Degree Program Documentation Master's Program Environmental Engineering

Part A

TUM Department of Civil, Geo and Environmental Engineering
Technical University of Munich

General Information:

Administrative responsibility:	TUM Department of Civil, Geo and Environmental Engineering
Name of degree program:	Environmental Engineering
Degree:	Master of Science (M.Sc.)
Standard duration of study and credits:	4 semester of enrollment and 120 credit points (CP)
Form of study:	full time
Admission:	Aptitude assessment (EV – Master's),
Start:	Winter semester (WiSe) 2006/07
(s) of Instruction:	English
Main Location:	Munich
Additional information:	1:1 cooperation with DTU, Copenhagen
Academic director:	Univ.-Prof. Dr.-Ing. Jörg E. Drewes
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1 Degree Program Objectives

1.1 Purpose

Environmental Engineering aims to understand and engineer the complex interactions between natural systems, human activities and technological systems with respect to the requirements of sustainability. Sustainability is achieved in a balanced environment, in which the exploitation of resources, technological developments, the direction of investments, and institutional change are all in harmony and enhance both the current and future potential to meet human needs and aspirations. Environmental Engineering is based on the principles of systems thinking aiming to measure, evaluate, direct and control the complex interactions of engineered systems with the environment.

The environment is according to the Oxford's dictionary defined as "*the air, water, and land in or on which people, animals, and plants live*"[1]. From the perspective of environmental engineering the three elements air, water and land are complex environmental systems that are interconnected by a multitude of interactions and working principles. Their conditions have a direct effect on humans, animals and plants.

Human activities and their respective technical systems are in constant interactions with the environmental systems. These interactions can be intentional, where the needs of the society require the use of natural resources. In such cases we have a planned human intervention in the environment. It other cases it can be unintentional where the consequences of human activity, though not targeted to a certain environmental system, affect it in a negative way. Furthermore, human-environment interactions can take place in the opposite direction when natural phenomena pose a threat to human life and property. Beside such unambiguous situations, there is a superposition of many different causes and effects that add layers of complexity.

Examples for such interactions are manifold: The natural water cycle of precipitation, evapotranspiration and runoff clashes with the need for water in certain quantities and qualities whereas the production of wastewater is impacting the receiving aquatic environment. The societal need for mobility of people and goods leads to externalities such as emission of pollutants and greenhouse gases which will affect the environment. In contrast, extreme weather phenomena can overwhelm the natural water cycle leading to floods which disrupt human activities.

Throughout the history of the human kind, such interactions almost always lead to a deterioration of the natural systems to the detriment of animal and human liveability. Through this instance derives the necessity to take influence into these complex systems[2] and develop them under the prin-

[1] https://dictionary.cambridge.org/de/worterbuch/englisch/environment , aufgerufen am 21.06.2021
[2] Definition of complex system: *"[…] phenomena, structure, aggregates, organisms, or problems that share some common theme:(i) They are inherently complicated or intricate [...]; (ii) they are rarely completely determin-istic; (iii) mathematical models of the system are usually complex and involve non-linear,ill-posed, or chaotic behavior; (iv) the systems are predisposed to unexpected outcomes(so-called emergent behaviour)."* In Richard Foote. Mathematics and complex systems.Science, 318 p. 410, October 2007.

ciples of sustainability – where sustainability is understood according to the Brundtland Commission[3] as a trinity of environmental protection, economic growth and social equity. This influence of the systems is not meant as a reactive action to ongoing changes. It is necessary to utilize upon a thorough understanding of the systems and pro-actively engineer them.

Engineering in its core is a control cycle that aims at influencing a complex system. Its principal steps are illustrated in Figure 1.

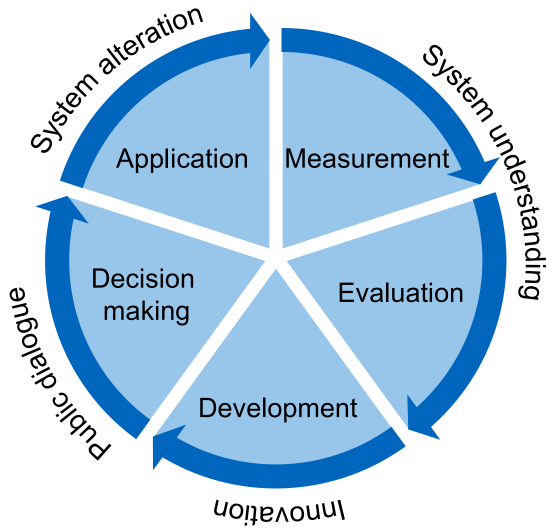

Figure 1: Engineering as a control cycle to be applied on environmental systems

Environmental Engineers must develop a holistic understanding of the systems they focus on – an understanding which is reached by observation, measurement but also modelling and simulation of the relevant processes and interactions within engineered or natural systems. Innovation in engineering often goes beyond the mere creation of an artefact. Beginning with the development of technologies it can extend to rules, methods and even regulations. These are a-priori verified, applied and used to affect the system in a desired way. They all are aligned with the main goal of achieving a sustainable effect, whereby the environmental effect is in the main focus, however always taking economic impacts and societal needs into account. Environmental Engineers input their expertise in all relevant political and societal discussions relevant to their system of focus. They are primarily involved in the implementation of innovations which lead to changes in the system. These changes will restart the assessment cycle again (Figure 1): the monitoring of the system in order to identify the need for new interventions. Engineers must master the entire cycle though a differentiation in the methods is dictated by the nature of their system of focus.

[3] World Commission on the Environment and Development, *Our Common Future*, 1987

1.2 Strategic Significance

In its mission statement, the Technical University of Munich (TUM) is committed to promoting innovation in all scientific fields that promise to improve the quality of life and cohabitation in the long term. The responsibility owed to future generations forms the basis for the interdisciplinary focal points of “Health & Nutrition”, “Energy & Natural Resources”, “Environment & Climate”, “Information & Communications”, and “Mobility & Infrastructure”. The Department of Civil, Geo and Environmental Engineering, including its central mission statements “Construction” – “Infrastructure” – “Environment” – “Planet Earth”, plays a leading role in covering interdisciplinary research fields and therefore contributes to the international appeal and reputation of the TUM. With its international orientation, the Master’s Program in Environmental Engineering strengthens worldwide positioning of the Technical University of Munich in one of the most relevant academic fields of our modern life, engineering and the environment. Within the department BGU, the degree program covers the central academic key factors (construction – infrastructure – environment – planet Earth) in an interdisciplinary manner.

Construction

According to the department’s mission statement, civil construction is of high relevance as building and living represent both: basic needs of human beings as well as an important industrial sector and considerable cultural good. The aim is to approach the ideal building scenario – that means a minimum consumption of resources and a minimum of emissions when producing building materials, building, operating, rebuilding, and demolishing constructions – by using sustainable building materials and constructions.

As such civil construction leaves a footprint in the environment. Not so much the single building, which is more of a subject of the civil engineering program, but the concept of engineering an environment for human activities that reaches from the buildings over the settlement to the complete engineered landscape in all of its sustainability related facets is focus of the program in several specializations. The studies combine tasks of sustainability in the consumption of resources, the consideration of the life cycle of constructions as well as the interdependency of the expansion of this built environment with the provision of energy and the production of food.

Infrastructure

In its overall concept the Department of Civil, Geo and Environmental Engineering considers construction of infrastructure as only one aspect of transportation. Today, efficient, environmentally friendly and safe operation of transportation systems is growing in importance. Transport planning is increasingly becoming a design and management task within an overall complex system that comprises passenger and freight transport as well as all other carriers. A functional high-performing transportation system is a prerequisite for economic development.

In Environmental Engineering, the topic of infrastructure is viewed from a holistic perspective and in the entire range of fields of action. The area is examined from three perspectives: the causes (settlement structure, contract structure), the consequences (urban water cycle, traffic problems, emissions, resource consumption) and the integrated planning of settlements and their respective water cycles, traffic needs and energy management. As such the program aims in the proactive engineering of this complex system in order to achieve the best possible provision of infrastructure while at the same time minimizing its impact on the environment.

Environment

The environment is the central theme of the Master's program and is mentioned in particular in the mission statement of the TUM Department of Civil, Geo and Environmental Engineering as well as in the mission statement of the Technical University of Munich. It is also one of the leading topics on the international agenda. "Dealing with natural hazards and catastrophe prevention, i.e. the issue of "preparedness" (more generally referred to as disaster and risk management) based on complex information, prevention and intervention is extremely important for the built and natural environment. Therefore, it is of social, ecological and economic priority. This subject represents a precautionary contribution to sustainable environmental protection and the management of ecological problems. Innovation results from the unique networking of the disciplines that previously merely existed alongside each other. In the foreseeable future, the state, municipalities, the economy and society in general will greatly benefit from this. Inevitably, the socioeconomic aspects are pivotal for many essential research issues. The goal is to develop a continuous concept from one source for various risk areas such as flooding, food and water scarcity, landslides and mass movements etc. In this connection, the development of a dynamic system and handling concept in the shape of a complex expert system on the topic of environmental risk management is planned.

The fields of study of the master's program address the key elements of these action fields. They are structured in fields of study, each dedicated to an action field. The action fields combine the different competences of the department with the inclusion of professors beyond its boundaries. The interdisciplinary approach of the specializations and the flexibility in their combination allow for a well thought coverage of the Environmental field.

Planet Earth

The Department of Civil, Geo and Environmental Engineering is also focusing globally on our planet, as many environmental processes are global phenomena. The department's strategy aims at observing dynamic changes and processes in and on the earth, the oceans and the atmosphere and to model their mutual interactions. Though the department's structure has changed since 2019 by moving the relevant field of geodesy in the newly founded department of Aerospace and Geodesy, this part of the strategy remains valid and is implemented in interdisciplinary teaching.

In environmental engineering, the global processes in water, soil and the atmosphere play an important role due to their strong mutual influence with human activity. The cross-cutting parts of the curriculum contain methods for recording, modelling and evaluating these processes. The application of the methods takes place in the thematic fields of study.

The growing awareness of the society about climate change and the consumption of natural resources is increasingly evident in the students' engagement with the public discussion and challenges of our time. The Master's program responds to this by in-depth examination of strategies and methods for using and protecting the valuable resources of water and soil, expanding renewable energy sources and designing sustainable settlements and means transportation. It provides students the opportunity to deal with these future-oriented topics from a diverse and interdisciplinary perspective, as it provides in-depth knowledge primarily from engineering, natural science and ecology, but also from economics and computer science.

The Master's program in Environmental Engineering is very practice-oriented and conveys a mixture of theoretical and methodical knowledge and application of knowledge using examples and exercises. Due to the Master's thesis and the applied study project, the program consists to a significant extent of independent scientific work, i.e. real projects from research and engineering practice. The students are enabled to pursue a career in the private sector or public administration as well as to continue further academic qualification through a doctorate.

The program is intentionally international. This is due to the considerable need for know-how transfer in environmental technologies and solutions as well as the intensive scientific and economic cooperation between Germany and other countries. Thus, in the training of engineers, regardless their country of origin, who can work at an international environment is crucial. Well-trained environmental engineers are needed for the global challenges – graduates who have a new way of thinking and ultimately the ability to work across local and national borders.

