Module Handbook

Master of Engineering
in
International Material Flow Management
(IMAT M.Eng.)

[Version October 2020]

Contents

Preamble

This ***Module Handbook*** (MH) presents the detailed technicalities of the study programme, ***Master of Engineering in International Material Flow Management*** (IMAT M.Eng.), which was designed, developed and launched in 2006 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***.

IMAT M.Eng. programme is designed as a bilateral postgraduate programme for master-level qualification in the domain of engineering specifically focusing on the discipline of International Material Flow Management recognising the lacuna in the fields of environmental engineering and sustainability sciences.

At the inception, IMAT M.Eng. was launched with IfaS' Japanese partner —the prestigious Ritsumeikan Asia Pacific University (APU), and subsequently spanned across the globe inducting renowned and prestigious partners on five continents forming ***the IMAT Network University*** (IMAT-NU). As it stands now the IMAT-NU has six partner universities that include:

- 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

As a dynamic network of universities, IMAT-NU constantly reaches out to new potential partners to augment the portfolio of specialising subjects/disciplines offered in the programme. To that end, IMAT-NU will be joined by three new partner universities in the near term that include:

- Universidade Lusófona, Lisbon, Portugal
- Sultan Qaboos University, Muscat, Oman
- Hindustan Institute of Technology and Science, Chennai, India[1].

Each partner of the network offers a course of subjects on a specialized field —e.g. renewable energy engineering, integrated water resource management, etc.— where the students have to study the first two semesters of the IMAT M.Eng. programme at a partner university and subsequently relocate to Germany to IfaS/ECB-HT at the third (and fourth) semester. Upon completing the course work in the three semesters, the students are required to spend their fourth semester on research that leads to the master thesis —defended in a formal colloquium— and subsequently the award of the master qualification.

[1] See IMAT-NU map on p.6

In addition to its main course offering —i.e. in-class lectures, the network partners collaboratively conduct ***blended e-learning courses*** at regular intervals under the careful supervision of the IMAT coordinators[2].

These courses are registered at each partner university and approved by the respective academic administrations. Therefore, the students are assessed and the relevant grades, according to the European Credit Transfer System (ECTS), are provided in line with each partner universities' programme requirements. In this blended e-learning course, each partner conducts a webinar each according to the special focus of the institution and the region. The students of all partner universities form a '*global learning class*' and are grouped according to the requirements of the exercises/teamwork (e.g. case studies). Each group includes at least one student per partner university. In addition to the web-based e-lectures, the local IMAT coordinators conduct supplementary lectures locally to put the international contributions into perspective. The international panel of lecturers collectively evaluate the group work of the students to assess the performance and provide the grades, while the local lecturers also monitor, judge, and assess their students' performances in the individual assignments to ensure the quality of learning and the knowledge acquired. As the need be, the IMAT-NU also invites guest lecturers from reputed institutions, HEIs/universities to discuss the topics of global importance and timely relevance enabling the students to enrich their learning experiences while providing excellent insights into the global material flow management and sustainable development arenas.

