and current developments of the core subject areas of the IMAT M.Sc. programme in an international setting. Blended e-learning modules have been developed for the IMAT M.Eng. programme during the German Academic Exchange Service (DAAD) funded project of "IMAT Network University" and the first blended e-learning module was conducted in spring semester 2018.

The blended e-learning modules present/discuss topics of global interests —mainly global circular economy strategies and policies on the industrial, sectoral and national level— from various geographical and scientific disciplines' perspective. Hence, in these blended e-learning courses, IMAT-NU partners, acceding partners, and selected international guest lecturers conduct lectures (i.e. webinars via the internet according to the special focus of their institution and the region. Based on the broad scope of the IMAT blended e-learning modules, they are open for both IMAT programmes: IMAT M.Sc. and IMAT M.Eng. The differentiation between the programmes will be organised in the onsite class hours conducted by the local faculty member to review and discuss the contributions of the international partners.

In these modules, the IMAT M.Sc. students shall be part of the ***global learning class*** of the IMAT-NU partner universities and according to the requirements of the exercises/teamwork (e.g. case studies), form study groups and teams. This provides a unique opportunity for the students to work in an international collaborative group providing international exposure, praxis on web-based communication, exposure to collaborative working tools, and methodological knowledge on the IoT of education, research, and projects.

Module 7 [M7]: Circular Economy & Zero Emission Systems: Financing Strategies for Resilient Societies	
Duration	1 semester
Study Semester	2nd semester
Frequency	Annual (Summer semester)
Recommended Prerequisites	None
Classification	☒ Required Course ☐ Compulsory Elective Course
Credit Points	6
Weight of Grade	(6/90) 6.67%
Contact Hours	4 SWS/60 h
Self-Study	120 h
Total Workload	180 h
Language	English
Mode of Delivery & Didactics	This module is organised as a blended e-learning course together with the IMAT-NU partners and delivered online via the worldwide web. IMAT-NU faculty and international experts —guest speakers— on speciality topics will deliver the lectures.
Professor in-charge	Dr. Michael Knaus and IMAT-NU coordinators
Teaching Personnel	IMAT-NU faculty/coordinators and invited international guest lecturers.
Requirement for the Award of ECTS Points	All three elements of the grade assessment must be passed individually: **1.) Global group assignment (50%)** Students have to select a corporation/sector that can be analysed in each IMAT network country and perform a critical analysis against the provided parameters. Subsequently, the students collaborate for a report and deliver the finding online—oral presentation. **2.) Scientific article review (25%) - *individual work*** Students select an article published in English in a scientific journal with impact factor ≥ 2 that has *zero emission* in the title, and is, at least, 6 pages long. The review must include a brief summary of all topics covered in the article, and focus on a critical evaluation of the methods, results, and conclusions. The students individually submit a report and deliver a (recorded) online presentation. **3.) Lecture notes report (25%) - *individual work*** Students write a summary of each lecture presented online throughout the course, in English, and discursive form.

Methods of Evaluation (%)= allocation	☐ Written exam ☐ Viva voce ☐ Colloquium ☒ Project presentation/group assignment (50)	☐ Class participation ☒ Term paper or essay (Scientific article review 25% + Lecture notes report 25%) ☐ Practical exam ☐ Laboratory performance

1. Learning Objectives

The students have a thorough knowledge of the historical background, the latest developments, and the theoretical basis of Circular Economy and its embedded sub-strategies like bio-economy and Zero Emission (ZE), the linkages to resilience and resilient societies as well as sustainable development goals (SDGs) and material flow management. Students have an overview on international CE/ZE applications and their techno-economic & social implications on various societal sectors such as energy sector, (fresh) water (sanitation) sector, (municipal solid) waste sector, construction sector, industry, transportation as well as their drivers, push-and-pull factors.

Students are competent to transfer international CE/ZE strategies into different national context and analysis barriers and chances for local/national adaptations of international existing strategies.

Students understand how to evaluate the financial implications of new CE/ZE implications on the project and regional/national added value level using various economic toolsets and methods and have a basic technical understanding of the underlying technical subsystems and technologies.

