

VISION ON SUSTAINABILITY

**A REVIEW AND STRATEGY
as of 2021**

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by

GreenTU Delft



Preface

Building on the foundational work *GreenTU Delft's Vision on Sustainability: A Review and Strategy 2020-'30*, the current report aims to draw a vision to achieve the targets set by TU Delft and those set by GreenTU. These goals include contributing to the SDGs through education and research, as well as building a campus which is circular and carbon neutral by 2030.

This report focuses on four main portfolios which are sustainability in education, research, operations, and social engagement. For each of these areas, an overview of different facets is provided according to how these are found to be in the current environment. This work is based on a quantitative research depending on the availability of data, as well as on interviews, literature review, and experiences of the authors and other stakeholders of the university.

The coronavirus pandemic, which reached the Netherlands at the start of 2020, continued throughout the 2020-2021 academic year. This sudden change had and still has significant effect on the students and staff of TU Delft. The university operations have seen a dramatic shift, which has also affected the possibilities for social engagement. Luckily, hard work has allowed for almost all education to continue to full capacity through online methods. However, there have been outspoken concerns about the effects this mode of education and living has on student well-being and later performance. From the point of view of sustainability, interesting to point out is the decrease in consumption observed for TU Delft, although one must imagine that this has come at the cost of increased consumption from home offices.

The creation of this report in the present environment has been challenging. Although extensive, it is limited by the knowledge held by the GreenTU community and the communicative barriers the pandemic has brought with it, coupled with the time constraints inherent to an academic year. Any questions or remarks regarding this report's content can be directed towards GreenTU@tudelft.nl.

This report is the direct product of the dedication of the 2020-2021 GreenTU research committee. Ashwin, Gayathri, Onsi, Sai Suprabhath, and Sujith have each shaped this report into the work it is now. I am grateful for their insight and commitment. The contributions of the wider GreenTU

community have also been crucial. The three other GreenTU committees have contributed, as well as every active GreenTeam and all members of the board. I would be remiss not to mention the support of Andy van den Dobbelen and Deirdre van Gameren in the creation of this report through the sustainable TU Delft project. Finally, the repeated cooperation of Gilbert de Nijs and Cedric Ruts from the Campus & Real Estate department has been crucial in our understanding of energy at TU Delft and for the improvement of the carbon footprint model described in this report.

Thomas Arblaster

Secretary

GreenTU Delft Board 2020-2021

Executive summary

This report builds on the *GreenTU Delft's Vision on Sustainability: A Review and Strategy 2020-'30* by focusing on the developments of the 2020-2021 academic year. For each of the four pillars of TU Delft's vision for sustainability, an overview is provided of the state of affairs at the university, the contributions of GreenTU to this pillar are detailed, and the vision of the 2020-2021 GreenTU student board is presented.

Background information

GreenTU is a student-lead organisation that acts as an advisory organ for organisations and managements across the university and its student body. Its focus is to engage with and inform on sustainability and campus development.

In order to contextualise sustainability at TU Delft, it is important to point out the increase in centrally coordinated contributions to sustainability that have occurred over the past year. With each year, GreenTU has grown and, at the time of writing, there are active GreenTeams at seven of TU Delft's eight faculties. The GreenTU community also includes four committees, which work to further GreenTU's mission in a variety of ways.

Across faculties and departments, the amount of staff members connected to each other through their efforts towards sustainability has also increased, thanks to the sustainable TU Delft project. This wide-reaching project was started by Andy van den Dobbelsteen, who was appointed as sustainability coordinator in 2021.

Education

This report focused on the educational programmes TU Delft offers at bachelor and master level, including thematic minors. Several of these programmes are partially or fully geared towards education for sustainability, notably including the master programmes Industrial Ecology, Environmental Engineering, and Sustainable Energy Technology, and master specialisation tracks such as Sustainable Air Transport, Materials for Sustainable Development, Urbanism, and Water Management. Many of the thematic minors TU Delft offers

place a strong focus on sustainability, particularly those which are offered through the regional Leiden-Delft-Erasmus network of universities.

GreenTU's vision for education includes that all students are aware of, and can engage with, the engineering problems associated with sustainability as this relates to their field of study. This includes attaining a basic grammar concerning sustainability and social issues, enabling these future engineers to collaborate in interdisciplinary environments. To enable a transition towards such education within the current framework at education at TU Delft, GreenTU developed the Green Thread Initiative in collaboration with Lijst Bèta, a party on the university's central student council. Pilots at the faculties of AS and CEG demonstrated that existing courses can be adapted to feature sustainability in a practical context without increasing the workload of students following the course or the lecturers teach it.