The central themes of the Master's program Environmental Engineering, engineering sustainability in water, soil and urban environments, are suitable for cross-faculty networking offering opportunities to publicly present this profession as a modern and interdisciplinary field. The degree program selectively incorporates methods and competences from other disciplines, such as civil engineering, nature sciences and geodetic engineering. In its particular focus on environmental issues this degree program is unique and differs from other master degree programs of the department. It is obvious that because historically most of the department's programs evolved from aspects of Civil Engineering, there are overlaps and interfaces in their specializations. However, Environmental Engineering expanded significantly beyond this ancestral core. It has a holistic view on water in ways that embed the aspect of civil construction in the understanding and engineering of large, interconnected and complex systems – starting from phenomena of climate and precipitation and include all of the subsequent effects, surface and sub-surface bodies of water and connecting them to the human use. In the field of urban planning and sustainable transportation there are interfaces with the programs of Resource-efficient and sustainable Building as well as Transportation Systems. The master's program in Environmental Engineering refrains from incorporating elements of building constructions. It lays focus on the sustainability in the sustainable engineering of a system that begins with land use and settlement planning to its interdependencies with transportation and mobility as well as the energy and resource consumption.

2 Qualification Profile

Graduates of this Master's program possess a wide portfolio of relevant competences in environmental engineering and they are capable of applying them while working in a dynamically growing field. The qualification profile meets the requirements of the Qualifications Framework for German Higher Education Qualifications ("Hochschulqualifikationsrahmen" – HQR) from 16th February 2017. For Master's programs, the following four areas of competence have been defined: Knowledge and understanding (1), Usage, application and generation of knowledge (2), Communication and Cooperation (3), and Scientific self-understanding/ professionalism (4).

Knowledge and Understanding

Building on the competences achieved during their Bachelor's program, graduates from the Master's Program in Environmental Engineering have deepened or expanded this knowledge during the course of the Master's program. They have the knowledge and sound understanding to engineer complex and interconnected environmental systems and human made systems. They are able to define and interpret the particular terminology and concepts of the systems they are addressing. The graduates are able to employ their knowledge and understanding in research and practical applications, having been exposed to common problems or novel scientific challenges.

Graduates know and understand the acquisition techniques of manifold environmental data as well as the common ways of their processing, visualization and interpretation. They have the skills to analyse and evaluate problems related to their observed environmental and human made systems and understand their interconnections – an understanding that extends also to other, closely related systems. Based on their evaluation they are able to solve practical problems as well as answer scientific questions. For this purpose, they possess a broad, detailed and critical understanding of the latest developments of mathematical modelling of natural and human made systems as well as the latest technological applications in the relevant fields. They align their problem solving techniques with the requirements of sustainability and develop solutions beyond mere technology, such as new planning and management strategies. They are able to evaluate the epistemic correctness of their specialist knowledge, utilize the strengths and understand limitations of their modelling means and own innovations in consideration of scientific and methodological approaches.

Usage, application and generation of knowledge

On a general level, graduates from Environmental Engineering have the ability to develop and optimize solutions for a wide range of tasks for different complex systems. They are capable to systematically structure engineering tasks as well as to methodologically work out approaches to deal with different engineering problems, utilising upon but also extending mathematical methods. Graduates know how to achieve knowledge and competence in special fields of engineering and they can use their theoretical-analytical skills on manifold applications. More specifically, the graduates have the competence to analyse the complex systems of human activity – for example the use of resources or the use of transportation modes - and the natural environment – applied for example on water cycles, soil systems, and air quality. They can derive the requirements for the functioning of the natural systems and the requirements of the society for the human activity but also of healthy living spaces. Building upon this layer, they identify the interrelations between the natural and the human made systems and understand their mutual influence, specifically their footprint on water, soil and air and the environmental risks. The graduates are furthermore able to utilize upon a technological competence of using the rules of this interrelation to achieve a sustainable impact on both systems. In this process they are able to evaluate a-priori the consequences of their engineering intervention and can adapt this competence also for aspects beyond their narrow field of specialization. They are capable to overview and to give consideration not only to environmental aspects of engineering but also to its relevant economic and social dimensions. Graduates of this degree program are familiar with the important concept of sustainable development which requires new planning and management strategies.

The graduates can reflect upon given scientific questions as well as develop new scientific questions through the identification of research gaps. They can research and absorb the required information from the state of the art and on-going research, evaluate and edit the findings in a specific context and comprise own methodologies for tackling their research questions. They are able to justify their selection of scientific solutions as well as to reflect upon their decisions critically. This ability to structure complex issues enables them to operationalize open research fields and develop new, relevant research questions. They are able to present their findings in a logical and convincing way as well as discuss them with a specialist audience. Thus, they have profound competence in the use of scientific methods as well as in the development of solutions for practical problems based on scientific findings. Graduates from the Master's program in Environmental Engineering are able to design research and engineering projects related to specific scientific fields. Their research competences enable them to utilize upon the usual means for publication and presentation of scientific research as well as to initiate a PhD process.

Graduates from the Master's program in Environmental Engineering are equipped with abstract, analytical and networked thinking. They have the ability to familiarize with new, unknown fields of work quickly and methodically, as well as the ability to act interdisciplinary.

Communication and Cooperation

The graduates know how to obtain their goals, how to organize themselves and how to work in an independent and self-consistent way.

They are aware of the importance of cultural differences and know how to deal with cross-cultural issues in an effective way. They are experienced in working together in multinational and interdisciplinary groups and have also achieved cross-cultural competence and the ability to work efficiently in diverse teams. Thus, graduates are trained to be open-minded, pragmatic but thorough, analytical and structured, good communicators, and quick thinking. Graduates are able to act in a tolerant and responsible way. Thus, they have social and strong communication skills, combined with the ability to handle conflicts in an adequate way. They are able to bring their expertise in relevant public disputes as well as provide educated assistance to political decision making processes concerning their own work or in general their field of expertise.

Apart from that, graduates of this degree program have the ability to enter into dialog with both academics and non-academics from various disciplines and fields. They are able to discuss feasible alternatives for solving discipline-specific and subject-related problems.

Scientific self-understanding / professionalism

Graduates of the Master's program in Environmental Engineering at TUM have developed a professional self-understanding based on the objectives and standards of professional action in academia as well as in society. They are able to justify their own professional actions in the field of environmental engineering with theoretical and methodological knowledge and reflect on alternatives. During their studies they have learned to assess their own abilities and to make use of their freedoms of disciplinary design and decision-making independently, and to further develop them under supervision. The graduates recognise ethical implications of their professional actions and align their behaviour with respect to the law. They have learned to critically reflect their professional actions with regard to social expectations and consequences.

3 Target Groups

3.1 Target Audience

The Master's program in Environmental Engineering is the consecutively deepens the knowledge and abilities provided in the Bachelor's program in Environmental Engineering at TUM. The target group of the degree program therefore consists primarily of Bachelor graduates in Environmental Engineering or comparable degree programs.

Due to its strong interdisciplinary focus, it can be also studied as a specialization for graduates of other degree program, e.g. Chemical Engineering, Civil Engineering, Mechanical Engineering or Geoengineering. . Graduates of these programs have the opportunity to deepen their basic knowledge in the global context of its interaction with the environment.

3.2 Prerequisites

Due to the scope of the degree program, special emphasis is placed on a balanced mix of competencies in both, engineering and natural sciences. Emphasis is given in on engineering fundamentals that strengthen analytical and abstract thinking and lay the foundation for understanding the behaviour of basic environmental media such as fluids, gases and solids. Furthermore, basics for understanding natural systems such as macro- and microbial ecosystems as well as the global climate are necessary pre-requisites. In addition to these basics also competences of engineering the interaction of human activity and the environment on an undergraduate level is of importance. In order to allow a cross disciplinary access to the program also the educated and well justified interest in one's own development into an environmental engineer plays is seen as very important. An above average academic performance in the undergraduate studies is also expected

3.3 Target Numbers

The master's program in Environmental Engineering and its corresponding professional profiles address long standing necessities of economy and society. The increased importance of environmentally responsible action in multiple levels of human activity indicate a future increase in demand for graduates with related competences. Thus TUM as a leading university in this field does not target a limitation of the study places. The eleven possible specializations and the wider range of elective modules distribute the load relatively well and can allow for a large number of students to study the program.

Building upon a homonymous bachelor's program at TUM, the master's program accepts beginning students in the winter as well as in the summer term. However, due to the annual cycle of bachelor's programs around the world, the number of applications and admissions in the summer terms is lower. Following figure shows the development of applications, acceptances and immatriculations since the introduction of the TUMonline application that allows for systematic data analysis.

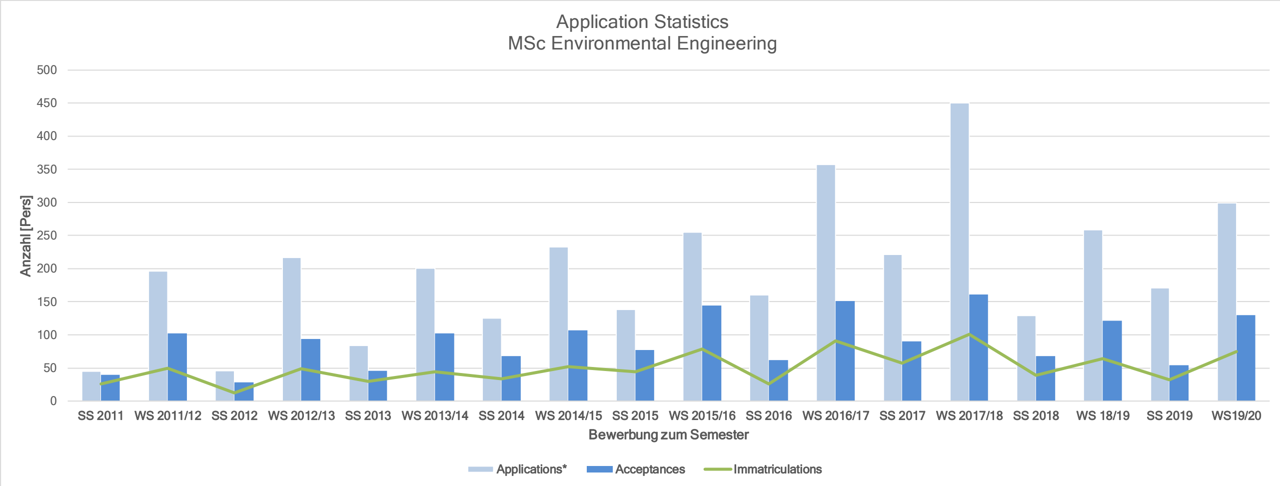

Figure 2: Applications statistics in the master's program since 2011. Source: TUMonline application statistics. *the number of applications refers to applications that were completed and fulfilled the formal criteria for studying in Germany.

The application numbers had an increasing trend until the introduction of the Uniassist VPD requirement for all graduates of universities outside the EEA. The subsequent reduction in the number of applications did not have a significant impact on the total number of qualified applicants as it moreover reduced the not well considered applications.