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

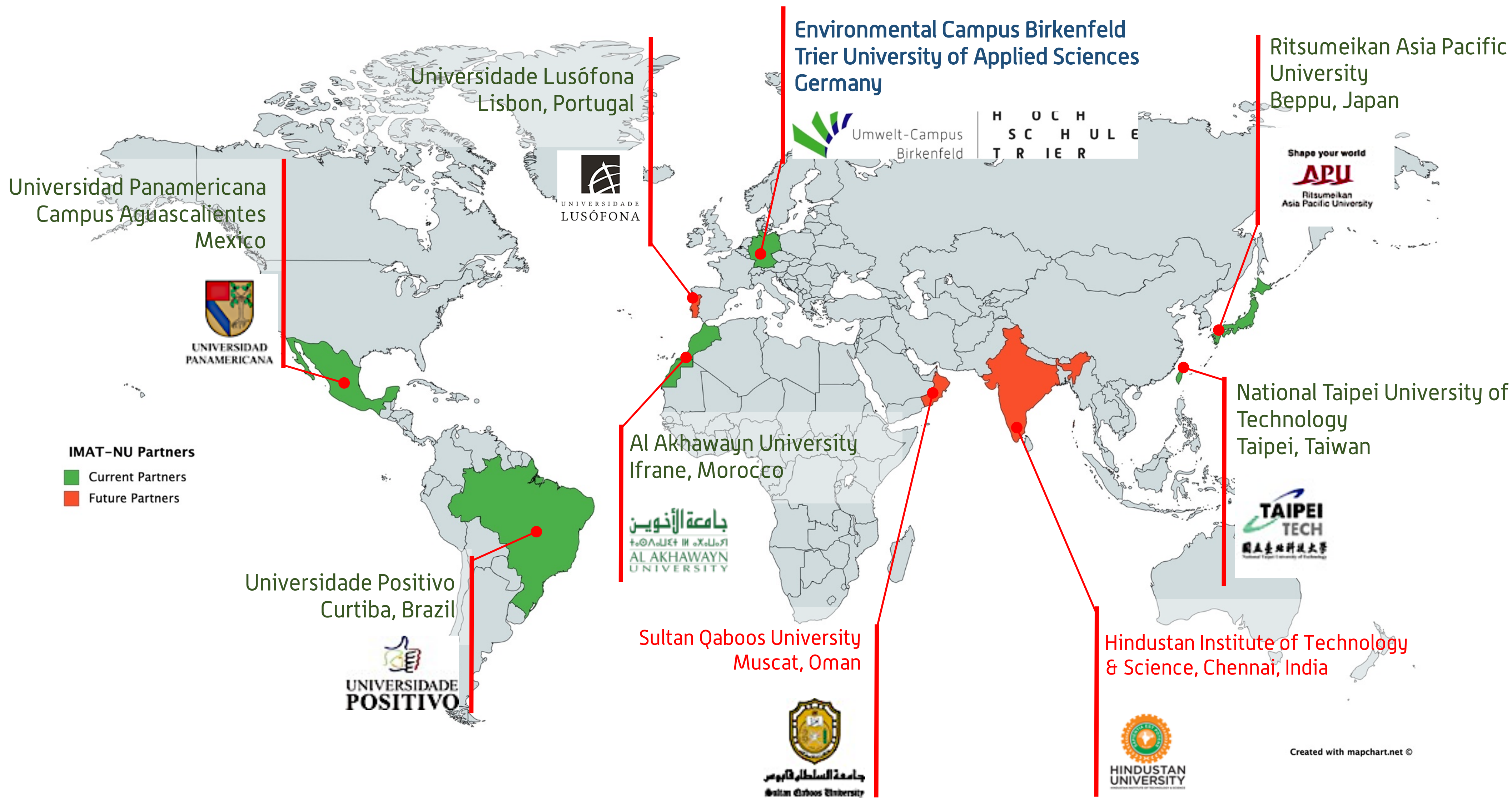
There, perhaps, exist some variations in the names of courses offered by the IMAT-NU partners due to the differences in applied nomenclature. Nevertheless, necessary steps are taken to assure that the learning objectives, the contents and the quality of the courses are equivalent/similar in nature. To that end, the partners of the IMAT-NU meet and confer at regular intervals to ensure the programme's quality by reforming, revising, and streamlining the contents considering the latest/current global dynamics in this field of studies.

Accordingly, this award-winning IMAT M.Eng. 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.Eng. produces competent and skilled young professionals —also known as ***Material Flow Managers***— to undertake the global challenges of Sustainable Development (SD).

[2] IMAT-NU Coordinators

1. Environmental Campus Birkenfeld, Germany: Dr. Michael Knaus
2. Al Akhawayn University, Morocco: Prof. Dr. Abdelghani El-Asli
3. Sultan Qaboos University, Oman: Prof. Dr. Amer Al-Hinai
4. Universidade Lusófona, Portugal: Prof. Dr. Cândida Rocha
5. Ritsumeikan Asia Pacific University, Japan: Prof. Dr. Faezeh Mahichi
6. National Taipei University of Technology, Taiwan: Prof. Dr. Chaocheng Tseng
7. Universidade Positivo, Brazil: Prof. Dr. Mario Sergio Michaliszyn
8. Universidad Panamericana, Mexico: Prof. Dr. Pia Berger
9. Hindustan Institute for Technology & Science: Prof. Dr. M.K. Badri Narayanan

IMAT Network University *(as at Q2-2020)*



Study Plan IMAT M.Eng.

Visualized in the following table is the study plan including the modules, in-class learning hours (SWS[3]), credits (according to the European Credit Transfer System – ECTS), the workload and the weight of the modules (in %) that determines the final average grade (Grade Point Average - GPA).