In addition to this centrally-coordinated project, GreenTeams have made education for sustainability more accessible to students by highlighting various master electives and minor choices at the faculties of AE and 3mE. Course adjustments are also being pursued at the faculties of 3mE, ABE, AE, and TPM following a dynamic similar to that of the Green Thread, without being directly connected to this initiative.

Research

Alongside education, research is TU Delft's main activity. Sustainability is a central topic in many research activities, enabled through structures such as the four TU Delft research initiatives, the LDE Centre for Sustainability, on-campus technological demonstrations at the Green Village, and the newly-launched Climate Action Programme.

To further improve research for sustainability, a key factor identified is clear and accessible communication between departments on active fields of research. The interdisciplinary nature of sustainability combined with the hierarchical structure of research departments has resulted in researchers between faculties who are related by topic being unable to identify each other. An inventory listing researchers contributing to sustainability is expected to be an effective measure to this end.

Operations

TU Delft's activities are enabled by a wide range of operations, from the construction and maintenance of its campus buildings to the management of its energy grid, procurement, and waste streams. Ambitious goals have been set

to reduce the environmental impact of these operations and to improve the contribution the campus makes to ecological and human health. This is being achieved through a variety of initiatives, all of which now fall under the sustainable TU Delft project.

Topics addressed can be divided along the areas energy & buildings, mobility, waste, and food, all of which GreenTU contributes to in some way. In the 2020-2021 academic year, GreenTU's primary projects included the organisation of pilots to encourage students and staff to forego flying when travelling abroad. To this end, a map of European destinations was generated to be used as policy tool. With contributions of the GreenTeams and the projects committee, progress has also been made to improve waste separation and the environmental impact procuring audio-visual equipment.

Social engagement

The ongoing transitions and those to come require an engaged and resilient campus community. GreenTU is one of many organisations across TU Delft which inform and activate students on topics adjacent to sustainability and sustainable development.

GreenTU's activities on social engagement are diverse, including (online) lunch lectures, symposiums, and career days. Particularly since the pandemic, online platforms have become a significant element of GreenTU's engagement strategy, including social media, the GreenTU website, and a podcast. GreenTeams also provide such contributions, geared towards the students of their own faculty.

GreenTU's vision extends outside of the 'sustainability bubble' of those with a prior interest in sustainability. A primary project realising this is a sustainability label, which incentivises student organisations to reduce the environmental impact of their activities.

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I

Introductions & background information

Welcome

This report was written in the academic year 2020-2021 as an update to *GreenTU Delft's Vision on Sustainability: A Review and Strategy 2020-'30*, which was written in the year prior. The aim of both reports is to give an overview of the contributions of TU Delft towards sustainable development. The present report places a focus on how GreenTU is performing its function as central sustainability hub for the university, as well as what the vision of GreenTU is for the coming years.

1.1. Methodology

This report is based on literature research of the published documents and on data provided by experts in TU Delft. Statements are referenced where possible, with published works being included in the bibliography and web-pages referenced being included as a footnote. Many statements also come from the perspective and experience of the GreenTU community itself, which will be introduced in depth in chapter 2. This community comprises bachelor and master students from all of TU Delft's faculties, who hold diverse perspectives, but a shared commitment towards sustainability.

GreenTU Delft has collaborated with TU Delft Campus & Real Estate (CRE), most notably Gilbert de Nijs and Cedric Ruts, in obtaining an understanding the energy production and consumption on campus and related data. These were used for the energy model presented in chapter 32.

The development of GreenTU Delft's vision on sustainability in all of education, research, operations and social engagement is partially built on the standards developed by the recognized sustainability assessment system STARS. The Sustainability Tracking, Assessment & Rating System (STARS) defines itself as “a voluntary, self-reporting framework for helping colleges and universities track and measure their sustainability progress” [12].

1.2. Report structure

This first part of the report, the introduction, will introduce several important facets of sustainability at TU Delft. First, GreenTU Delft (generally referred to simply as ‘GreenTU’) will be introduced, followed by an overview of relevant ambitions. Finally, the wider organisation around the sustainable TU Delft project is elaborated on. Once these introductions have been made, this report is structured along the four pillars of GreenTU’s vision. In part II, the implementation of sustainability goals in education is tackled, followed by research in part III, campus operations in part III, and social engagement in part V.