The number of immatriculations of approximately 150 students per academic year is seen as a realistic figure that allows for a sufficient number of graduates but still allows well-functioning teaching and learning at a master's level.

4 Demand Analysis

The overall responsibility for sustainable engineering practices in the meeting point of human activity and the environment is found across manifold levels of public administration, industrial companies as well as a vast scene of private engineering firms and consultancies that cater planning, engineering and consulting services to the former. The ever growing importance of this field finds also representation in cutting edge research and development in private companies and research institutes as well as universities.

Exact data about the need of public administrations for graduates are not statistically published. In Typical tasks in environmental protection and the human made systems addressed in this programme are found on all levels of the German federal system. The Federal level is responsible for railway and transportation, waste disposal and pollution control. Relevant positions for graduates of the programme can be found in the Federal Ministries for Environment, Nature Conservation and Nuclear Safety and for Transportation and Building as well as several agencies. Superior authorities in this field are the German Environment Agency and the Federal Agency for Nature Conservation. The single federal states are co- responsible for waste disposal and pollution control and are solely responsible for local transportation, water management, landscape protection and natural hazards. Agencies of the states that are relevant to the programme are found (depending on the state) on superior, intermediate and lower authority levels. They are often de-centralised and are distributed in different locations in their territory. Part of the tasks, mainly the waste management, the urban water engineering. Clean air actions and local transportation are in the responsibility of the municipal authorities – always in co-ordination with the state agencies[4]. Graduates of the programme are capable to work on positions of responsibility on all levels of administration.

Beyond the public sector there is a vast range of private companies that deliver products, services and consultation in environmental engineering, environmental protection and application of sustainable principles in all parts of economy and society. These companies are organised in associations who publish studies on the development and needs of their branches. A sharp assignment of individual industries would not do justice to the diversity of the job profile and the complexity of the associated enterprises. Thus rough clusters for the companies are used in most studies.

Figure 3 shows the most important sectors of the Bavarian environmental economy with their current employment figures and the expected annual growth rate from 2017.

[4] German Environment Agency (Umweltbundesamt) Section I 1.3; „A Guide to Environmental Administration in Germany“; Dessau-Roßlau, 2017

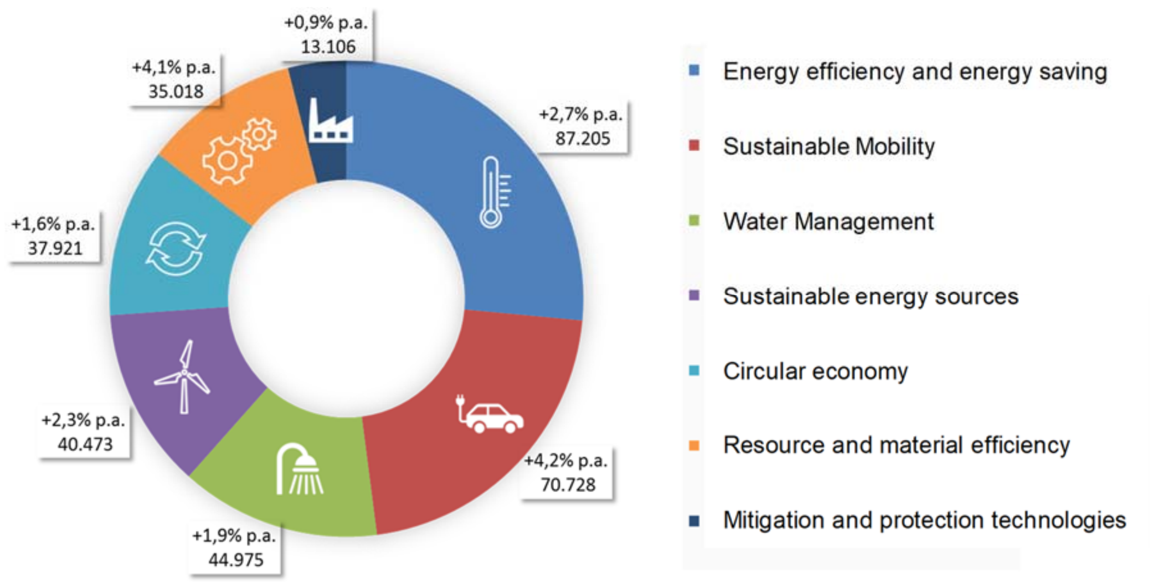

Figure 3: Sectors, employment figures and growth rates in 2017 in the Bavarian environmental economy[5]

The strategic orientation of the programme covers this scope of sectors, though not all equally. The programme aims predominantly in the fields of water management and the sustainable energy recourses that are related to water, sustainable mobility as well resource and material efficiency of the built environment. Provided the given annual growth rates are sustained the need for employees in these sectors in Bavaria alone would be ca. 6.000 people per year. Since not all positions in these branches are filled with engineers making a random assumption that 10% of these employees should have an engineering background this figure still is around 600 which outweighs the number of expected graduates from the programme.

One branch not represented in the statistics above are societies for international development and cooperation such as the German Gesellschaft für internationale Zusammenarbeit GIZ, the World Bank, Units of the United Nations as well as numerous non-governmental organizations (NGO). They are also in need of well educated professionals with skills to set up and manage engineering projects, are in deep knowledge of technical solutions but also have the overview and the transfer capabilities of manifold fields of environment and sustainability.

Regular surveys among graduates give indications on their professional path after the successful completion of the programme. Following figure shows results from the survey of 2020, in which all graduates of the study regulations of 2016 (earliest possible graduation 2018) gave information on their current occupation.

[5] Umweltwirtschaft in Bayern und Deutschland – Überblick, Bedeutung und Perspektiven, Vortrag Jannis Lambert, Prognos AG an der TUM, 11.02.2020

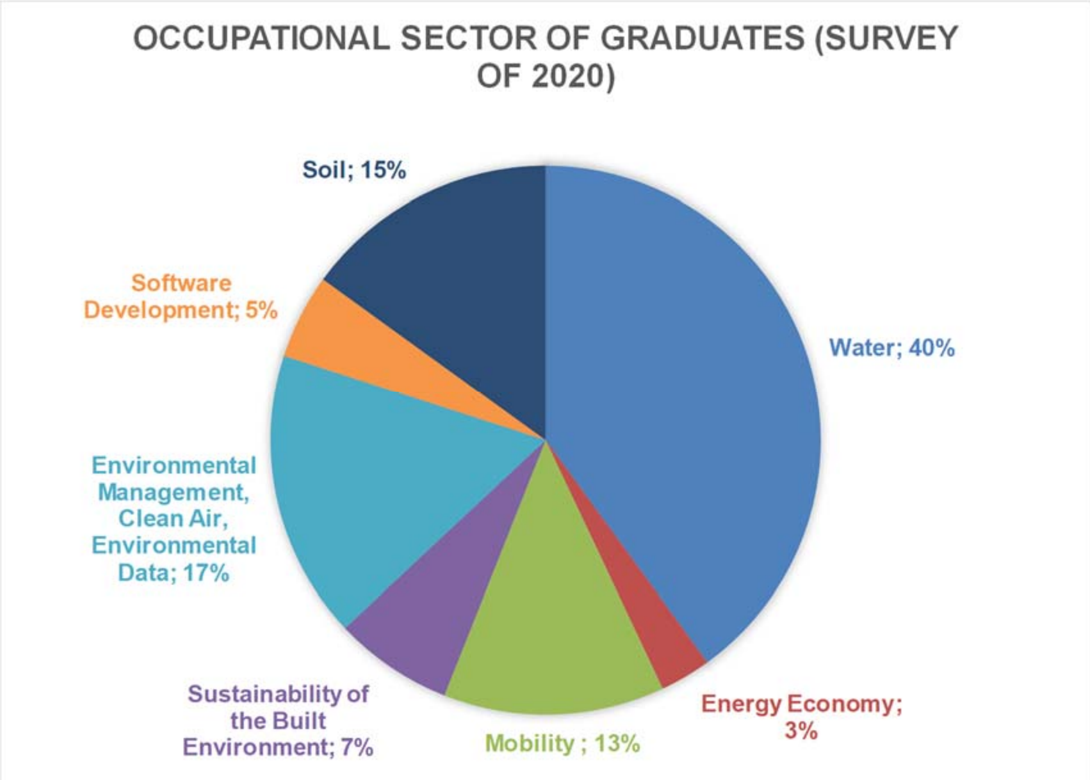

Figure 4: Professional profiles of the graduates from the survey of 2020

The dominance of the water sector is evident, yet expectable since water related specialisations account for ca 50% of the programme's fields of study. The administrations and companies related to that field are manifold and were not differentiated in the survey. The field of environmental management, clear air and environmental data (17%), though not further differentiated in the survey, indicates an involvement in either public administration with overarching responsibilities or a consultancy with a versatile portfolio. Soil (15%) is also one major environmental system that is addressed by several specialisations of the programme – either in relation to natural and human made hazards as well as in combination with groundwater related issues. The field of mobility (13%) stretches over the public sector on municipal, state and federal level, corresponding engineering firms but also industries providing mobility technologies and services. The field of sustainability of the built environment (7%) is often closely related to mobility, due to the traditional merging of settlement development, infrastructure and mobility in the administration and engineering firms. Perhaps unusual for an engineering programme, 5% of the responders are occupied in software development. However, since modelling and simulation are an integral part of modern engineering work, the development of related software requires the expertise of engineers who work closely together with the software development teams.

5 Competition Analysis

5.1 External Competition Analysis

Engineering the interaction of human activity and the environment is despite the increasing debates on current policy, neither a recent topic nor a niche. It is a broad, continuous task that requires a continuous supply with graduates. This is reflected by the large number of environmental engineering study programmes throughout the world. That is not seen as a competitive but more as a co-operative situation, that aims to reach a comparable design in order to create recognisable professional profiles – though each university has some special topics of focus. The following comparison of national and international programmes shall analyse the structure, scope and some individual specifics of each university.

University: RWTH Aachen

Programme: MSc Umweltingenieurwesen (taught in German)

Structure: Students pick one of five specialisations. All specialisations have a common "cross cutting" field from which they choose 10 to 15 Credits. The remaining credits come from a required and a required elective field specific to each specialisation. The programme is concluded with a 30 credits master's thesis.

Scope: The specialisations here are Energy and Environment in Civil Engineering, Urban Water Engineering, Water Management, Environmental Process Technology and Recycling.

Specifics: consecutive to a homonymous BSc programme. The access to the MSc is possible only with this BSc or a comparable undergraduate degree

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University: BTU Cottbus

Programme: MSc Umweltingenieurwesen (taught in German)

Structure: The programme has ten specialisations from which students pick three. In each specialisation, the students must complete 18 Credits in required modules. Furthermore, the students have to complete 24 credits in required electives, chosen freely out of the complete catalogue of the specialisations. The programme includes a mandatory study project and a master's thesis.