2. Module Content

The lecture series starts with an introduction to the historical development and the theoretical basis of Circular Economy (CE), Zero Emission (ZE) and Material Flow Management (MFM) and their implications on different societal sectors.

The IMAT-NU partners and international experts provide sets of 2 to 4 SWH lectures each, focussing on international case studies on interesting and future-oriented CE implementations, policies, strategies and projects on certain societal sectors and their financial implications.

The lectures are delivered as webinars and also recorded and distributed for asynchronous learning. Subsequently, the local coordinating lecturers organise onsite discussion classes with their participating student to discuss the contents of each lecture in order to put the key concepts into perspective.

Key areas discussed in this module include:

General CE framework

1.) Historical development of CE/ZE/MFM and future role

2.) A European perspective on CE and its impact on various societal sectors

3.) Current tools to determine circularity of policies and sectors

4.) The connection between CE, SDGs and international climate protection policy

5.) Role of Bio-Economy (BE) in Circular Economy and international BE strategies

6.) The resilience of systems: concepts and evaluation tools

CE case studies

7.) CE in sustainable resource management: from municipal solid waste management to integrated soil and energy protection and support systems

8.) Energy autarky and nutrition recovery in water sanitation systems

9.) Biochar: sources and applications in waste-food-energy nexus

10.) 100% Renewable Energy (Island) Systems: Challenges and regional economic welfare

11.) 100% Renewable energy systems: regional added value of Power-to-x strategies

12.) Contribution of building sector towards resilience

13.) Consumer trends and supply chain pressures towards zero-emission industries

14.) CE trends in individual mobility

15.) CE trends in the transport sector

The list of case studies is not exclusive and will be constantly supplemented by actual topics and technological/policy developments.

3. Required Reading

The required reading is announced prior to the start of the module.

Following resources are recommended:

EMF, (2020). *Financing the circular economy: Capturing the opportunity*. https://www.ellenmacarthurfoundation.org/assets/downloads/Financing-the-circular-economy.pdf

EMF, (2021). CE and related publications. https://www.ellenmacarthurfoundation.org/publications

Module 8 [M8]: Industrial Ecology and Industry 4.0

Duration	1 semester
Study Semester	2nd semester
Frequency	Annual (Summer semester)
Recommended Prerequisites	Basic comprehension of ecosystem management and green business potential (M1)
Classification	☒ Required Course ☐ Compulsory Elective Course
Credit Points	6
Weight of Grade	(6/90) 6.67%
Contact Hours	4 SWS/60 h
Self-Study	120 h
Total Workload	180 h
Language	English
Mode of Delivery & Didactics	This module is organised as a blended e-learning course together with the IMAT-NU partners and delivered online via the worldwide web.
Professor in-charge	Prof. Dr. Susanne Hartard and Prof. Dr.-Ing. Matthias Vette-Steinkamp
Teaching Personnel	Prof. Dr. Susanne Hartard (IE), Prof. Dr.-Ing. Matthias Vette-Steinkamp (Industry 4.0), IMAT-NU faculty/coordinators and invited international guest lecturers.
Requirement for the Award of ECTS Points	The two elements of the grade assessment (see method of evaluation) must be passed individually.

Methods of Evaluation (%)= allocation		
	☐ Written exam	☐ Class participation
	☐ Viva voce	☒ Term paper or essay (50)
	☐ Colloquium	☐ Practical exam
	☒ Project presentation (50)	☐ Laboratory performance

1. Learning Objectives

The first part of the module concentrates on industrial ecology and eco-industrial parks. The students have a thorough knowledge of the historical background, the latest developments, and the theoretical basis of industrial ecology (IE) and industrial symbiosis (IS), their interdisciplinary approaches to resource managements, the tools employed, and the techno-economic & social implications, etc. towards sustainable development. Students are also competent in the identification/assessment of the material and energy flows using state-of-the-art tools of IE/IS including MFA, SFA, LCA, CF, etc. and able to provide techno-economic solutions in terms of sustainable resource management following the principles of IE.