In each of these parts, the current contributions of TU Delft towards sustainability and climate action are listed. The penultimate chapter of each part is dedicated to recent accomplishments and projects of GreenTU, while the last chapter goes into detail on GreenTU’s vision for that pillar.

Finally, this report is concluded in part VI. Several appendices are included as well, notably one to expand on the model described in chapter 32.

GreenTU Delft

In 2014, the initiative arose to start a TU Delft sustainability community (SusCom), which Studium Generale TU Delft (SG) facilitated. The goal of this student-lead community would be to bring together all existing initiatives and organisations which dedicated themselves to sustainability, thereby facilitating cooperation and broadening the scope of sustainability at TU Delft through university funding. The SusCom was received well and to improve its functioning, it was expanded into the Delft Green Office the following academic year.

In July 2019, the Green Office was renamed to GreenTU, which was accompanied by a redefining of its responsibilities. The main topics were (1) assisting and advising students, study associations, student societies, faculties, and managements on the topic of sustainability and (2) engaging and informing students and staff members on the topics of sustainability and campus development.

Today, GreenTU still operates as an umbrella organisation for sustainability organisations, but is also dedicated to the above two responsibilities. This is made possible through the GreenTU community, which includes four committees and seven GreenTeams.

2.1. Committees

The GreenTU board is supported by four committees: projects, events, career, and research. These committees are made up of student volunteers who contribute to realising GreenTU's ambitions for a sustainable campus. Detailed information is provided in the "GreenTU's accomplishments and projects" sections spread throughout this report.

The operations coordinator within the GreenTU board has a wide range of projects they are invested in. The projects committee contributes by working out a selected number of topics in more detail and collaborating with the involved staff members or organisations. This way, they are able to provide in-depth student input on a variety of projects.

The events committee supports the board function of communication and events. This includes contributing to the organisation of a variety of events, as are detailed across various sections of chapter 39. Additionally, the committee plays an important role in managing the online presence of GreenTU across social media platforms. This includes creating original content along one of several themes, such as highlighting (student) initiatives which further sustainability.

The career committee was founded in the 2020-2021 academic year and has spent that time trying to realise three core values: inspiration, awareness, and motivation. They strive to inspire TU Delft students to want to pursue a career in sustainability, to motivate them to actually do so, and to raise awareness about the increasing number of opportunities in a large variety of sectors to work according to the core values of sustainability. They do this through a variety of events, from lunch lectures, to workshops, to career days.

The writing of the annual sustainability report – this report – is coordinated by the research committee, who work with the secretary of the board. This is done with the goal to bridge the gaps in communication which naturally occur with an organisation as large and diverse in scope as TU Delft. The state of affairs on a university-level is gathered and presented, including a focus on the progress and ambitions of GreenTU.

2.2. GreenTeams

The renaming of the Green Office to GreenTU in 2019 also coincided with the creation of the role of GreenTeams coordinator. Student teams focusing on the improvement of sustainability at their faculty were already active at 3mE and ABE (respectively Green-mE and BKGreen), with the ambition of the GreenTeams coordinator being to set up similar teams at some of the remaining six faculties. This was a success, with five new teams being set up in rapid succession.

By the end of the 2019-2020 academic year, GreenTeams of five faculties had written an inventory reports which detailed the state of affairs in terms of sustainability across the four pillars [1, 2, 7, 9, 11]. Green-mE had previously written a report focusing on education [4].

In the 2020-2021 academic year, almost all GreenTeams were continued, with a new one being set up at IDE¹, which also wrote an inventory report [3].

¹This means there is a GreenTeam active at every faculty, with the exception of EEMCS. Although there was a GreenTeam active here in the 2019-2020 academic year, it does not have successors at the time of writing.

These teams contribute to their faculties in a variety of ways, as will become clear in the “GreenTeam accomplishments and projects” subsections spread throughout this report.

United Nations' Sustainable Development Goals

Adopted by the UN in 2015, the Sustainable Development Goals (SDGs) aim to inspire global action towards sustainability across different domains. The 17 SDGs also form the backbone for TU Delft's vision on sustainability. The call for action is structured at three levels: global action, local action, and people action. As an educational and research institute, TU Delft has a great potential to contribute to action at the local and people level. Of the 17 SDGs, 10 of them are identified to be relevant to TU Delft's activities. These are: (i) Good health and wellbeing, (ii) Quality Education , (iii) Gender equality, (iv) Clean water and sanitation, (v) Affordable and clean energy, (vi) Industry, innovation and infrastructure, (vii) Sustainable cities and communities, (viii) Responsible consumption and production, (ix) Climate action and (x) Partnerships for the goals.