Scope: The specialisations of the programme are: Hydrology, Methods, Processes, Renewable Energy, Simulation, Technical Air Protection, Environmental Management, Water Treatment, Hydraulic Engineering, Materials

Specifics: consecutive to a homonymous BSc programme. The access to the MSc is possible only with this BSc or a comparable undergraduate degree

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University: Univesität Kassel

Programme: MSc Umweltingenieurwesen (taught in German)

Structure: The programme offers seven specialisations in two groups. Students must pick one specialisation from each group. They complete 24 Credits within these specialisations. Furthermore, the students have to complete 18 credits in supplementary modules of environmental engineering or general engineering. 6 credits must come also from each of the following categories: Mathematics/Nature Science, Additive Qualification: Environmental Economics, Additive Qualification: Environmental Law. The programme is concluded with a 30 credits master's thesis.

Scope: *Group 1*: Waste- and Resources, Advanced Urban Water Engineering, Hydraulic Engineering and Water Resources, Transport and the Environment. *Group 2*: Industrial Ecology and Sustainable Engineering, Renewable Energies: Sun, Wind Water, Renewable Energies: Thermic Processes

Specifics: The access to the MSc is possible only with a BSc in Environmental Engineering or a comparable undergraduate degree with a duration of seven semesters, which is unusual for German universities. The combination of specialisations is limited by the grouping.

University: TU Braunschweig

Programme: MSc Umweltingenieurwesen (taught in German)

Structure: All students have to complete 24 Credits from a field of Fundamentals, which is composed by modules in mathematics, modelling, legislation. The programme offers 9 specialisations from which the students pick 3 and complete 20 credits in each. An additional area of Key Qualifications (Soft Skills) has 6 mandatory credits. The programme is concluded with a 30 credits master's thesis.

Scope: The specialisations of this programme are: Soil Protection and Geotechnics, Energy Technology, Environmental Sustainability and Life Cycle Engineering, Public Transport, Environmental Monitoring, Environmental and Resource Friendly Building, Transport and Infrastructure, Supply and Disposal, Water Engineering.

Specifics: consecutive to a homonymous BSc programme. The access to the MSc is possible only with this BSc or a comparable undergraduate degree

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University: TU Darmstadt

Programme: MSc Umweltingenieurwissenschaften (taught in German)

Structure: the programme has 4 specialisations from which the students pick 2. They must complete 36 credits in required electives from these specialisations and 42 credits from the elective catalogue of the complete programme. Furthermore, all students must complete an interdisciplinary project with 6 credits, a cross cutting module of environmental science for 6 credits and a soft skills module of 6 credits.

Scope: The specialisation offered are Hydrology and Hydraulic Engineering, Water Technology and Pollutants, Spatial Planning and Resources Management, Environmental Monitoring.

Specifics: consecutive to a homonymous BSc programme. The access to the MSc is possible only with this BSc or a comparable undergraduate degree

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University: Bauhausuniversität Weimar

Programme: MSc Umweltingenieurwissenschaften (taught in German)

Structure: The study programme has one field of fundamentals of mathematics, statistics and GIS that sums up to 18 credits. 3 specialisations are offered from which students must choose one. Beyond their 24 credits of specialisation modules they can pick 24 credits of modules from all other specialisations. The programme has a mandatory study project of 12 credits and is concluded with a 30 credits master's thesis.

Scope: the specialisations are Waste Management, Urban Water Engineering and Transportation.

Specifics: The programme includes engineering fundamentals such as mathematics and statistics. The programme is consecutive to a homonymous BSc programme. The access is possible only with this BSc or a comparable undergraduate degree

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University: TU Hamburg

Programme: MSc Wasser- und Umweltingenieurwesen (taught in German and English)

Structure: The programme has a cross cutting core of competencies on Chemistry, Biology, Geology, Risk Management, Non-technical and economical courses that sums up to 24 credits. Students choose beyond that one of three possible specialisations in which they have 48 credits of required modules and a catalogue of required electives. The programme is concluded with a 30 credits master's thesis.

Scope: The specialisations are "City", "Environment", "Water". The courses in the specialisations seem mostly identical, but the status of required or elective changes according to the specialisation.

Specifics: The common core includes several fundamental courses from natural science. The teaching language is mixed English and German. The programme is consecutive to a homonymous BSc programme. The access is possible only with this BSc or a comparable undergraduate degree.

University: ETH Zürich

Programme: MSc Umweltingenieurwissenschaften (taught in English)

Structure: The study programme has 5 specialisations. Students must complete one specialisation (36 credits required modules, 18 credits elective modules, 12 credits study project). Furthermore, students freely choose 12 credits electives from all specialisations, make 10 credits computer lab and 2 credits soft skills. The programme is concluded with a 30 credits master's thesis.

Scope: the five specialisations are: Urban Water Management, Environmental Technologies, Resource Management, Water Resources Management, River and Hydraulic Engineering.

Specifics: The programme is consecutive to a homonymous BSc programme. The access is possible only with this BSc or a comparable undergraduate degree.

University: DTU Kopenhagen

Programme: MSc Environmental Engineering (taught in English)

Structure: The programme offers two options to the students: to compose their own study plan or pick one of seven specialisations (study lines), which is recommended. The courses of the programme are categorised in General Competences (30 credits), Technological specialisation (30 credits) and electives (30 credits). The programme is concluded with a 30 credits master's thesis.

Scope: The offered study lines are: Climate Change, Environmental Informatics, Environmental Chemistry, Environmental Management, Residual Resource Engineering, Urban Water Engineering, Water Resource Engineering.

Specifics: Access to the programme is given through a wide range of bachelors, beside the BSc in Environmental Engineering.

University: KTH Stockholm

Programme: MSc Environmental Engineering and Sustainable Infrastructure (taught in English)

Structure: The programme offers seven specialisations (competence profiles) from which students pick one. There is one common mandatory course in Theory and Methodology of Scientific Application. The remaining coursework is comprised by required elective modules that correspond with the selected specialisation The programme is concluded with a 30 credits master's thesis.

Scope: The specialisations are: Water Technology, Environmental Geotechnology and Hydrogeology, Water and Wastewater Technology, Environmental Information Analysis and Management, Sustainable Infrastructure, Environmental Systems Analysis, Sustainable Societies.

Specifics: Entry requirement is a Bachelor's degree in Civil Engineering or Environmental Engineering (or closely related programmes).

University: Politecnico di Milano

Programme: Laurea Magistrale (equivalent to Master of Science) Environmental and Land Planning Engineering (taught in Italian with one full track taught in in English)

Structure: The programme is divided in five specialisations (tracks) from which students choose one. For each track and academic year several categories of courses are being offered from which the students have to either pass all or pick a defined number of credits. The courses of the first year also include engineering fundamentals. The programme is concluded with a 30 credits master's thesis.

Scope: The tracks offered are: Land Protection and Natural Risk Prevention, Environmental Monitoring and Diagnostics, Natural Resources Planning and Management, Environmental Protection and Remediation Technologies, Environmental Engineering for Sustainability – the latter taught in English.

Specifics: Access requires a Bachelor's degree in a related field, which leaves open space for more study programmes than the consecutive one.

The list above is only one part of the numerous environmental engineering programmes available throughout the world. On a general level all programmes have comparable structures. One small portion of credits come from a general or cross cutting category. The majority of the study workload is invested in one or more chosen specialisations that target distinct professional fields of environmental engineering. The scope of these specialisations are recognisably similar in all programmes – though not all universities offer the same spectrum, the differences are relatively small and mostly based on the thematic orientation of each university. Beside the specialisation, one small number of credits can be chosen freely within the programme. The element of a study project is seen on many, though not all, programmes while all conclude the studies with a semester long master's thesis. This common philosophy in the structure of most environmental engineering programmes is seen particularly positive as it supports the establishment of the degree in the labour market – in contrast to the manifold niche masters that emerged in recent years.

As chapter 6 will highlight, the programme of TUM aligns itself with the general structure of the other programmes. The range of specialisations shows a similar range as the other programmes that however, also includes some unique thematic focal points of the department of Civil, Geo and Environmental Engineering. In terms of teaching language, TUM follows the pattern of most top rated European universities, offering the undergraduate programme in the native language and the master's programme in English. In this, TUM is one of the few exceptions in Germany. The MSc in Environmental Engineering at TUM ranks 17th in the world on the latest Shanghai ranking[6]. It ranks first among the programs of German universities and fourth among the European programs, surpassed by the ETH Zürich, the DTU Copenhagen and the University of Copenhagen.

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[6] http://www.shanghairanking.com/shanghairanking-subject-rankings/environmental-science-engineering.html (consulted in February 2021)

5.2 Internal Competition Analysis

Several study programmes exist within the department of Civil Geo and Environmental Engineering that show interfaces with environmental engineering, especially since they historically all evolved from aspects of civil engineering and the impact of human settlements on the environment. Furthermore, other departments of TUM offer master's programmes in the broad field of environment and sustainability with which some level of interaction is possible.

MSc Civil Engineering

Goal: Civil Engineering aims ensuring the safety (stability, operational safety, usability), economic performance and low environmental impact of buildings, transport infrastructure, supply and disposal infrastructures.

Relation to Engineering: Civil Engineering is a genuine engineering programme. The graduates apply an engineering cycle on the built environment, focussing on conceptualizing, planning, calculating, constructing and organizing construction projects. The environment is always considered in the goal to minimize the ecological footprint of settlements and infrastructure, as well as a beneficiary from environment related infrastructures.

Interfaces with Environmental Engineering: Environmental Engineering as a professional field has been gradually derived from Civil Engineering. At first Infrastructures for supply and were constructed and operated as part of civil construction. Later also the direct environmental impact of transport infrastructures was integrated in civil engineering. However, a separation of the two disciplines was decided upon the recognition that a holistic understanding of the environmental systems and their interaction with the human activity, even beyond the mere civil construction, was necessary to cope with environmental problems – a task that required more nature science and less competence in constructional aspects. The interfaces between the two programmes continue to exist in the aforementioned fields of water related infrastructures, transportation as well as aspects of urban development in which both professions work co-operatively on engineering projects.

MSc Transportation Systems

Goal: Transportation Systems aims to engineer the complex system of transportation and mobility. It considers the system from its origin in the necessity of humans and goods to travel from different origins to destinations, the necessity for the construction of infrastructure as well as the operation of manifold transportation systems. Societal aspects are considered as well as the ecological footprint of transportation.

Relation to Engineering: Transportation Systems can be alternatively called transportation engineering. Graduates apply the engineering cycle on the distinct and interrelated human made systems of land use and transportation.

Interfaces with Environmental Engineering: Same as Environmental Engineering, Transportation Engineering has been historically derived from Civil Engineering. The environmental relevance of traffic creates many interfaces between the two programmes who consider transportation from slightly different points of view with significant common ground. Environmental Engineering focusses planning sustainable urban mobility systems, managing traffic and understanding/ mitigating their environmental effects. It does not focus on capacity planning and constructional features of transportation infrastructure. In transportation systems these aspects are in the immediate focus with the environmental impact being a considerable effect. Graduates from both programmes can be found working co-operatively on engineering projects.