	Modules No.	Modules / Subjects	SWH	ECTS	Workload	Module Weight / Total Grade [in %]
Semester 1	M1	Global Environmental Challenges and Green Business Opportunities	4	6	180	5,26
	M2	Business Planning for Engineers	4	6	180	5,26
	M3	Research Management and Applied Material Flow Management	4	6	180	5,26
	M4	International Policies, Strategies and Case Studies on Circular Economy	4	6	180	5,26
	M5	Elective (Natural Science for Engineers)	4	6	180	5,26
Semester 2	M6	Sustainability Management in Industry	4	6	180	5,26
	M7	GHG Mitigation in Industry and Society: Technical and Economical Aspects of Climate Protection	4	6	180	5,26
	M8	Internship / Practical MFM Research Project *	4	6	180	0,00
	M9	Industrial Ecology and Industry 4.0	4	6	180	5,26
	M10	Elective **	4	6	180	5,26
Semester 3	M11	Regional Material Flow Management	4	6	180	5,26
	M12	Integrated Water Resource Management	4	6	180	5,26
	M13	Sustainable Energy Systems	4	6	180	5,26
	M14	Technical Aspects of Bio-Economy and Resilient Societies	4	6	180	5,26
	M15	Elective **	4	6	180	5,26
Semester 4	M16	MASTER THESIS	[20]	[30]		
		Colloquium		6	180	5,26
		Thesis		24	720	21,05
	TOTAL		80	120	3600	100

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

M8*= Module with pass/fail grading

M10** & M15 ** are to be selected from the elective course catalogue for the course of study regulated in these regulations. This may include modules for which attendance is compulsory as a prerequisite for achieving the learning objectives and passing the examination, in accordance with §12(2) of these regulations.

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

This programme has 15 modules. Each module carries 6 ECTS and the corresponding workload of 180 hours (per module), whereas the total credits accounted for the final grade amounts to 114 (M8 is a pass/fail, thus not included in the final grade). M4, M9 and M14 are blended e-learning modules conducted by the IMAT-NU partner universities via the worldwide web. M5, M10 and M15 are elective modules offered by the IMAT-NU partner universities at their respective universities.

The elective modules (M5, M10, M15) of this programme offer students the possibility to deepen their knowledge in specific fields of interest. IMAT M.Eng. offers a large variety of choices in this regard purposefully selected from each partner university in line with the key objectives of the IMAT M.Eng. programme.

Elaborated here is how the electives work. The module M5, for example, is designed for students who have not taken any natural science courses at their undergraduate level. Accordingly, they are required to take this course to increase their comprehension of the other courses of the IMAT M.Eng. programme. Whereas, those who have followed any natural science studies at their undergraduate studies are able to dispense with this 'refresher course' and instead select another elective from the portfolio of electives offered by the partner university after consulting the local IMAT coordinator at the partner university and the IMAT coordinator at ECB. This procedure is in place to ensure adherence to the learning agreement, to ensure comparability, and also to guarantee the recognition of the modules.

A noteworthy aspect of this approach is that IMAT M.Eng. is offered to and open to all potential students notwithstanding their non-natural-science-based baccalaureates such as economics, social & political sciences, etc. Accordingly, as mentioned earlier, the required basic technical knowledge is provided to the students through specifically designed courses to successfully tackle the technical-heavy modules of the programme.

M15, in particular, is another unique elective offered in the third semester of IMAT M.Eng. which is termed the ***Travelling University*** (TU). The 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.Eng. programme into practice. TU exclusively deals with the practical applications of Applied Material Flow Management (AMFM), Zero Emission (ZE), and the business aspects of environmental project development. TU also provides students with the opportunity to engage with the private and public sectors directly and understand how these systems function in real terms before they get employed in these sectors. Being true to form, TU has proven its utility as a cost-effective and efficient tool in the pedagogical dimension whilst delivering superior research results which could be transferred by the clients towards the praxis of sustainability. 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.

TU usually is conducted in collaboration with an international team of students (IMAT M.Eng. students and the students of the institute(s) of the host country) and are tasked to scientifically analyse 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 objective commanded by the M15 module— new technological and managerial improvement strategies and develop financing strategies and business plans for the subsequent implementation of the projects.

Thus far, TU has proven its success on five continents in over 20 countries such as Brazil, Canada, Germany, Sweden, Morocco, Cape Verde, Namibia, Turkey, China, Japan, Oman, Sri Lanka, etc.