Figure 3.1: The UN Sustainable Development goals

The TU Delft strategic framework 2018-2024 is drafted with the SDGs as cornerstone. With world class education programmes at all levels (bachelors, masters and continued education), TU Delft is already contributing to moulding future engineers who can work towards sustainability. In terms of operations, TU Delft is committed to making the campus circular and energy neutral by 2030. With its world-class facilities and research personnel, TU Delft is also making strides in research that is socially responsible. The institute hopes to connect ongoing research systematically to societal challenges and make them more visible to the world. To this end, cooperation with the social sciences and humanities both on and off campus is of immense importance. TU Delft's activities and vision with respect to the implementation of SDGs can be understood through the 4 pillars of sustainability: education, research, operations, and social engagement. This report is an effort at summarising the work done so far along these themes, proposed frameworks in the near future and long-term vision.

Coordinating sustainability at TU Delft

Before heading any deeper into the report, it is good to take a moment to look at the wider structure concerning sustainability at TU Delft. Besides GreenTU having a coordinating role (primarily) among student groups and initiatives, Andy van den Dobbelsteen was appointed as sustainability coordinator in January 2021¹. In doing so, he succeeds Gerrit Kahlman, who retired in November 2020. The activities of the sustainability coordinator are focused on improving the sustainability of TU Delft's operations, but also branch out to some extent to the other pillars.

Figure 4.1 illustrates how this structure has placed itself in relation to TU Delft's various faculties (bottom left; coloured petals) and service departments (top right; grey petals). One overlapping organisation is of course GreenTU, which is illustrated as overlapping over the faculties.

Smaller petals within this structure indicate the theme teams. These teams – sometimes already active in some form before the setting up of this wider structure – meet to discuss and develop a specific topic. These teams are primarily geared towards community (four teams: governance, social engagement, communication, and reporting) and operations (seven teams: Eco-Campus, energy system, construction & renovation, mobility, food & beverage, procurement & waste management, and ICT, AI, & data management).

Finally, a core team, comprising of representatives from several faculties and service departments, is placed centrally. This team updates each other on the progress of the theme teams and discusses the overarching topics related to the mission of sustainability.

The expansion and centralisation of the type of sustainability-related initiatives as illustrated in figure 4.1 has already produced considerable results since January 2021. Most notable is the upcoming *Vision and action plan*

¹See: <https://www.tudelft.nl/en/2021/tu-delft/andy%2Dvan%2Dden%2Ddobbelsteen%2Dappointed%2Dsustainability%2Dcoordinator> [cited 6 June 2021]

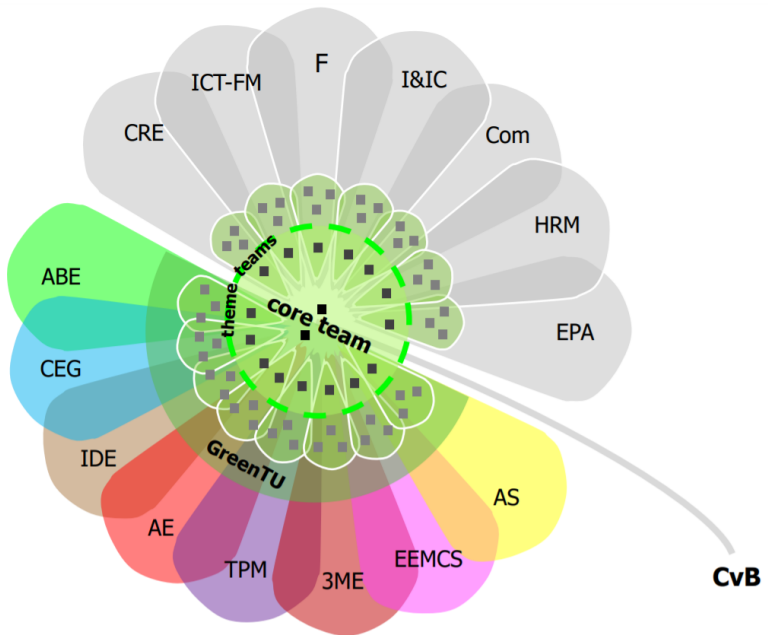


Figure 4.1: Diagram of the organisational structure of the sustainable TU Delft project [14]

submitted to the executive board in early 2022 for approval [14]. This report centres around the topics treated by theme teams. For each topic, proposals are provided according to the general aims and principles and what projects, pilots, and actions are already in existence. These are backed up by sketching a desired future situation and by providing an overview of the situation at present – in a way, similar to this report.