MSc Ressourceneffizientes und Nachhaltiges Bauen

Goal: Goal of this interdisciplinary programme in the meeting point of architecture and civil engineering is the sustainable transformation of conventional planning, constructing and operating processes for buildings and in extension reducing the CO_2 and resource footprint of settlements.

Relation to Engineering: This is an engineering programme that aims at the entirety of processes related to building construction, beginning from the planning and regulatory procedures, the commodities and materials up to the operation and end of life of buildings.

Interfaces with Environmental Engineering: The interfaces with environmental engineering are given in the sustainable strategies for urban areas, though both programmes focus on different systems. Ressourceneffizientes und Nachhaltiges Bauen focusses on the building, including its constructional and design features, as an artefact and extends to the settlement and its ecological performance as a scale up of functions from the operation of the buildings. Environmental Engineering approaches the subject from a macroscopic view of large scale area plannings for settlements, energy, transportation and water and extends into the interaction with the natural environment.

MSc Ingenieurökologie

Goal: Goal of this Master’s programme is the Management of ecosystems that are impacted or even generated through agriculture and forestry. A special focus of the programme lies in the solving of conflicts between competing land uses.

Relation to Engineering: This master’s programme sees itself in the overlap of several disciplines, one of which is engineering. However, the relation to natural science such as ecology but also life sciences such as agriculture and forestry are significantly more prominent. The programme contains principles of engineering such as the goal oriented development of measures in order to achieve an effect in a system of interest. These measures though are more in the field of land use planning and management than in engineering.

Interfaces with Environmental Engineering: The systems of focus or Ingenieurökologie are mostly agriculture and forestry as well as the natural ecosystems they interact with – herby extending deep into living organisms and biodiversity. Environmental engineering has a deeper link to the technosphere and a weaker towards living organisms and biodiversity. On the other hand, it considers broader scope of human activities than the life sciences. An interface to environmental engineering is created with the natural water cycle as part of the engineering solutions, especially in the field of hydraulic engineering and water resources management, have a link to the use of water for agriculture and to the utilisation of river basins for human and natural activity.

MSc Sustainable Resource Management

Goal: The goal of this programme is to address the problems deriving from the exploitation of natural resources through the development and application of policy and management measures. The programme combines aspects of economics, governance and sustainability. It has an interdisciplinary approach that fuses nature science, political science and management.

Relation to Engineering: Sustainable Resource Management is not an engineering programme. Its methods are in the field of an interdisciplinary management of natural environment and resources.

Interfaces with Environmental Engineering: Both programmes provide their graduates with a profound understanding of environmental systems and the requirements of sustainability. Their methods however lie in different fields of expertise- the one from a technical and the other from a policy perspective. Graduates will be called to work co-operatively when it comes to large scale deployment of technological and management solutions for tackling environmental problems.

MSc Nachwachsende Rohstoffe

Goal: This programme aims to educate professionals in several aspects of renewable raw materials, especially ones derived from agriculture and forestry and are not meant for the food chain. It covers the aspects of growing agricultural raw materials, chemical processing of those commodities, energy use of renewable raw materials as well as their economic and management aspects.

Relation to Engineering: The programme is not an engineering programme though some of its specialisations show an overlap with chemical engineering or process engineering.

Interfaces with Environmental Engineering: The interfaces with environmental engineering are few. Certain aspects of the energetic utilisation of organic matter can be applied for energy production from agricultural products/by-products and alternatively by-products of wastewater treatment. Also in the area of solid waste management – though this topic is not explicitly addressed in either programmes at TUM – graduates can co-operate from both sides to develop sustainable life cycles of products.

6 Program Structure

As described in chapter 1.1., environmental engineering is the application of an engineering cycle on the interaction of natural environments and human activities. The programme has the aim to equip its graduates with the necessary competences for this application; not only on a general abstract level but corresponding with distinct professional fields. The structure of the programme operationalises the qualification profile and implements it in a way that:

- is corresponding with the major professional fields of environmental engineering in a comprehensive way,
- is easy to understand for students and employers alike
- gives guidance to students so that they keep a targeted profile
- leaves room for the students to extend their competences beyond their profile
- is recognisably a scientific environmental engineering programme, comparable with the homonymous programmes throughout the world.

Some tools that can be utilised for manifold purposes within environmental engineering, can be taught on a general, transferable level that is independent from specialisations. This includes the acquisition techniques of environmental data by the means of remote sensing and satellite observation as well as the common ways of their processing, visualization and interpretation by the means of geographical information systems. Applications of data processing and computer programming are also to be found in such general competences. Beyond these technical aspects also competences in understanding global environmental phenomena such as climate change and the energy footprint of human activities are considered cross cutting competences. With special emphasis though, the research design on given scientific questions, the competences of presentation and defence of own scientific work and the public discourse on environmental and engineering topics are also a common core of all students. Thus the programme has a basic structural element of "**Cross Cutting Methods**". The importance of scientific application, research competence and communications skills is emphasised by a mandatory module in this field. Beyond that, students can choose from a catalogue of cross cutting electives according to their own interests or the necessity of their targeted fields of specialisation. Counselling on this choice is given by mentors.

The systems the engineering is aiming at, show a very wide scope that determines the methods, technologies and innovations required from the graduates. Based on the necessities of the labour market it is never required from professionals to have deep knowledge of this scope's completeness. Moreover, employers require an in depth competence in a specific field and the ability to understand the interfaces with the other, related fields of environmental engineering as well as other disciplines with which environmental engineers will have to co-operate. Thus the programme offers a scope of specialisations called "Fields of Study", each corresponding with a distinct, profession-related field as well as an area of "Individual Choice Electives" that allows the extension beyond the limits of the Field of Study.

Each **Field of Study** determines a coherent space which contains specific environmental systems and their characteristics of interaction with the human activity that the graduates will be working on in their further carer. Beside the basic tools provided by the Cross Cutting Methods the Fields of Study complete the competences necessary for the graduates to be able to apply the complete engineering cycle on the aforementioned space of environmental systems and human interaction. They provide the particular terminology and the concepts of those systems. They ensure the profound understanding of the observed natural systems and relevant human activities – hereby the need of the society is an immanent component on both those sides. They provide the methods to identify and analyse problems emerging from observed or anticipated interactions with respect to the principles of sustainability as this is applied in the respective system. They help identify and understand the interfaces with further systems beyond their narrow scope. They provide the modelling and simulation techniques that are specific to those environmental and human made systems and provide them with the necessary critical thinking upon the requirements of their system as well as the capabilities and limitations of the specific models. Furthermore, the Fields of Study provide the graduate with the specific methodological toolkit to solve the identified problems with respect to the aims of sustainability – a toolkit that can contain technological application and innovation specific to the system but also management and regulatory measures.

The competences necessary to achieve system understanding and the core of the analytical and problem solving techniques are combined in the required modules of each Field of Study. Through them the programme ensures that all graduates with the respective specialisation are equipped with those core enablers. Building upon this foundation, a selection of elective modules is provided that helps deepen the competences in specific topics. These can be bespoke modelling techniques, specialised engineering technologies and innovations, laboratory competences adapted to the specific field or hands on project courses that strengthen their cooperative capabilities. The Fields of Study provided by the programme are:

1. Urban Water Engineering
2. Water Resources Management
3. Hydraulic Engineering
4. Hydrogeology, Groundwater, Geothermal Energy
5. Modelling and Measurement of Flow and Transport
6. Resource Efficiency in Urban Planning
7. Environmental Geotechnics
8. Environmental Hazards and Risk
9. Sustainable Urban Mobility Planning
10. Transportation Engineering and Control
11. Water-Energy-Food Nexus

The programme aims in delivering both specialisation but also broad system and connected thinking. For this reason, the students choose two Fields of Study - preferably such with meaningful interfaces to each other. The choice of this combination does not affect their ability to apply the engineering cycle, but simply extends the range of their activity to related and meaningful systems. Advice upon the choice is given through recommended combinations of Fields of Study but also with individual counselling by mentors. The choice of the Field of Study is binding. A change of one or both chosen fields of study during the course of the programme is possible provided it happens on an educated basis, after thorough academic counselling and provided the change does not threaten the study progress control of the students.

It is noted that a distinct specialisation in clean air engineering is not part of the programme but is only taught as part of the environmental impact of transportation. Efforts will be made by the department to offer additional courses to address the overall theme better – though not in a separate field of study.

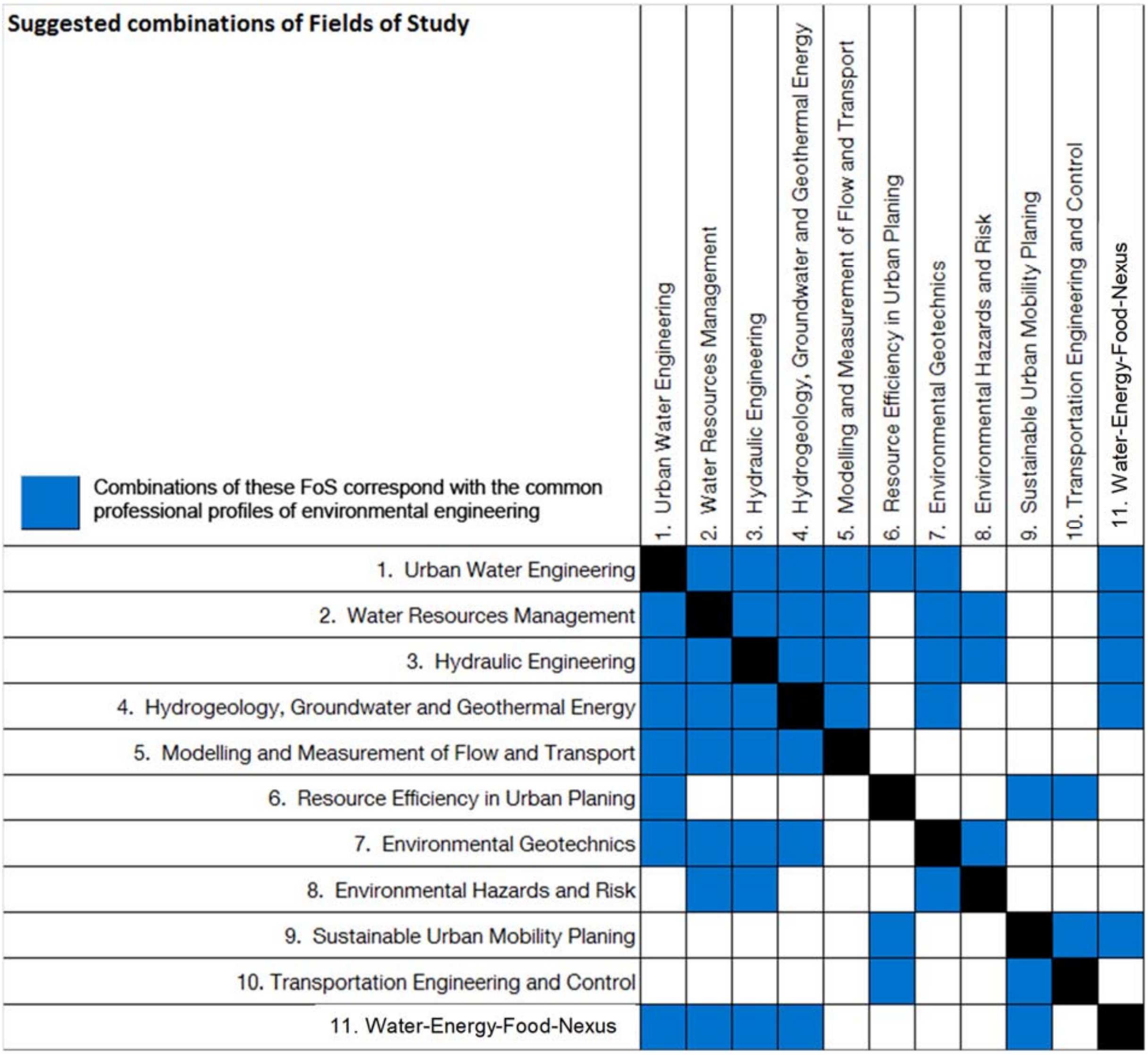

Figure 5: Recommended combinations of Fields of Study

The **Individual Choice Electives** give the students the ability to broaden their competences beyond their Fields of Study. They provide the graduates with the ability to familiarise themselves with new topics beyond their specialisation and transfer knowledge and methods from one field of competence to another. They give several levels of flexibility in this choice:

- Students can choose modules freely from the complete environmental engineering programme and so cultivate their transfer capabilities and system understanding even further.
- They can choose modules from other study programmes of TUM that contribute to their overall profile – most common choices are modules in economics, public policy, mechanical and electrical engineering. Choice of modules that are not part of the environmental engineering programme takes place after consulting with a mentor.