They are knowledgeable in concepts such as industrial metabolism (and the indicators thereof), dematerialisation, impact and resource decoupling, etc. and have a thorough understanding of the technologies and processes involved in recycling, upcycling, cascading, biorefinery, etc.

They also have a thorough understanding of the IE implementations around the world that includes eco-industrial parks, industrial symbioses, etc. in the key geographic regions of the world including Asia, Africa, Europe, and the Americas.

In the second part, students know the current trends in the domain of Industry 4.0 and are able to apply its concepts and the theoretical basis in resolving industrial challenges sustainably.

The students know different methods from Industry 4.0 in practical application. Especially the advantages of the digital twin in combination with the "Internet of Production" (IoP) and methods of Artificial Intelligence (AI) and how these can be used for efficient and economical production. An important topic is supply chain management. The students have knowledge about digital methods with which suppliers and OMEs can better coordinate their production and thus react faster to changing market conditions. They know how to make faster decisions based on valid data. The students not only know the different methods but can also transfer them to new applications.

2. Module Content

The IMAT-NU partners/international partners provide 2 SWH lectures each, plus a session for Q&A. The lectures include an introduction to the historical development and the theoretical basis of the country-specific IE implementations, policies, strategies and projects and wherever possible present national examples of eco-Industrial parks as well as examples for applications of industry 4.0.

The lectures are delivered as webinars and also recorded and distributed for asynchronous learning. Subsequently, the local coordinating lecturers organise onsite discussion classes with their participating student to discuss the contents of each lecture in order to put the key concepts into perspective.

Key areas discussed in this module include:

1.) History and roots of IE

2.) Material and energy intensity of processes and products

3.) Industrial parks and symbioses

4.) Current trends in IE, in particular, Industry 4.0 (I4.0 or the Fourth Industrial revolution): its design principles and goals, technicalities as well as I4.0' social, economic, and environmental consequences, I4.0' limitations and strengths, etc.

5.) Important I4.0 technologies: digital twin, predictive maintenance, blockchain technology, artificial intelligence methods and Internet of Production

Indicated below are some potential areas of discussions/lectures that provide a global/international perspective.

1.) Introduction, history, terminology, and global trends in IE and I4.0 and their implications on sustainable development.

2.) IE and I4.0 strategy of Germany

3.) Contributions of the IMAT networking university partners with case studies on IE, IE strategy, and eco-industrial parks in Brazil, Canada, Japan, Mexico, Morocco, Portugal, Taiwan , Oman and India.

3. Required Reading

The required reading is announced prior to the start of the module.

Elective Module

The elective module M10 of this programme offers students the opportunity to deepen their knowledge in specific fields of interest in line with the key objectives of the IMAT programme. The list below indicates some of the potential electives, which might be offered in cooperation with the IMAT partner universities.

- Social & cultural processes in the Asia Pacific
- Global environmental politics & economics
- Environment & Sustainable Development
- Changing social landscape and cultural change
- Air pollution monitoring and control
- Water management and pollution control
- Green building and building automation
- Advanced environmental geosciences
- Environmental policy, law & administration
- Urban sustainability
- Industrial ecology
- Development finance
- Community development
- Managerial issues in energy companies
- Energy & environment

For those students who have not taken any natural science courses at their undergraduate level, as IMAT M.Sc. is offered to and open to all potential students notwithstanding their non-natural-science-based baccalaureates, the elective ***Basic aspects of Natural Science*** is recommended.