II

Education

Introduction to education

The main activity of TU Delft as university is the creation and transfer of knowledge. Yearly, more than 26,000 students study at TU Delft, under the guidance of more than 6,000 TU Delft employees. Through its various courses, TU Delft can put students on the path to applying sustainable development in a wide range of fields.

This part of the report will look at six types of education offered at TU Delft: bachelor (BSc) programmes¹, minor programmes (specifically thematic minors)², master (MSc) programmes³, master annotations, honour programmes (Honours Programme Delft, or HPD), and online courses (including Massive Open Online Courses, or MOOCs). Arguably, Joint Interdisciplinary Projects (JIPs) would be part of this part too, but the choice has been made to include these under research, in part III, where they can be found in section 20.4.

Due to the setup of GreenTU, the community holds a lot of knowledge on BSc- and MSc-level education. Because of this, only the six types of education listed previously are treated here. Education which does not fall un-

¹The core of bachelor programmes at TU Delft generally offers a broad introduction to relevant fields of engineering sciences in the first year, which is build upon in the following years. It is typical for students to only have a few choices available to them within the programme, which is otherwise standardised to offer a broad foundation for further study.

²All bachelor students at TU Delft are required to complete 30 ECTS through some type of minor. Within the guidelines there is space for students to follow (part of) their minor at another Dutch university or even abroad. The form of the minor can be free, composed by the student themselves, or pre-composed with a certain goal in mind. Pre-composed minors at TU Delft are designed with students from certain bachelor programmes in mind and provide students with a curriculum surrounding a certain theme. This report will only deal with thematic minors organised by TU Delft. See: <https://www.tudelft.nl/en/student/education/minor/minors-for-tu-delft-students> [cited 4 July 2021]

³TU Delft master students have many ways of customising their degree programme. Besides the core courses, many master programmes also make students choose a specific specialisation track, which might even be further divided into profiles. In addition to track and profile courses, students also have elective courses, which are free to choose within degree-dependent restrictions. All of these lead up to an extensive thesis. Many programmes also allow or require the pursuit of an internship relevant to the area the student studies. The flexibility in how to set up a degree programme – from courses, to thesis topic, to internship – means all students are already able to integrate sustainability in their master education to some extent.

der the online education chapter and caters completely or primarily to PhD candidates (such as the doctoral education organised through the Graduate School) or other professionals (typically characterised as “post-academic” education) is not treated in this report, as these are too distantly connected from the GreenTU vision to treat holistically.

The vast majority of education at TU Delft is coordinated on a faculty level. Each faculty has a director of education, who is in close contact with bachelor and master programme directors. Choices on the precise content of courses for a significant portion also resides with the individual lecturers. Therefore, bachelor and master programmes will be treated per faculty. Minor programmes will also be discussed in the chapter of the coordinating faculty. Master annotations, Honours Programme Delft, and online learning will be treated separately, from a more university-wide perspective.

In the chapters that follow, ongoing projects and GreenTU’s vision for education at TU Delft are discussed. This vision calls for sustainability to be rooted in all existing programmes, providing all students with the basic grammar necessary to consider sustainability aspects of their fields. Simultaneously, students should be provided robust, attractive, and relevant opportunities to explore sustainability further and to eventually become a sustainability expert, to varying capacities, in their continued studies. Education for sustainability is here understood as providing students with the methods, tools, and way of thinking needed to solve (field-specific) sustainability problems.

Faculty of Aerospace Engineering

The Faculty of Aerospace Engineering (AE) houses expertise in a wide range of fields which allow for the application of light-weight and durable systems such as aircraft, spacecraft, satellites, and wind turbines. Interesting to note is that its bachelor programme is one of the few at TU Delft to be offered completely in English, resulting in a comparatively international student body.

6.1. Bachelor programme

The **Aerospace Engineering** bachelor programme aims to teach the engineering sciences and interdisciplinary skills required to work on innovation in sectors such as aviation, spaceflight, and wind energy. Typical to the programme are both highly theoretical courses and a focus on group projects.