The latest information regarding the TU could be found at ***www.imat-master.com/travelling-university***.

Description of the Modules

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

<table>
<tr><th colspan="3">Module 1 [M1]: Global Environmental Challenges & Green Business Opportunities</th></tr>
<tr><td>Duration</td><td colspan="2">1 semester</td></tr>
<tr><td>Study Semester</td><td colspan="2">1st semester</td></tr>
<tr><td>Frequency</td><td colspan="2">Annual (Winter semester)</td></tr>
<tr><td>Recommended Prerequisites</td><td colspan="2">None</td></tr>
<tr><td>Classification</td><td colspan="2">☒ Required Course
☐ Compulsory Elective Course</td></tr>
<tr><td>Credit Points</td><td colspan="2">6</td></tr>
<tr><td>Weight of Grade</td><td colspan="2">(6/114) 5.26%</td></tr>
<tr><td>Contact Hours</td><td colspan="2">4 SWH/60 h</td></tr>
<tr><td>Self-Study</td><td colspan="2">120 h</td></tr>
<tr><td>Total Workload</td><td colspan="2">180 h</td></tr>
<tr><td>Language</td><td colspan="2">English</td></tr>
<tr><td>Mode of Delivery & Didactics</td><td colspan="2">Lectures, group work and discussions, case studies</td></tr>
<tr><td>Professor in-charge</td><td colspan="2">Prof. Dr. Peter Heck</td></tr>
<tr><td>Teaching Personnel</td><td colspan="2">Prof. Dr. Peter Heck; Mr. Ranahansa Dasanayake</td></tr>
<tr><td>Requirement for the Award of ECTS Points</td><td colspan="2">Passed module examination(s) and passing the interim assessment(s)</td></tr>
<tr><td>Methods of Evaluation (%)= allocation</td><td>☒ Written exam (50)
☐ Viva voce
☐ Colloquium
☒ Project presentation (20)</td><td>☐ Class participation
☒ Term paper or essay (30)
☐ Practical exam
☐ Laboratory performance</td></tr>
</table>

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 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 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 1st and 2nd laws of thermodynamic 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

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

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

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

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

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

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

Worldwatch Institute: State of the World yearly publications.

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

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

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

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

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

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

Module 2 [M2]: Business Planning for Engineers		
Duration	1 semester	
Study Semester	1st semester	
Frequency	Annual (Winter semester)	
Recommended Recommended Prerequisites	None	
Classification	☒ Required Course ☐ Compulsory Elective Course	
Credit Points	6	
Weight of Grade	(6/114) 5.26%	
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, 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 (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 valuation of projects, e.g. Capital Asset Pricing Model, Discounted Cash Flow Calculation (DCFC), etc. Also includes the aspects of comparison of 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", (macroeconomic) methods and tools to "determine" the additional values of ZE/CE projects throughout all value chains and life cycles.

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. All other required learning material such as cases are provided throughout the course.

Following titles are recommended for further insights.

Pacheco-Torgal, F., Rasmussen, E., Granqvist, C-G., Ivanov, V., Kaklauskas, A., and Makonin, S., (Eds.) (2016). *Start-Up Creation: The Smart Eco-Efficient Built Environment*. Woodhead Publishing.

Drake, P. and Fabozzi, F. (2008). Mathematics of Finance. https://onlinelibrary.wiley.com/doi/pdf/10.1002/9780470404324.hof003055

Schubert, D. and Bühler, J. (2009). *A Guideline for the Management of Regional Value-Added Partnerships*. Regional Planning Authority Altmark.https://neulandplus.de/wp-content/uploads/2015/04/RWP_Guideline_Englisch.pdf

Hoffmann, D. (2009). Creation of regional added value by regional bioenergy resources. Renewable and Sustainable Energy Reviews, 13(9), 2419–2429. https://doi.org/10.1016/j.rser.2009.04.001

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	(6/114) 5.26%	
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 conduct the 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 6 [M6]: Sustainability Management in Industry		
Duration	1 semester	
Study Semester	2nd semester	
Frequency	Annual (Summer semester)	
Recommended Prerequisites	Basic comprehension of industrial management and production processes	
Classification	☒ Required Course ☐ Compulsory Elective Course	
Credit Points	6	
Weight of Grade	(6/114) 5.26%	
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