Module 10 [M10]: Elective – Basic Aspects of Natural Sciences

Duration	1 semester	
Study Semester	2nd semester	
Frequency	Annual (Summer semester)	
Recommended Prerequisites	None	
Classification	☐ Required Course ☒ Compulsory Elective Course	
Credit Points	6	
Weight of Grade	(6/90) 6.67%	
Contact Hours	4 SWS/60 h	
Self-Study	120 h	
Total Workload	180 h	
Language	English	
Mode of Delivery & Didactics	The course includes lectures, in-class discussions of theory, and practical laboratory work. Students who have not followed natural sciences courses at the undergraduate level are required to take this course. Those who've followed natural sciences are entitled to drop this refresher course and advised to select a portfolio course at the respective partner university after consulting the local IMAT coordinator at the partner university and the IMAT coordinator at ECB in order to facilitate the learning agreement and to ensure the comparability and module recognition.	
Professor in-charge	Current IMAT programme coordinator	
Teaching Personnel	Lecturers according the selected topics	
Requirement for the Award of ECTS Points	The two elements of the grade assessment must be passed individually.	
Methods of Evaluation (%)= allocation	☒ Written exam (75) ☐ Viva voce ☐ Colloquium ☐ Project presentation	☐ Class participation ☒ Term paper or essay(25) ☐ Practical exam ☐ Laboratory performance

1. Learning Objectives

The students have adequate knowledge on the fundamentals of physics and chemistry required for the comprehension of technically advanced studies in energy, water and bio-economy related modules. They are able to identify and recognise engineering concepts and principles related to mechanics, thermodynamics, hydraulics and microbiology.

1.1. Physics for the Environment

Students have a good understanding of the basic concepts of thermodynamics, the notion of thermodynamic state, equilibrium state, thermodynamic properties, pure substances, equation of state and thermodynamic process, etc. Students are able to apply the first law of thermodynamics to simple closed and open systems, including calculation of work and heat transferred in several processes. Hence, the students are able to apply various theoretical notions to different ZE concepts in renewable energy, energy efficiency, and cross-cutting industrial technologies.

1.2 Chemistry for the Environment

The students are able to conduct basic laboratory experiments employing the fundamentals of chemistry. They have good command in the applications of the basic knowledge in chemistry, able to resolve issues related to the environment, biosphere and the bio-systems, etc. The students are skilled in the basics of laboratory work/procedures: i.e. liquid handling, solid handling, sample preparation, data interpretation, statistical analysis, etc. The students are also competent in analytical methods and unit operations in the laboratory: i.e. density measurements, measurement of pH and conductivity, acid-base reaction, titration, extraction, UV-vis spectroscopy, cell rupture, enzymatic reactions, liquid chromatography, gas chromatography, etc.

In addition, the students have the competence in applying green chemistry principles for the management of environmental issues where they have a good understanding of the environmental concepts, phenomenon, technologies, etc. including the buffer capacity of natural waters, phosphorous removal from wastewaters, natural pH indicators, greenhouse effect, biodiesel production, biogas production, biogas analysis, biogas cleaning and upgrading, etc.

2. Module Content

2.1) Introduction to laboratory work and experimental design

Provides safety and security instruction and an introduction to working with volumetric devices (including pipettes, micro-pipettes, cylinders, flasks, etc.) and gravimetric devices (balances and scales) and measurements of the density of liquids and solids, etc.

Provides insight into the interpretation of data and application of statistical concepts (i.e. calculation of mean, standard deviation, etc.), and also the information on sensitivity and accuracy of the labware and instruments, etc.

2.2) Theory and practice of pH and conductivity measurement

Discuss theory and praxis of the correlation between pH and concentration of liquids, the correlation between conductivity and concentration of liquids, determination of the buffer capacity of natural waters, theory and practice of phosphorous removal from wastewaters, investigates the effect of a flocculation aid for phosphorous removal.

In addition, the preparation of a natural pH indicator using an extraction method, the determination of the characteristics of this natural Indicator, theory and practice of acid-base reactions, and titration are discussed.

2.3) Theory and practice of UV-vis-spectroscopy

Provides some insights into the measurement principle of UV-vis-spectroscopy, the Lambert-Beer Law, relation between colour and absorption spectra, dilution of samples, preparation of a calibration curve, UV-vis measurements with different samples, etc.

Provides hands-on praxis on the recovery of intracellular biomolecules by cell rupture, work with a ball-mill and ultrasonic device, detection of biomolecules with UV-vis-spectroscopy, etc.