Sustainable aviation is an important characteristic of the faculty¹, which is also presented as a core aspect of the bachelor programme². Particularly the capstone project, known as the Design-Synthesis Exercise (DSE) puts a strong focus on innovation and sustainability. Students' consideration of sustainability weighs significantly on the evaluation. Projects are novel systems such as a hydrogen-powered blended-wing-body aircraft or an airborne wind energy system to power anything from TU Delft to a martian habitat.

However, the faculty's GreenTeam reports that, besides this capstone project, sustainability is lacking in the curriculum [1]. A focus is placed on efficiency and performance. A well-performing design of course correlates with a sustainable one, but should not be the only consideration. Other aspects of sustainable aviation, such as alternative fuels, noise, and end-of-life solutions are not brought to students' attention in lecture halls. It is also the case that there are no bachelor courses which explicitly focus on wind energy.

¹See: <https://www.tudelft.nl/en/ae/sustainable-aviation> [cited 20 May 2021]

²See: <https://www.tudelft.nl/en/ae/education/bsc-aerospace-engineering> [cited 20 May 2021]

6.2. Minor programmes

The minors coordinated by the Faculty of Aerospace Engineering coordinates two minors. Each of these minors make an explicit effort to discuss sustainability.

Airport Development³ is organised in collaboration with the faculties of IDE, CEG, and TPM. To study and design for the complex, competitive environment of the airport, students are instructed in several areas, one of which is the environmental effects associated with airports, such as noise pollution. Students are invited to investigate how to balance economic, social, and environmental interests.

Offshore Wind Energy⁴ is organised in collaboration with the faculties of CEG and TPM. It goes into depth on the installation, maintenance, and future of offshore wind. Not only the technical and financial aspects are examined, but also the policy perspective. Topics specifically geared towards sustainability include the study of energy systems and the life-cycle assessment of turbines [1].

6.3. Master programmes

There are two masters hosted by the Faculty of Aerospace Engineering: Aerospace Engineering and European Wind Energy.

The **European Wind Energy Master (EWEM)** is offered jointly with Danish university DTU, Norwegian university NTNU, and the German University of Oldenburg. Three of the master's four tracks have students spending at least one semester at a TU Delft faculty:

- Rotor Design (AE)
- Offshore Engineering (3mE)
- Electrical Power Systems (EEMCS)

EWEM has a focus on (offshore) wind energy and its logistics, politics, history, and future. Students are challenged to consider the intricacies of the energy transition and what the requirements are for innovation⁵.

³See: <https://www.tudelft.nl/en/ae/education/minors/airport-development-minor> [cited 20 June 2021]

⁴See: <https://www.tudelft.nl/en/ae/education/minors/offshore-wind-energy-minor> [cited 20 June 2021]

⁵See: <https://www.tudelft.nl/ewem/about/programme> [cited 20 June 2020]

The **Aerospace Engineering**⁶ master programme is divided into five tracks, each with a very distinct character. These are:

- Aerodynamics and Wind Energy
- Aerospace Structures and Materials
- Control and Operations
- Flight Performance and Propulsion
- Space Flight

The Space Flight track has been identified as the only track in which sustainability does not have a noticeable place in the core courses [1]. In the other tracks, sustainability is featured primarily as a function of fuel efficiency, in terms of considerations such as alternative fuels, and of course in the integration of renewable energy (from wind) [1]. Additionally, it is interesting to point out that, within Control and Operations, there is the Sustainable Air Transport profile⁷, which focuses on noise, air quality and climate effects, while looking at ways of integrating related measures with interests of cost, resilience, and safety.

⁶See: <https://www.tudelft.nl/onderwijs/opleidingen/masters/ae/msc-aerospace-engineering> [cited 20 June 2021]

⁷See: <https://www.tudelft.nl/onderwijs/opleidingen/masters/ae/msc-aerospace-engineering/master-tracks/control-operations/programme/profile-sat> [cited 20 June 2021]

Faculty of Applied Sciences

The Faculty of Applied Sciences (AS) is perhaps the broadest TU Delft faculty in terms of subject area. Research areas range from nanobiology, to chemical engineering, to various fields of applied physics, but also science education and communication.

7.1. Bachelor programmes

The Faculty of Applied Sciences is the only faculty at TU Delft to have four distinct bachelor programmes.