Course-related links/Internet Resources

Cleaner Production Germany: https://www.cleaner-production.de/index.php/de/

The International Organization for Standardization: https://www.iso.org/home.html

World Business Council for Sustainable Development: https://www.wbcsd.org

Global Reporting Initiative: https://www.globalreporting.org/Pages/default.aspx

Module 7 [M7]: GHG Mitigation in Industry and Society: Technical and Economical Aspects of Climate Protection		
Duration	1 semester	
Study Semester	2nd semester	
Frequency	Annual (Summer semester)	
Recommended Prerequisites	Basic comprehension of M2 and Net-M4	
Classification	☒ Required Course ☐ Compulsory Elective Course	
Credit Points	6	
Weight of Grade	(6/114) 5.26%	
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	
Teaching Personnel	Dr. Michael Knaus; selected international guest lecturers	
Requirement for the Award of ECTS Points	The two elements of the grade assessment (see the method of evaluation) must be passed individually. Note: scientific paper and oral presentation form one evaluation block.	
Methods of Evaluation (%)= allocation	☐ Written exam ☐ Viva voce ☐ Colloquium ☒ Project presentation (50)	☐ Class participation ☒ Scientific paper with oral presentation (50) ☐ Practical exam ☐ Laboratory performance

1. Learning Objectives

The students understand the historical context and development of international climate mitigation action and UNFCCC mechanisms starting from the Kyoto Protocol towards the Paris Accord (COP21). On the macro level, they are able to read, understand and critically evaluate the comprehensiveness of national strategies codified in the Nationally Determined Contributions (NDC´s) as well as the underlying conditional and non-conditional sectoral strategies.

On a project level, students learn about terms and methods needed to transparently account for the GHG emission in industry and be able to quantify emission reductions created by industrial energy efficiency (EE) projects or programmes.

Students will gain in-depth knowledge on the process of GHG accounting for EE actions conducted at a single end user's site or at multiple users' sites included in area-wide programmes, linking the requirements of common international GHG accounting (such as ISO 14064-2) with the UNFCCC's CDM programme und its underlying GHG baseline and additionality methods.

Students are enabled to determine the efficiency and emission level of general cross-cutting technologies applicable to the major industrial producers such as steam production, compressed air, lighting, pump systems, engines and motors, air handling units and chillers and predict green business potentials.

2. Module Content

The course is divided into three main parts:

2.1) National GHG mitigation action and reporting

Within the first part, the historical and future-oriented development of the global GHG abatement and carbon trading regimes based on the United Nation Framework Convention on Climate Change (UNFCCC) are explained and different (multi-) national manifestations (e.g. in EU Emission Trading Scheme) analysed. Using a business game (simulation of a COP/MOP) the students learn about the complexity, provisions and implications of international climate protection negotiation processes.

The practical part emphasis on the reporting procedure outlined and started during COP21 in the Paris Accord. Students will analyse various NDCs of both developed and developing countries and discuss the methods and assumptions used to classify condition and unconditional actions with the focal point on the mitigation areas of energy, water and waste management. Based on the NDC the transferred national climate actions and legal frameworks to help to understand the complexity and interconnection between international climate protection pledges and (national) domestic actions.

2.2) Project/programme-based GHG mitigation action and reporting

The second part will be an in-depth analysis of existing carbon market/trading modalities and procedures (as well as industrial carbon accounting standards) using the (programmatic) Clean Development Mechanism with its embedded assessment of baseline, additionality and sustainability.

CDM case studies will be analysed in order to familiarise themselves with the terms, concepts (baseline & additionality) and underlying (approved) methods in predicting GHG mitigation potential at the project level.

This part includes a review of existing GHG accounting tools and strategies in the industry as well as basic economic aspects and tools to determine "marginal cost of abatement (MAC)" and compare it with the business-as-usual scenario.

2.3) Case studies on industrial GHG mitigation projects

The third part is based on practical oriented exercises, where the students analyse IfaS case studies in industrial GHG mitigation in order to understand the methodological and administrative requirements to calculate and document industrial GHG mitigation projects focusing on energy (renewable energy, energy demand-side efficiency, fuel switching projects), organic waste management (biogas) and wastewater projects will enable the students to calculate the GHG abatement potentials of their own designated research projects in related areas.

This part includes technical background information and tools to determine the efficiency and emission of cross-cutting industrial technologies; like steam production, compressed air, lighting, pump systems, engines and motors, air handling units and chillers.