2.4) Chemical-basis of bio-reactors and biogas production

Provides an introduction and the historical perspective of industrial biotechnology, bioreactors, etc. and the types of bioreactors and their modes of operation. Also discusses the bioreactors for submerged and solid-phase production, bioreactor modelling, the application of microbiology in industrial processes, etc.

And also, provides hands-on praxis with assembling a set-up for biogas production and produce biogas using biomass substrate. Discusses the theory of biogas cleaning, the principles of absorption of gaseous compounds with liquids, separation of a gaseous stream with a scrubber, and the depletion of sour gases from biogas, etc.

Provides insights into the basic principle of liquid chromatography, size exclusion chromatography, and undertake the preparation of buffer solution and sample, and the separation of a mixture of salts and protein with liquid chromatography.

And also, discusses the basic principles of gas chromatography, the measurement of gas contents from bioreactors, and the practice and theory of WLD-detectors.

2.5) Basic aspects of mechanics

Presents translational kinematics where areas such as the definition of displacement, velocity, and acceleration, derivation of kinematics equations for one-, two-, and three-dimensional motion using algebra, trigonometry and calculus, etc. are covered. And also, focuses on solving kinematics problems.

Discusses force and motion where Newtonian laws of motion are focused. Explains the concepts of mass and weight, discusses the function of various types of forces, such as gravitational, frictional, and elastic forces.

In the area of work and energy, the application of the definition of work and power to solve standard text problems is focused. In addition, the efficient usage of work-energy concepts is discussed in-depth. Also, the derivation of kinetic, gravitational, and elastic energy and the work-energy theorem are done.

2.6) Fundamentals of thermodynamics

Presents the concepts of system and the system boundary, neighbourhood and adjacent systems, open, closed and isolated systems, etc. Also discusses the thermal state variables such as temperature, pressure, volume, mass, internal energy, the thermodynamic equilibrium, state and processes, heat, work, internal energy and enthalpy, cyclic processes, specific heat, calorimetry and heat transfer, the 1st law of thermodynamics applied to closed systems of Ideal gases, mass and energy balances, Carnot principle, Carnot cycle, Clausius principle, entropy and the 2nd law of thermodynamics, heat engines, heat pumps and chillers, etc. and the thermal efficiency.

Furthermore, other cycles such as Otto, Diesel, and Rankine cycles are also presented and discussed.

3. Required Reading

1. A number of peer-reviewed, latest and seminal papers will be provided as required reading in both domains.

2. Tipler, P.A., Mosca, G. (2007). *Physics for Scientists and Engineers,* 6^{th} Ed. W.H. Freeman & Co., New York.

3. Baird, C., Cann, M. (2012). *Environmental Chemistry*, 5th Ed. W.H. Freeman & Co., New York.

Another regularly offered elective topic is the ***Travelling University (TU)***. TU is a signature seminar course developed by IfaS aiming to deploy its expertise in tangible projects worldwide that allows the students to put their acquired theoretical knowledge in the IMAT M.Sc. programme into practice. Annually IfaS organises a TU in Fall Semester with its global research partners and clients providing the exclusive opportunity for students to work 'hands-on' on a pre-defined project. Projects in the past had been the development of zero-emission university/industry strategies, planning of comprehensive waste management structures, development of eco-industrial parks, etc.

Travelling University has proven its success on five continents in over 20 countries such as Brazil, Canada, Germany, Sweden, Morocco, Cape Verde, Namibia, Turkey, China, Japan, and Sri Lanka. Furthermore, true to its premise, TU has proven its utility as a cost-effective and efficient tool in the pedagogical dimension whilst delivering superior research results which could be adopted towards the practice. It also serves as a common platform bringing together a large number of stakeholders from both public and private sectors for a common cause; sustainable [business] development through the intelligent management of resources.

The general TU setting is that the students travel to the project location, form four groups, viz.