In the **Applied Physics**¹ programme, students acquire in-depth knowledge of physical phenomena. The areas of physics are diverse, including thermodynamics, fluid mechanics, quantum mechanics, electromagnetism, and optics. These topics are selected based on their applications in technology. There are of course many systems in which such knowledge of physics is required to come to the most sustainable solution. Students generally come into contact with sustainability in the first-year project courses TN1003: ‘Design Engineering for Physicists’ and TN1101: ‘Technology Management’ [11]. Sustainability is part of the course objectives for TN1003, while in TN1101 the relevance of sustainability depends on the case the student groups work on. However, outside of these projects, students are generally not informed about sustainability [11].

Life Science & Technology² applies the study of how cells work to what technological applications cells can contribute to. Based on a student survey, this is the AS bachelor which currently pays the most attention to sustainability [11]. This can most clearly be seen in the first-year project course LB2611: ‘Design of a Sustainable Biotechnology Process’, in which students design a production plant with sustainability in mind [11].

¹See: <https://www.tudelft.nl/en/education/programmes/bachelors/tn/bachelor-of-applied-physics> [cited 20 June 2021]

²See: <https://www.tudelft.nl/en/onderwijs/opleidingen/bachelors/life-science-technology/bsc-life-science-technology> [cited 20 June 2021]

The bachelor programme **Molecular Science & Technology**³ is coordinated jointly with Leiden University. Molecular science is a broad field, and students are able to specialise their knowledge in synthesis, materials, or technology. The curriculum has many courses which are adjacent to sustainability, although a direct link is not always made [11]. Students typically follow two courses where sustainability does play a major role: one dependant on their major choice of synthesis, materials, or technology, and also the second-year course 4052ENRV6: 'Energy, Recycling and Safety' [11].

Nanobiology⁴ is the only bachelor programme at AS to be taught entirely in English and is organised in cooperation with the Erasmus School of Medicine of Erasmus University Rotterdam. The programme combines fields of medical research with physics and biology. Investigation indicates that sustainability as a topic is generally not treated in this programme. It comes up in the theoretical courses NB1140: 'Physics 1a' and NB2141: 'Physics 2' [11], with since this academic year sustainability also being a topic treated during the scientific writing course NB1052: 'Journal Club 1', thanks to Green-Team AS.

7.2. Minor programmes

The Faculty of Applied Sciences is the host of four minor programmes. None of these programmes have a particular focus on environmental sustainability.

In the minor programmes **Modern Physics**⁵ and **Quantum Science and Quantum Information**⁶, students are taught physics on a level which exceeds their regular bachelor programme. These minors focus on the underlying mathematics and physical theories needed to come to an understanding of their potential for technological innovation.

The **Education**⁷ minor allows students to gain experience and the qualifications to teach a course of their choice in certain levels of secondary education. Quality education is important for sustainable development, which

³See: <https://www.tudelft.nl/en/education/programmes/bachelors/mst/bsc-molecular-science-technology> [cited 20 June 2021]

⁴See: <https://www.tudelft.nl/en/education/programmes/bachelors/nb/bsc-nanobiology> [cited 20 June 2021]

⁵See: <https://www.tudelft.nl/en/faculty-of-applied-sciences/education/minors-and-electives/modern-physics> [cited 27 June 2021]

⁶See: <https://www.tudelft.nl/en/faculty-of-applied-sciences/education/minors-and-electives/quantum-science-and-quantum-information> [cited 27 June 2021]

⁷See: <https://www.tudelft.nl/tnw/studeren/minoren-en-keuzevakken/educatie-1> [cited 27 June 2021]

is reflected in SDG 4.

Communication Design for Innovation⁸ lets students unlock the further potential of the science and engineering skills they have acquired. With the goal of being able to connect between engineers, the public, the media, politicians and businesses, students will be introduced to strategic communication. Innovation, and the required communication associated, is of course vital to sustainable development.

7.3. Master programmes

At the Faculty of Applied Sciences organises six master programmes. The area of interest of four of these can be matched to that of the four bachelor programmes of the faculty, with these programmes building further on the concepts taught there.

The **Applied Physics**⁹ master programme is designed to educate students to be able to stay at the forefront of fundamental understanding, and to develop practical applications. The programme is divided into five tracks:

- Physics for Energy
- Physics for Fluids Engineering
- Physics for Health and Life
- Physics for Instrumentation
- Physics for Quantum Devices and Quantum Computing

The Physics for Energy track deals with solar cells, nuclear reactor physics, and many other concepts relevant for the energy transition. A link to climate science can also be made in the tracks Physics for Fluids Engineering and Physics for Instrumentation.