- Soft Skills and Languages. Students are encouraged by their mentors to include soft skills, e.g. from the Carl von Linde Academy, in their curriculum. Language courses from the TUM Language Centre are also eligible (with some limitations) for this category.

With the exception of language courses there are no limitations on how students choose from these categories. The function of the mentor who advises on these choices is fulfilled by examiners from the students' Fields of Study as well as the study advisor of the programme. Guidelines for the choice of personal electives can be found in chapter 10.1.

The **Study Project** aims in providing the students with the ability to operationalise a given research question or a larger but delimited engineering problem and analyse it in its interrelations with the relevant environmental and human made systems. It helps them choose state of the art analytical methods to understand the problem and utilise upon standards methods or technologies to compose an implementable solution to the problem. They have to present their work in a convincing way as a written engineering report and a presentation in front of a thematically educated audience. This is the first step towards common engineering practice. The study project can be done in cooperation with one of the chairs of the department and must be thematically related to the student's fields of study or chosen cross cutting competences. Students are however also encouraged to make the project in co-operation with a company or public administration. In this case an examiner of the department has the academic co-supervision, the student however is integrated in the working environment of the external institution that provides the topic, the necessary data and the technical periphery. Guidelines for the study project can be found in chapter 10.2.

Finally, the programme is concluded with the **Master's Thesis**. Aim of this scientific work is to analyse a given research topic, identify the relevant scientific questions and derive own methodologies to answer them. This process of half a year teaches students to critically reflect upon their methodological choices, evaluate them based on novel scientific findings. At the end they get enabled to identify the limitations of their own scientific work, to recognise remaining or emerging research gaps and to make the first attempts to develop new research questions. Emphasis is given on the application of scientific principles throughout the process – up to the composition of a scientific paper and its presentation in front of a specialist audience. As in the Study Project, students have the opportunity to make the thesis in co-operation with an external institution. An academic supervision by one of the department's chairs ensures that the high scientific standards of the thesis are kept throughout the process. The topic of the thesis must be thematically related to the student's fields of study and have a contribution to the resulting academic profile. This is ensured by the mandatory academic supervision by one of the department's chairs – beside that, there is no other restriction in the choice of the topic.

The structure of the programme with the credit requirements is shown in following table:

Category	Credits
Fields of Study	Required: 24
	Elective: 24
Individual Choice Electives	12
Cross Cutting Methods	Required: 6
	Elective: 12

Category	Credits
Study Project	12
Master's Thesis	30

Table 1: Study structure and credit requirements

The increased demand for international mobility is met by a student-friendly practice in the recognition of modules from partner universities. Up to 30 ECTS credits of electives from a partner-university can be recognised without the mandatory identification of a module at TUM that delivers the same competences. A mentor must approve them on the basis of the module descriptions as fitting to the students' academic profile and assure that they are not redundant with modules already passed by the student. Only the recognition of required modules demands the passing of a module in the partner university that delivers the same competences as the required module of the programme. A decision also taken by the examiner of the TUM-module upon comparison of both module descriptions. A study project or a master's thesis can also be recognised with the quality control of one of the department's chairs. Thus the most suitable semester for international mobility is the third. The students have passed their required modules by then. The recognition of electives has a very high flexibility and the study project can be done also in the partner university – either as full project or as an accumulation of practical or project based courses

The aforementioned rules apply to ERASMUS, TUM Exchange and free mover motilities as well as the ATHENS programme. International mobility on a higher level is also possible through the 1:1 programme with the DTU Copenhagen, which allows the recognition of 60 Credits from the partner university as well as various genuine double degree programs, for example with the KTH Stockholm, Madrid Polytechnic or EPF Lausanne.

Following figures shows the generic structure of the study program and one exemplary study plan for the most popular combination of fields of study. More exemplary study plans can be found in Annex I

Semester	Modules					Number of credits/ exam
1	**Required Module FoS A** 6 ECTS	**Required Module FoS B** 6 ECTS	**Required Module Cross Cutting Methods** exam: scientific paper 6 ECTS	**Elective Module FoS A** 6 ECTS	**Elective Module FoS B** 6 ECTS	30 cr./ 5 ex.
2	**Required Module FoS A** 6 ECTS	**Required Module FoS B** 6 ECTS	**Elective Module FoS A** 6 ECTS	**Elective Module FoS B** 6 ECTS	**Elective Module Cross Cutting Methods** 6 ECTS	30 cr./ 5 ex.
3	**Elective Module Cross Cutting Methods** 6 ECTS	**Individual Choice Elective** 6 ECTS	**Individual Choice Elective** 6 ECTS	**Study Project** exam: project report 12 ECTS		30 cr./ 4 ex.
4	**Master's Thesis** exam: scientific paper 30 ECTS					30 cr./ 1 ex.
Key	TUM blue = Field fo Study required modules light bue = Field of Study elective modules dark green = Cross Cutting Required Module light green = Cross Cutiing Elective Module white = Individual Choice Module dark blue = study project and master's thesis					

Figure 6: generic study structure of the master's programme

Semester	Modules					Number of credits/ exams
1	**Water and Wastewater Treatment Engineering** (required) written exam 6 ECTS	**Integrated Water Resources Management** (required) written exam 6 ECTS	**Scientific Methods and Presentation Skills** (required) exam: scientific paper 6 ECTS	**Urban Flood Modelling and Resilience** (elective) project report 6 ECTS	**Fundamentals of Hydrochemistry** (elective) written exam 6 ECTS	30 cr./ 5 ex.
2	**Advanced Water Treatment and Anaerobic Processes** (required) written exam 6 ECTS	**Flood Risk and Flood Management** (required) written exam 6 ECTS	**Remote Sensing in Hydrology** (elective) written exam 6 ECTS	**Hydrochemistry Lab** (elective) laboratory work 6 ECTS	**Application of an Life Cycle Assessment for Civil Engineering** (elective) written exam 6 ECTS	30 cr./ 5 ex.
3	**Introduction to Photogrammetry, Remote Sensing and Image Processing** (elective) written exam 6 ECTS	**Individual Choice Elective** 6 ECTS	**Individual Choice Elective** 6 ECTS	**Study Project** (required) exam: project report 12 ECTS		30 cr./ 4 ex.
4	**Master's Thesis** exam: scientific paper 30 ECTS					30 cr./ 1 ex.
Key	TUM blue = Field fo Study required modules light bue = Field of Study elective modules dark green = Cross Cutting Required Module light green = Cross Cutiing Elective Module white = Individual Choice Module dark blue = study project and master's thesis					

Figure 7: Study plan for a common combination of fields of study: Urban Water Engineering x Water Resources Management

7 Organization and Coordination

The Master's Program Environmental Engineering is offered at the Department of Civil, Geo and Environmental Engineering of the Technical University of Munich, where it is jointly taught by all professors. As it has an interdisciplinary approach, and therefore several other chairs, professorships and departments of the TUM are involved. Several elective modules can be attended at other departments or schools.

The following administrative tasks are performed partly by the TUM Center for Study and Teaching (TUM CST) and its administrative units, partly by offices in the schools or departments:

- Student Advising: TUM Center for Study and Teaching (TUM CST)
  Student Advising and Prospective Student Programs
  Email: studium@tum.de
  Phone: +49 (0)89 289 22245
  Provides information and advising for prospective and current students (via hotline/service desk)
- Departmental Student Advising: Program Coordinator and Academic Advisor
  Dr.-Ing. Antonios Tsakarestos
  Email: antonios.tsakarestos@tum.de
  Phone: +49 (0)89 289 22424
- Academic Programs Office: Examination Administration and Advising
  Renate Bayer
  Email: r.bayer@tum.de
  Phone: +49 (0)89 289 22404
- Study Abroad Advising/Internationalization:
  TUM-wide: TUM Global and Alumni Office, globaloffice@tum.de
  Departmental: International Affairs Delegate
  Nadin Klomke, M.A.
  Email: n.klomke@tum.de
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- Advising – Barrier-Free Education: TUM-wide: Office for Disabled and Chronically Ill Students (TUM CST)
  Email: Handicap@zv.tum.de
  Phone: +49 (0)89 289 22737
  Departmental: Dipl.-Ing. Michaela Wenzel
  Email: m.wenzel@tum.de
  Phone: +49 (0)89 289 25261
- Admissions and Enrollment: Advising and Information (TUM CST), Admissions and Enrollment
  Email: studium@tum.de
  Phone: +49 (0)89 289 22245
  Admissions, enrollment
  StudentCard, leaves of absence,
  student fees payment, withdrawal
- Aptitude Assessment (EV): Where applicable:
  TUM-wide: Advising and Information (TUM CST), Admissions and Enrollment
  Departmental: Aptitude Assessment Commission,
  Chair: Univ.-Prof. Dr.-Ing. Jörg Drewes
  Program coordinator: Dr.-Ing. Antonios Tsakarestos
  Email: ntonios.tsakarestos@tum.de
  Phone: +49 (0)89 289 22424
- Semester Fees and Scholarships: Advising and Information (TUM CST), Semester Fees Management
  Email: beitragsmanagement@zv.tum.de
- Examination Office: Central Examination Office (TUM CST)
  Campus Munich
  Graduation documents, notifications of examination results, preliminary degree certificates
- Departmental Examination Office: Renate Bayer
  Email: r.bayer@tum.de
  Phone: +49 (0)89 289 22404
- Examination Board: Prof. Dr.-Ing. Peter Rutschmann (Chair)
  Renate Bayer (Secretary)

- Quality Management – Academic and Student Affairs:

  TUM-wide: Quality Management (TUM CST)
  http://www.lehren.tum.de/startseite/team-cst/
  Departmental: Consultants for Studies and Teaching
  Dr. Lars Fuchs, lars.fuchs@tum.de
  Dipl.-Ing. Sandra Spindler, sandra.spindler@tum.de
  Prof. Dr. Stephan Freudenstein (Dean of Studies)
  Organization QM Circle: Dipl.-Ing. Sandra Spindler, sandra.spindler@tum.de
  Evaluations Representative: Dipl.-Ing. Sandra Spindler, sandra.spindler@tum.de
  Coordination, Module Management : Dipl.-Ing. Sandra Spindler, sandra.spindler@tum.de

8 Enhancement Measures

The Master's program Environmental Engineering started with the winter semester 2006/07. The initial idea was that the needs of the key environmental issues in a globalized world are no longer covered by the traditional education as German civil engineer. Therefore, a new degree program should be set-up with a clear international perspective and attitude as well as a focus on interdisciplinarity. The degree program Environmental Engineering represents one of the first degree programs at TUM that was fully conducted in English. The new program was meant to produce specialists with a clear environmental engineering specialization, backed by the broad basis of an environmental engineering bachelor's program.