1. **Material Flow Management Team**: research on procurement, data analysis, key actors/stakeholder analysis, potential assessment, and the evaluation of the legal, environmental, institutional, economic and technical framework conditions pertinent to the undertaking
2. **Technology Team**: research into alternative and innovative technical-/technological solutions to valorise the uncovered potentials of the resource flows through the 'system' in time and space within the defined framework conditions
3. **Finance Team**: assess the economic feasibility of the undertaking (project) and subsequently developing the business plans of the suggested solutions
4. **Communication and Organization Team**: principally observes the stakeholder management aspects of the research project. This team is also tasked to observe the overall organisational aspects of the TU including the public relations, coordination, and planning of all onsite and offsite activities

and strives to solve the challenge(s)/achieve objectives within 14 days under real-life working conditions. Subsequently, the students must present their findings and proposed solutions to —in a formal conference— to the key stakeholders including high-ranking public and private sector officials. And also, the students must submit a comprehensive technical report, as agreed upon with the client/key stakeholder, that concisely presents the techno-economic solutions.

Under the supervision of Prof. Dr. Peter Heck, the international team of students —usually assisted by two senior project managers of IfaS— carry out the specific tasks of scientific analysis of a system —a company/business entity, a university, a municipality, a region, etc.— for its resource flow characteristics through time and space for a given system boundary in order to identify the subject's existing challenges and development potentials towards a sustainable system. Based on the findings, the TU develops —as a research exercise— new technological and managerial improvement strategies and develop financing strategies and business plans for the subsequent implementation of the project.

Although the TU has proven its pedagogical uniqueness, it sometimes requires financial contributions of the participating students to cover the costs of travel to foreign countries, which cannot entirely be funded by the programme for a large group of students. Should this be a financial burden for the participating students, they are encouraged but not obliged to take another regularly offered elective and trade it off against suitable modules at the partner universities or ECB.

Module 10 [M10]: Elective (Example: Travelling University)		
Duration	1 semester	
Study Semester	3rd semester	
Frequency	Annual (Summer semester)	
Recommended Prerequisites	None	
Classification	☐ Required Course ☒ Compulsory Elective Course	
Credit Points	6	
Weight of Grade	(6/90) 6.67%	
Contact Hours	4 SWS/60 h	
Self-Study	120 h	
Total Workload	180 h	
Language	English	
Mode of Delivery & Didactics	Group-based undertaking to resolve a practical problem under the supervision and guidance of professional IfaS managers	
Professor in-charge	Prof. Dr. Peter Heck and IfaS project manager(s)	
Teaching Personnel	Prof. Dr. Peter Heck and IfaS project manager(s)	
Requirement for the Award of ECTS Points	Personal participation at the onsite project execution	
Methods of Evaluation (%)= allocation	☐ Written exam ☐ Viva voce ☐ Colloquium ☒ Project presentation (40)	☒ Class participation (30) ☒ Report (30) ☐ Practical exam ☐ Laboratory performance

1. Learning Objectives

The students are able to successfully apply the theoretical knowledge acquired in the IMAT M.Sc. programme to resolve practical problems in practical work environments. They have the necessary practical experience and in-depth knowledge of certain environmental technologies, economics and management strategies.

Students are able to recognise complex systemic problems and develop novel future-oriented solutions applying their knowledge on cutting-edge ZE technologies. Students are able to calculate, document and present the technical and economic feasibility of the designed project solutions, including the predictions/forecasts of regional added value and GHG mitigation potential.

2. Module Content

The TU consists of the following phases and the specific work thereof.

Phase I: Preparatory Phase

The preparatory activities of TU include desktop research pertinent to the subject prior to visiting the TU location. Following specific tasks shall be undertaken by the students and regularly report the progress during the pre-departure meetings at ECB.

a) A literature-based investigation (desktop research) in order to assess the status quo of the research subject and familiarize and orient the TU research team towards the key tasks
b) Evaluation of any former studies those that particularly identify the sustainability issues of the subject and any measures taken to rectify them towards achieving zero-emission
c) Identification and assessment of potential technologies and strategies suitable for the subject considering its potentially employable resource flows, geographical location, and eco-climatic region
d) Communication with participating stakeholders in order to establish cooperation towards data procurement, organisation of onsite project activities, and to identify the deployable resources
e) Analysis of the legal, institutional, economic, and environmental framework conditions pertinent to the development of the research objective

This preparatory phase is a mix between teamwork —guided by the module representative and IfaS key project managers— and preparatory lectures, workshops and information sessions to equalise the overall knowledge of all student researchers in order to execute the onsite project activities efficiently.