3. Required Reading

Selected chapters (TBA) of the following guidebooks:

UNEP Risoe Centre (2011): CDM Information and Guidebook

UNEP Risoe Centre (2009): CDM Sustainable Development Impacts

Available as PDF download (free of charge) at: http://cd4cdm.org/Guidebooks.htm

Selected tools and publications at: https://ghgprotocol.org/

Appropriate CDM baseline tools at: https://cdm.unfccc.int/methodologies/index.html

Further readings and case study materials will be provided.

Module 8 [M8]: Internship/Practical MFM Research Projects		
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	0% (Pass/Fail)	
Contact Hours	4 SWH/60 h	
Self-Study	120 h	
Total Workload	180 h	
Language	English	
Mode of Delivery/Didactics	Practical project period	
Professor in-charge	Prof. Dr. Peter Heck	
Teaching Personnel	Prof. Dr. Peter Heck & local IMAT NU coordinators	
Requirement for the Award of ECTS Points	Proof of execution of the research project by the host entity during the project period and presentation of the project.	
Methods of Evaluation (%)= allocation	☐ Written exam ☐ Viva voce ☐ Colloquium ☒ Project presentation (100)	☐ Class participation ☐ Scientific paper ☐ Practical exam ☐ Laboratory performance

1. Learning Objectives

The students are able to successfully apply the theoretical knowledge of MFM acquired in the IMAT M.Eng. 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.

2. Module Content

The students must conduct/undertake a practical internship in a company, research or a (non-)governmental organisation, etc. working on a real-life topic within any of the IMAT M.Eng. core areas such as ZE, CE, REN, energy efficiency, water and wastewater management, IWRM, waste management, ISRM, upcycling, recycling, WER-Nexus, etc. The students are encouraged to use the internship as a stepping stone towards the successful undertaking of the master research and thesis. Accordingly, the students are encouraged to get some impressions/insights into the latest environmental technologies, management approaches, etc.

The internship should last at least 4 weeks and must be completed before the commencement of the master thesis semester.

3. Required Reading

None

Module 11 [M11]: Regional Material Flow Management (rMFM)		
Duration	1 semester	
Study Semester	3rd semester	
Frequency	Annual (Winter semester)	
Recommended Prerequisites	None	
Classification	☒ Required Course ☐ Compulsory Elective Course	
Credit Points	6	
Weight of Grade	(6/114) 5.26%	
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/or 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 12 [M12]: Integrated Water Resource Management		
Duration	1 semester	
Study Semester	3rd semester	
Frequency	Annual (Summer semester)	
Recommended Prerequisites	Basic comprehension of ecosystem management & the basic aspects of natural science	
Classification	☒ Required Course ☐ Compulsory Elective Course	
Credit Points	6	
Weight of Grade	(6/114) 5.26%	
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	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 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 good understanding/hands-on expertise in technological aspects of the urban water infrastructure.

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/resources are recommended for further insights:

GWP/INBO. (2009). *A Handbook for Integrated Water Resources Management in Basins*. https://www.inbo-news.org/IMG/pdf/GWP-INBOHandbookForIWRMinBasins.pdf

UN-WATER. (2020). Publications on *Integrated Water Resources Management.* https://www.un.org/waterforlifedecade/iwrm.shtml

de Oliveira, E., Samuel Sandoval-Solis, S., de Albuquerque PedrosaJ, E. and Ortiz-Partida, P., (Eds.). (2020). *Integrated Water Resource Management: Cases from Africa, Asia, Australia, Latin America and USA*. Springer Nature Switzerland AG. https://doi.org/10.1007/978-3-030-16565-9

Module 13: Sustainable Energy Systems		
Duration	1 semester	
Study Semester	3rd semester	
Frequency	Annual (Winter semester)	
Recommended Prerequisites	None	
Classification	☒ Required Course ☐ Compulsory Optional Subject	
Credit Points	6	
Weight of Grade	(6/114) 5.26%	
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

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

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

Course-related links/Internet Resources

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

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

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

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

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

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

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

Blended e-learning modules

The following modules M4, M9 and M14 are modules 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.Eng. programme in an international setting. Blended e-learning modules have been developed during the German Academic Exchange Service (DAAD) funded project of *IMAT Network University* with the long-term objective to merge the various dual degree programmes into one multinational degree programme. The first blended e-learning module was conducted in the Spring semester of 2018 and the module is a standardized offering since.