The strategic and content-related orientation of the degree program is continuously developed based on the requirements of the job market and the research landscape. The degree program was introduced with the winter semester 2006/07. The first version of the program structure provided for an overall catalogue of all required elective modules and an overall catalogue of elective modules. The students had to navigate compose their own academic profiles and in extension their professional qualifications by choosing a suitable combination of modules from these lists. The structure was criticised by students and externals alike. The students had problems identifying the correct combination of modules that can balance their individual interests and the requirements of a professional profile. The potential employers accordingly had difficulties understanding what the graduates of environmental engineering from TUM can do in their respective field of occupation since no distinct profile was clearly visible.

In the course of the modularization of the degree programs and the introduction of the new general study regulations (APSO), considerations were made regarding the restructuring of the Master's program. In cooperation with the students and with the participation of the Department of Environmental Engineering at Danmarkse Tekniske Universitet (DTU), a new structure for the degree program were developed. On the one hand, the cross cutting and the profile related competencies were listed in separate catalogues, so that the students can recognize general thematic fields more easily. In this way, students will be able to study both profession related and cross-cutting modules in a more balanced and targeted way. Employers could identify the core competences of the graduates more easily. Four specialization directions, so-called "Fields of Study", were introduced, which represented grouped fields of recognizable professional profiles. They were broad, yet easier to communicate. The once very extensive general catalogue of the modules was therefore divided into a comprehensive catalogue "Cross-Cutting Methods, Technologies and Fundamentals" and four specialized catalogues of the Fields of Study:

1. Urban Environments and Transportation
2. Environmental Hazards and Resources Management
3. Environmental Quality and Renewable Energy
4. Energy Performance and Sustainability of Buildings

Within the chosen field of study, the students were again able to choose required elective and elective modules based on their special inclinations. The new structure was introduced in the winter semester 2011/12 and was well accepted by the students compared to the previous one.

Between 2011 and 2014, experience with the new structure was gathered. Parallel discussions with representatives of employers and of the university landscape were carried out. Weaknesses of the four broad fields of study showed quite quickly.While topics included in one field could be combined easily, there was a divide between the fields that ran across systems that had interfaces to each other. This led to a sharpening of the fields of study. A more modular approach was chosen. Eleven narrower, more manageable and easier to identify profiles were composed that work as building blocks. Recommended combinations of those profiles lead to a professional specialisation that is broad enough to fulfil the requirements of a versatile and engineer with transfer capabilities – who on the other hand is more focussed and achieves a deeper knowledge. The broadening of the knowledge beyond the specialisation was ensured by the individual choice electives while the cross cutting methods were kept as a common core of all specialisations.

The new fields of study were built upon following principles:

• The Fields of Study should have clearly recognizable guiding thread

• All sensible combinations of mission statements should be possible

• The range of modules in the Fields of Study should be targeted, transparent and designed in a way that professional competence can be acquired

• The multidisciplinarity of the Fields of Study should be maintained where it supports the associated mission statement – leading to the involvement of more than one chair in each field of Study

• The nomination of coordinators among the professors for each individual Field of Study will improve the mentoring of students in terms of professional choices

Since the revision of the degree program in 2016students choose in the first semester two out of eleven Fields of Study.

The Fields of Study are as follows:

1. Urban Water Engineering
2. Water Resources Management
3. Hydraulic Engineering
4. Hydrogeology, Groundwater and Geothermal Energy
5. Modelling and Measurement of Flow and Transport
6. Resource Efficiency in Urban Planning
7. Environmental Geotechnics
8. Environmental Hazards and Risk
9. Sustainable Urban Mobility Planning
10. Transportation Engineering and Control
11. Water-Food-Energy Nexus

Triggered by the upcoming accreditation renewal in the year 2020, discussions on corrections to the program were conducted. The basis of the discussions was feedback of the students from study program evaluations and direct input of the student council as well as the experience of the professors and the department.

Firstly, the general adjustment of module examinations in order to implement requirements of the German Education Minister Conference (KMK) were necessary, streamlining module sizes and trimming down the number of exams.

As second major need of improvement the field of Study Water-Food-Energy Nexus was identified. Especially the required modules did not clearly convey a consistent view on the Field of Study that enables the understanding of Water Food and Energy as an integrated system. Thus the required module of “Principles and Applications of Land Management” is to be developed further into “Integrated Land and Water Management” and the second required Module of “Ethics in Science and Technology” be replaced by “Planning the Water Energy Food nexus” with the former module being integrated into the elective catalogue. Finally, the name of the Field of Study is to be changed to “Water Energy Food Nexus” in order to adopt the standard international terminology.

The introduction of a required module for independent scientific working and the acquisition of competencies in composing and presenting scientific papers was seen as a necessity by both students and professors. The program’s beginning students do not have a uniform academic education of TUM standards. They come from diverse scientific and cultural backgrounds that often differ and sometimes significantly diverge from the commonly required standards. Compared to other master’s programs that already have a mandatory scientific working module, students of Environmental Engineering have a significantly higher occurrence of plagiarism in seminars and projects. However, checking such specific competences by the means of the application evaluation is not possible. Discussions with the student representatives as well as external experts in the regular quality circles undrlined the necessity to ensure the provision of these competencies as a fixed part of the curriculum that cannot be bypassed. Thus a new required module is introduced to the Cross Cutting Methods that allows the normalization of competences in scientific working and shall increase the scientific practices in the course of the program.

A further action point was the duration of the study project. Until now not strictly regulated, in order to allow for diverse project requirements, it tends to cause problems in the students’ study progress due to the lack of binding deadlines. Frequently failing to submit a long postponed project conclusion leads to unnecessary conflicts with the study progress control. Thus a limitation of the project duration of six months will be introduced.

Finally, the official title of the study program “Umweltingenieurwesen (Environmental Engineering)” does not necessarily reflect its international orientation. The department decided to adapt it to “Environmental Engineering (Umweltingenieurwesen)”.

9 Annex I – Exemplary study plans for different combinations of Fields of Study

Exemplary study plan with the combination of Fields of Study: (2) Water Resources Management and (3) Hydraulic Engineering

Semester	Modules					Number of credits/ exam
1	**Integrated Water Resources Management** (required) written exam 6 ECTS	**Water Resources and Hydropower** (required) written exam 6 ECTS	**Hydraulic Engineering and Hydromorphology** (required) written exam 6 ECTS	**Urban Flood Modelling and Resilience** (elective) project report 6 ECTS	**Introduction to Photogrammetry, Remote Sensing and Image Processing** (elective) written exam 6 ECTS	30 cr./ 5 ex.
2	**Flood Risk and Flood Management** (required) written exam 6 ECTS	**Scientific Methods and Presentation Skills** (required) exam: scientific paper 6 ECTS	**Remote Sensing in Hydrology** (elective) written exam 6 ECTS	**Ocean and Wind Energy** (elective) written exam 6 ECTS	**Project Lab Renewable and Sustainable Energy Systems** (elective) written exam 6 ECTS	30 cr./ 5 ex.
3	**Rapidly Varying Flows in Hydraulic Engineering** (elective) written exam 6 ECTS	**Individual Choice Elective** 6 ECTS	**Individual Choice Elective** 6 ECTS	**Study Project** exam: project report 12 ECTS		30 cr./ 4 ex.
4	**Master's Thesis** exam: scientific paper 30 ECTS					30 cr./ 1 ex.
Key	TUM blue = Field fo Study required modules light bue = Field of Study elective modules dark green = Cross Cutting Required Module light green = Cross Cutiing Elective Module white = Individual Choice Module dark blue = study project and master's thesis					

Exemplary study plan with the combination of Fields of Study: (7) Environmental Geotechnics and (8) Environmental Hazards and Risk

Semester	Modules					Number of credits/ exam
1	**Geotechnical Issues in Environmental Engineering** (required) written exam 6 ECTS	**Alpine Hazards** (required) written exam 6 ECTS	**Risk Analysis** (required) written exam 6 ECTS	**Earthworks and Building with Geosynthetics** (elective) project report 6 ECTS	**Computation in Engineering I** (elective) written exam + exercise 6 ECTS	30 cr./ 6 ex.
2	**Ground Water Handling and Sustainable Use of Geomaterials in Civil Construction** (required) written exam 6 ECTS	**Scientific Methods and Presentation Skills** (required) exam: scientific paper 6 ECTS	**Remote Sensing in Hydrology** (elective) written exam 6 ECTS	**Ocean and Wind Energy** (elective) written exam 6 ECTS	**Project Lab Renewable and Sustainable Energy Systems** (elective) written exam 6 ECTS	30 cr./ 5 ex.
3	**Rapidly Varying Flows in Hydraulic Engineering** (elective) written exam 6 ECTS	**Individual Choice Elective** 6 ECTS	**Individual Choice Elective** 6 ECTS	**Study Project** exam: project report 12 ECTS		30 cr./ 4 ex.
4	**Master's Thesis** exam: scientific paper 30 ECTS					30 cr./ 1 ex.
Key	TUM blue = Field fo Study required modules light bue = Field of Study elective modules dark green = Cross Cutting Required Module light green = Cross Cutiing Elective Module white = Individual Choice Module dark blue = study project and master's thesis					

Exemplary study plan with the combination of Fields of Study: (3) Hydraulic Engineering and (8) Environmental Hazards and Risk