Phase II: TU Execution Phase

The TU execution phase consists of the research application of the IfaS' **Material Flow Management [MFM] tool-set** (i.e. Material Flow Analysis, Sustainable Project Development and Project Financing, etc.) onsite. The research methodology involves the definition of a system boundary, assessment of the status quo (i.e. existing material and energy flows —including water and wastewater, energy input and waste, biomass and solid waste, raw materials and other resources, etc.— pertinent to the project's objective.

The onsite research activities shall follow a stepwise procedure for the quantitative and qualitative assessment of the material flows and includes:

a) Site visit(s), the establishment of a system boundary, and onsite procurement of data (e.g. energy and material consumption measurements) and assessment of the magnitude of site-specific variabilities of data

b) Assessment of the present condition of the resource and energy consumption and related impacts, the status of infrastructure including their maintenance aspects (i.e. status quo analysis of the system)

c) Visualisation ('mapping') of the material and energy flows of the defined system (inclusive of all processes)

d) Determination and assessment of the specific technologies and strategies for the Zero Emission shift (technical feasibility assessment)

e) Evaluation of the economic aspects of proposed ZE technologies and strategies including price and embedded costs for resource and energy use in the proposed ZE system on a full cost accounting basis (economic feasibility assessment)

f) Assessment of the CO_{2e} balance of the proposed system and compare it against the business as usual scenario

Phase III: Communication Phase

An essential part of the communication phase is the presentation of the preliminary research findings to a large stakeholder group in a final workshop/conference. The results of the research phases are comprehensively documented in a TU research proceeding and subsequently presented to the research partners.

3. Required Reading

None.

Module 12 [M 12]: Master Thesis & Colloquium

Duration	1 semester	
Study Semester	4th semester	
Frequency	Annual (Summer semester)	
Recommended Prerequisites	See §9 of the Examination Regulations (FachPO)	
Classification	☒ Required Course ☐ Compulsory Elective Course	
Credit Points	30 (Thesis= 24; Colloquium= 6)	
Weight of Grade	Thesis= (24/90) 26.67%; Colloquium= (6/90) 6,67%	
Contact Hours	N/A	
Self-Study	900 h	
Total Workload	900 h	
Language	English	
Mode of Delivery & Didactics	N/A	
Professor in-charge	Current IMAT programme coordinator	
Teaching Personnel	Lecturers according the selected topics	
Requirement for the Award of ECTS Points	For the award of the ECTS and subsequently the master qualifications, the student must at least acquire a grad of 'C' (i.e. 4,0) for the written master thesis. The duration of work including one semester (6 months) and it commences with the registration of the thesis. The time allocated for the oral defence/colloquium is approximately 30 minutes in accordance with the ECB/HT examination regulation.	
Methods of Evaluation (%)= allocation	☐ Written exam ☐ Viva voce ☒ Colloquium (20) ☐ Project presentation	☐ Class participation ☒ Master thesis (80) ☐ Practical exam ☐ Laboratory performance

1. Learning Objectives

The students have the ability to apply independently the specific methods, concepts, approaches and knowledge they have in the area of International Material Flow Management towards their research of the master thesis. They possess the necessary knowledge and skills to evaluate the economic, technical, social, and environmental impacts of the subject they intend to examine and draw the necessary conclusion in a scientific manner. The students also possess the competence to compose the master thesis adhering to academic writing/communications requirements employing technical/scientific language and also able to defend their findings in a colloquium.

2. Module Content

N/A

3. Required Reading

There are no required textbooks to peruse. However, the students are advised to familiarise themselves with the process of academic/technical writing by associating peer-reviewed publications.