The blended e-learning modules present/discuss topics of global interests—mainly global circular economy strategies and policies on an industrial, sectoral and national level—from various geographical and scientific disciplines' perspective. Hence, in this blended e-learning course, IMAT-NU partners, acceding partners, and selected international guest lecturers conduct lectures (i.e. webinars via the internet)—with an average of 2 SWH and the total amounting to 30 SWH—according to the special focus of their institution and the region. Subsequent to the online lectures/webinars, each local coordinator offers an in-class session to put the lecture content into the local context, provides perspective, discusses further and clarifies any remaining queries.

The students of all IMAT-NU partner universities collectively form a ***global learning class,*** 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 4 [M4]: International Policies, Strategies and Case Studies on Circular Economy	
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	(6/114) 5.26%
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 world-wide web. IMAT-NU faculty and international experts—guest speakers—on speciality topics will deliver the lectures. Key topics such as ***Global Policy Landscape for Sustainable Development, Beyond Circular Economy: the future trends in SD, Applications of CE in Economic Sectors: a global perspective***, etc. are some of the planned lecture topics in this module.
Professor in-charge	Dr. Michael Knaus
Teaching Personnel	IMAT-NU faculty/coordinators and invited international guest lecturers.
Requirement for the Award of ECTS Points	The students must successfully pass (individually) the following assignments: **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 (Global Group Assignment) (50)	☐ Class participation ☒ Term paper or essay (Scientific Paper review 25% and Lecture Notes Report 25%) ☐ Practical exam ☐ Laboratory performance

1. Learning Objectives

Students have an in-depth knowledge of the circular economy and zero-emission policy strategies and respective implementations in countries such as Brazil, Canada, Germany, Japan, Mexico, Morocco, Oman, Portugal, India, and Taiwan. Students are also able to analyse the country-specific best practices based on case studies of CE and ZE.

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 country-specific CE and ZE policies, strategies and projects and also presents selected case studies on various industrial sectors. 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.

Provided below are some examples of the lectures delivered in this module in the recent past.

1.) Introduction, history, definitions and global trends in Zero Emissions (ZE) and Circular Economy (CE)
2.) CE and ZE in Germany: *renewable energies and waste management*
3.) CE and ZE in Brazil: *buildings (infrastructure)*
4.) CE and ZE in Canada: *ZE initiatives in Canada*

5.) CE and ZE in Japan: *Eco-Cities, 3 R society & renewable energy policy*
6.) Policy aspects in Mexico: *Renewable energy law & policy in the state of Aguascalientes*
7.) CE and ZE in Morocco: *National biomass management and phosphorus sector*
8.) CE and ZE in Portugal: *Bio-Economy*
9.) CE and ZE in Taiwan: *Industrial low-carbon developments*
10.) CE and ZE in Oman: *Transition from oil and gas to renewables*
11.) CE and ZE in India: *Agribusiness sector & aviation*

3. Required Reading

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

Module 9 [M9]: 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	(6/114) 5.26%	
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 world-wide web.	
Professor in-charge	Prof. Dr. Susanne Hartard (IE), Prof. Dr.-Ing. Matthias Vette-Steinkamp (Industry 4.0)	
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 ☐ Viva voce ☐ Colloquium ☒ Project presentation (50)	☐ Class participation ☒ Term paper or essay (50) ☐ Practical exam ☐ 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 management, 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 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.) IE, IE strategy, and eco-industrial parks in Brazil

4.) IE and sustainable development in Canada

5.) Historical development of IE, IE policy and IE implementations in Japan

6.) IE policy aspects and socio-economic implications in Mexico

7.) IE: an emerging trend in Morocco

8.) IE in practise: industrial symbiosis in Portugal

9.) Challenges and opportunities in I4.0 in Taiwan

10.) IE initiatives and eco-industrial parks in Oman

11.) Challenges & opportunities for IE and I4.0 in India

3. Required Reading

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

Module 14 [M14]: Technical Aspects of Bio-Economy and Resilient Societies		
Duration	1 semester	
Study Semester	3rd semester	
Frequency	Annual (Winter semester)	
Recommended Prerequisites	Basic comprehension of MFM, ZE, CE, and other concepts for the sustainable management of resources towards SD.	
Classification	☒ Required Course ☐ Compulsory Elective Course	
Credit Points	6	
Weight of Grade	(6/114) 5.26%	
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 world-wide web. IMAT-NU faculty and international experts—guest speakers—on speciality topics will deliver the lectures.	
Professor in-charge	Prof. Dr. Peter Heck and IMAT-NU coordinators	
Teaching Personnel	Prof. Dr. Peter Heck, IMAT-NU faculty/coordinators and invited 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 ☐ Viva voce ☐ Colloquium ☒ Project presentation (50)	☐ Class participation ☒ Term paper or essay (50) ☐ Practical exam ☐ Laboratory performance