Semester	Modules					Number of credits/ exam
1	**Water Resources and Hydropower** (required) written exam 6 ECTS	**Alpine Hazards** (required) written exam 6 ECTS	**Risk Analysis** (required) written exam 6 ECTS	**Hydraulic Engineering and Hydromorphology** (required) written exam 6 ECTS	**Introduction to Photogrammetry, Remote Sensing and Image Processing** (elective) written exam 6 ECTS	30 cr./ 5 ex.
2	**Scientific Methods and Presentation Skills** (required) exam: scientific paper 6 ECTS	**Risk and Reliability Assessment** (elective) project report 6 ECTS	**Landslides** (elective) written exam 6 ECTS	**Rivers as an Ecosystem** (elective) written exam 6 ECTS	**Climate Change** (elective) written exam + project work 6 ECTS	30 cr./ 6 ex.
3	**Rapidly Varying Flows in Hydraulic Engineering** (elective) written exam 6 ECTS	**Individual Choice Elective** 6 ECTS	**Individual Choice Elective** 6 ECTS	**Study Project** exam: project report 12 ECTS		30 cr./ 4 ex.
4	**Master's Thesis** exam: scientific paper 30 ECTS					30 cr./ 1 ex.
Key	TUM blue = Field fo Study required modules light bue = Field of Study elective modules dark green = Cross Cutting Required Module light green = Cross Cutiing Elective Module white = Individual Choice Module dark blue = study project and master's thesis					

Exemplary study plan with the combination of Fields of Study: (5) Modelling and Measurement of Flow and Transport and (8) Environmental Hazards and Risk

Semester	Modules					Number of credits/ exam
1	**Fluid Mechanics and Transport Mechanisms** (required) written exam 6 ECTS	**Water Resources and Hydropower** (required) written exam 6 ECTS	**Hydraulic Engineering and Hydromorphology** (required) written exam 6 ECTS	**Rapidly varying Flows in Hydraulic Engineering** (elective) written exam 6 ECTS	**Introduction to Photogrammetry, Remote Sensing and Image Processing** (elective) written exam 6 ECTS	30 cr./ 5 ex.
2	**Numerical Methods in Hydromechanics** (required) written exam 6 ECTS	**Scientific Methods and Presentation Skills** (required) exam: scientific paper 6 ECTS	**Modeling and Simulation of Turbulent Flows** (elective) written exam 6 ECTS	**Contamainant Transport and Remediation** (elective) written exam 6 ECTS	**Project Lab Renewable and Sustainable Energy Systems** (elective) written exam 6 ECTS	30 cr./ 5 ex.
3	**Alpine Hazards** (elective) written exam 6 ECTS	**Individual Choice Elective** 6 ECTS	**Individual Choice Elective** 6 ECTS	**Study Project** exam: project report 12 ECTS		30 cr./ 4 ex.
4	**Master's Thesis** exam: scientific paper 30 ECTS					30 cr./ 1 ex.
Key	TUM blue = Field fo Study required modules light bue = Field of Study elective modules dark green = Cross Cutting Required Module light green = Cross Cutting Elective Module white = Individual Choice Module dark blue = study project and master's thesis					

10 Annex II - Guidelines for students

10.1 Guidelines for the individual choice electives

Writing exams outside the curriculum

Students of TUM can participate in almost all exams offered at the university. Exams that do not belong to their fixed curriculum will appear on the transcript as “additional courses” and will count to neither the total credits nor the average grade of the study programme. Students of the MSc program in Environmental Engineering however, can assign a number of credits from such “additional courses” into their **individual choice elective catalogue** - making them count to both total achieved credits and average grade. A mentor must approve the chosen personal electives.

Number of credits in the personal electives

Students who **started their studies until the summer term of 2022** have space for **18 credits** in their personal electives. Students who **started their studies from the winter term 2022/23 and later** (FPSO20221) have space for **12 credits** personal electives.

Selecting modules for the personal elective catalogue

Not all modules qualify for the assignment to the personal electives. They must be related to environmental engineering or have a contribution to the student’s broader profile as an engineer. Personal electives can be chosen from:

- Modules form other Fields of Study from the MSc program in Environmental Engineering
- Modules on MSc-level form other study programmes of TUM
- Soft skills from the CvL Academy and the TUM library
- Language Courses from the TUM Language Centre
  → up to a total of 6 credits, level A2 or higher. English and the own mother language are excluded.
- Modules of the ATHENS programme
- Modules passed during a stay abroad at a partner university

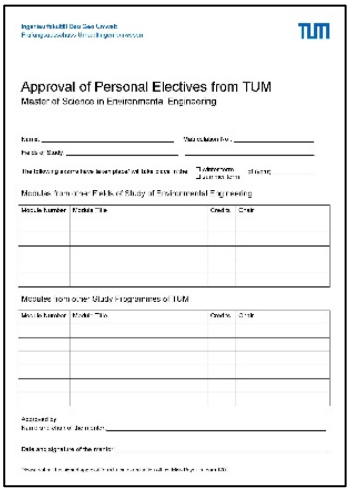
The approval of the modules is a subject to discussion between mentor and student.

Identifying a mentor

All approved examiners of the Department of Civil Geo and Environmental Engineering (professors, assistants and senior researchers) can become mentors. The students should choose a mentor from a chair that co-ordinates or has major involvement in one of their chosen Fields of Study.

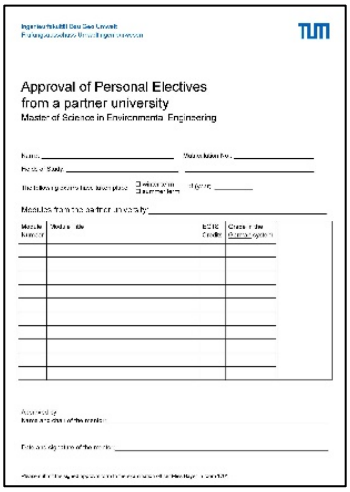
Procedure and deadlines

In order to assign modules to the personal elective catalogue, students must fill in an approval form, get a men-tor’s signature and **submit the signed form to the examination officer Miss Bayer**. The are two separate approval forms available under **www.bgu.tum.de/umwelt → Downloads** - one for modules from TUM and one for modules from a foreign university.


Approval of Personal Electives from TUM
Master of Science in Environmental Engineering

Modules from other Fields of Study of Environmental Engineering

Modules from other Study Programmes of TUM


Approval of Personal Electives
from a partner university
Master of Science in Environmental Engineering

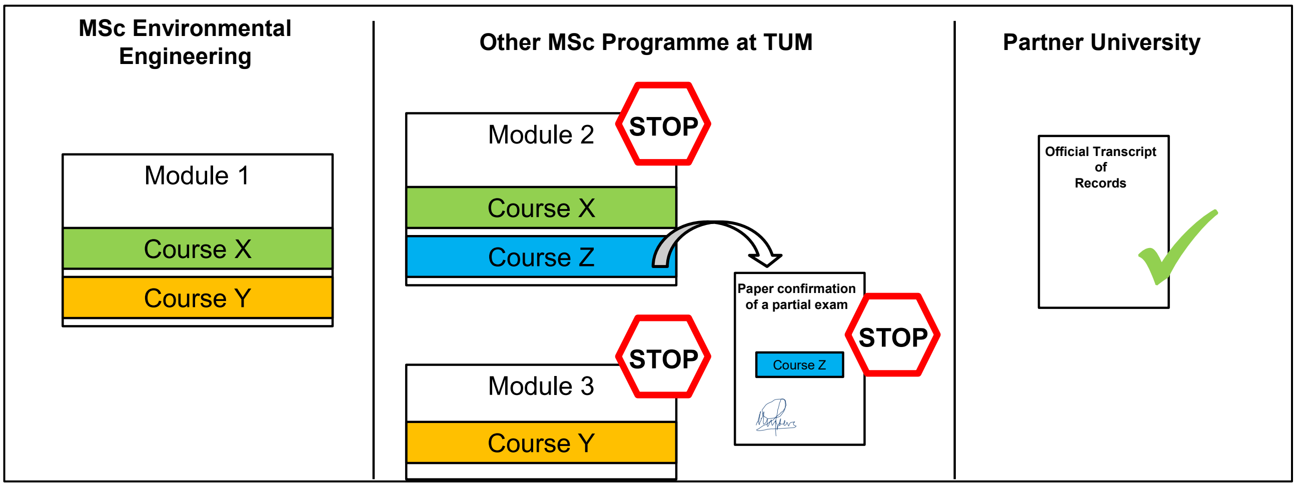
We advise students to get their mentor’s approval on their personal electives as early as possible in each semester in order to have the certainty that the modules qualify. **It is recommended to submit the approval form immediately after passing the exams.** Later submissions will be accepted. However, if the individual elective catalogue stays empty for too long, it can lead to a conflict with the study progress control.

Overlapping courses, partial exams and paper certificates

Single courses that are part of the Environmental Engineering programme might be included in modules of other study programmes in various combinations. In such cases only the modules of the Environmental Engineering programme are eligible for the personal electives. **Modules of other study programmes containing or consisting of parts of Environmental Engineering modules cannot be assigned to the personal electives.**

Do not submit paper confirmations of passed exams. **Only official exams that that exist in TUMonline** and for which you can officially register can be processed.

For the recognition of **modules form partner universities**, please use only the **official transcript of records** issued after you complete your stay abroad.



10.2 Guidelines for the study project

Goal and nature of the study project

Students of the Master's programme in Environmental Engineering must accomplish a study project within their studies. Main goal of the study project is to help students to gather experience on applied environmental engineering. This can be as part of a research project, practical work or a distinct task carried out in cooperation with a supervisor. Three basic requirements must be fulfilled:

- a clear contribution to the student's qualification as an environmental engineer
- a thematic relation to the student's specific academic profile
- the use of practical engineering tools and methods

The workload of the project must reflect the credit requirements. Depending on the study regulations of each student, credits and workload are:

For students who began their studies after the winter semester 16/17: 12 Credits, 360 workload hours

For students who began their studies before the summer semester 2016: 15 Credits, 450 workload hours

Students and supervisors are kindly asked to consider the workload requirements in advance.

Duration and Deadlines

The duration for the study project limited to six months, though the workload is not of six months in full time. Earlier deadlines can be arranged with the supervisor. Only the workload requirements must be fulfilled.

In order to complete their studies in two years, students must conclude the study project the latest in their third semester. A later submission is possible, however the after the end of the fifth semester the credits from the study project are necessary to keep up with the minimum progress control.

Supervision

In most cases the study project is carried out at the Department of Civil Geo and Environmental Engineering as part of a research project or an academic topic at one of the department's chairs. It is supervised by scientific personnel and graded by an approved examiner of the respective chair. However, it can be also carried out externally in cooperation with a private company, a public authority or a partner university - an academic supervisor from Department of Civil Geo and Environmental Engineering is in any case mandatory.

Examination form

The students have to compose a written report on their project and submit it to their supervisor. After the completion of the project, the students must give a short presentation (20 min) of their project to their supervisor and examiner. The weighting of report and presentation in the overall grade are:

- project report: 80%
- presentation: 20%

The brief structure of the project report is proposed as following:

1. Introduction

A brief overview of the project's scope and its relevance to environmental engineering

2. Description of the Project

In cooperation with which institution (university chair, company, public authority,…) was the project carried out? Description of the overall goal of the work; what specific work was undertaken and what methods, tools or technologies were used. In research driven projects a presentation of the state of the art can be included in this part.

3. Presentation and Discussion of the Results

Description and analysis of the project's results

4. Conclusions and Learning Outcome

Professional or technical conclusions drawn from the project's results. Description of the student's personal impulses for his/her further development as an Environmental Engineer.

Registration and grade submission

Study projects get registered over the BGU portal.