1. Learning Objectives

The students have a thorough understanding of the concepts and practices of bio-economy and resilient societies. They are knowledgeable in the technical aspects of the bio-economy, the policies (e.g. EU strategy/policy for bio-economy), and also have an overview of the bio-economy strategies and policies employed around the world and their implications on sustainable development.

2. Module Content

This blended e-learning course provides a global perspective and also some country-specific insights (through specific case studies) into bio-economy strategy implementations and the aspects of resilient societies.

It intends to provide a comprehensive understanding of the need for a new paradigm —i.e. the rationale/drivers of BE, the current status of BE policy/strategy with examples, and the implications of BE in achieving specific SDGs and building resilient societies. Covering five continents, the insights into BE and resilient societies in Japan, Taiwan, India, Germany, Portugal, Morocco, Oman, Canada, Mexico, and Brazil will be discussed in detail where the emphasis will also be placed on the challenges and opportunities for social, economic, and environmental sustainability. BE as a mechanism for rural and small-scale systems development, its utility in regional value addition, its complementarity with the circular economy, thus the ability to evolve into new paradigms such as circular bio-economy are discussed in detail with the latest examples.
3. Required Reading The required reading is announced prior to the start of the module.

Elective Modules

The elective modules —M5; M10; M15— of this programme offer students the opportunity to deepen their knowledge in specific fields of interest drawing on a large variety of choices at each partner university, which are in line with the key objectives of the IMAT M.Eng. programme. The list below indicates some of the electives on offer at the various 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

The content of elective module M5 in the first semester is specifically designed for the students those who have not taken any natural science courses at their undergraduate level, as IMAT M.Eng. is offered to and open to all potential students notwithstanding their non-natural-science-based baccalaureates. Accordingly, M5 is offered at the partner universities as a bridging module to successfully tackle the technical-heavy modules of the programme. The module M5 (see below for detail); ***"Natural Science for Engineers"*** is mandatory for non-natural-science-based baccalaureates to increase their comprehension of the other courses of the IMAT M.Eng. programme.

Whereas, those who have followed any natural science studies at their undergraduate studies are able to select another elective from the portfolio of electives offered by the partner university after consulting the local IMAT coordinator at the partner university and the IMAT coordinator at ECB to ensure compliance to the learning agreement, to ensure the comparability, and also to guarantee the recognition of the modules.

Module 5 [M5]: Elective - Example: Natural Science for Engineers		
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	(6/114) 5.26%	
Contact Hours	4 SWS/60 h	
Self-Study	120 h	
Total Workload	180 h	
Language	English	
Mode of Delivery & Didactics	This is an elective course provided by the IMAT-NU partners. The content of the course is coordinated and present equivalent materials, case studies, and experimental/laboratory work. 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 have 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	Dr.-Ing. Sybille Leiner	
Teaching Personnel	Dr.-Ing. Sybille Leiner, Faculty of the IMAT-NU partner universities	
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 & 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 basic principles of gas chromatography, the measurement of gas contents from bioreactors, and the practice and theory of WLD-detectors. 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.

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 Newton 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. The derivation of kinetic, gravitational, and elastic energy and the work-energy theorem is also 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 & 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

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

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

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

Another regularly offered elective topic in module M15 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.Eng. 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 of 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 15 [M15]: 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	(6/114) 5.26%	
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 team members.	
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.Eng. 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 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 prep-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 quo 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 16 [M16]: 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= (24/114) 21.05%; Colloquium= (6/114) 5,26%	
Contact Hours	N/A	
Self-Study	900 h	
Total Workload	900 h	
Language	English	
Mode of Delivery/Didactics	N/A	
Professor in-charge	Dr. Michael Knaus	
Teaching Personnel	Dr. Michael Knaus	
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 MFM 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. All other required learning material is provided throughout the course.