The world needs products like foods, cosmetics and electronic equipment, and this requires a production of chemicals from various resources as well as to have good storage and waste management. A lot of these have scope to implement sustainable aspects to the already existing ways in which

⁸See: <https://www.tudelft.nl/en/faculty-of-applied-sciences/education/minors-and-electives/template-minors> [cited 27 June 2021]

⁹See: <https://www.tudelft.nl/onderwijs/opleidingen/masters/ap/msc-applied-physics/applied-physics-programme> [cited 29 June 2021]

the production lines work. In the first year of **Chemical Engineering**¹⁰, students from all tracks also go through a design module, which students treat engineering problems from industry. Sustainability is a significant aspect of this, as is reflected in the course CH3804: 'Product & Process Design'. Additionally, a link to sustainability is made in the track courses CH3043A: 'Process Dynamics & Control' and CH3053: 'Applied Transport Phenomena'.

Life Science & Technology¹¹ works on unlocking the secrets of the cell and understanding its mechanisms. The three specialisations within the Life Science & Technology master programme are Biocatalysis, Biochemical Engineering, and Cell Factory. All three of these fields interact with sustainability, but particularly the curriculum of Biochemical Engineering is geared towards sustainability, which is also connected with the Environmental Biotechnology research group. The elective LM3311: 'Green Chemistry and Sustainable Technology' is open to all specialisations.

The master programme **Nanobiology**¹² studies the nanoscale complexities of life, with a primary focus on its implications for medicine. As such, it of course relates to the SDGs through the topic of health, but environmental sustainability does not appear as a theme within the core elements of this programme. However, students are to some extent able to integrate sustainability into their degree programme through electives, internship, and thesis topic.

The Faculty of Applied Sciences also organises the programme **Science Education and Communication**. The programme has two very distinct tracks. In Science Education¹³, students are trained to be a certified secondary school teacher in maths, physics, chemistry, informatics, and designing. This prepares students for the Dutch school system. The other track is Communication Design for Innovation¹⁴, which bridges the gaps within and between the world of science and technology with broader society. Fields of science communication investigated include science journalism, high-tech market-

¹⁰See: <https://www.tudelft.nl/en/education/programmes/masters/chemical-engineering/msc-chemical-engineering> [cited 29 June 2021]

¹¹See: <https://www.tudelft.nl/en/education/programmes/masters/life-science-technology/msc-life-science-technology> [cited 29 June 2021]

¹²See: <https://www.tudelft.nl/en/education/programmes/masters/nanobiology/msc-nanobiology> [cited 29 June 2021]

¹³See: <https://www.tudelft.nl/onderwijs/opleidingen/masters/sec/msc-science-education-and-communication/lerarenopleiding-science-education-track> [cited 29 June 2021]

¹⁴See: <https://www.tudelft.nl/en/education/programmes/masters/science-education-and-communication/msc-science-education-and-communication/communication-design-for-innovation-track> [cited 29 June 2021]

ing, psychology, and sociology of collaboration. Both of these tracks have a focus on innovation, meaning sustainability is discussed as well, and they each further sustainable development in different ways. Sustainability challenges are interdisciplinary ones, meaning good science communication is required, while at the same time, providing high-quality secondary school education contributes to a sustainable world, as illustrated in SDG 4.

Finally, there is the master programme **BioMedical Engineering**, which is co-hosted with the Faculty of Electrical Engineering, Mathematics & Computer Science and the Faculty of Mechanical, Maritime and Materials Engineering. Since this latter faculty is the main organiser, this programme will be discussed in section 12.3.

Faculty of Architecture and the Built Environment

The Faculty of Architecture and the Built Environment (ABE) integrates sustainability in its education in many ways. Examples include circularity in buildings, designing climate change resistant buildings, and designing spaces which promote well-being and safety.

8.1. Bachelor programme

The Faculty of Architecture and the Built Environment offers one bachelor programme: **Architecture, Urbanism and Building Sciences**¹. As is typical for TU Delft undergraduates, students receive a hands-on education in a broad range of fields, but with a particular focus on the technical.

From the beginning, students are taught to approach architectural problems holistically. It can be argued that this is TU Delft's bachelor programme with the most robust integration of environmental sustainability [14]. This can be seen in several courses, both technical and applied, which centre around sustainability and the role that energy, water, and materials play in buildings. In the final assignment of the programme, BK6ON6: 'Design 6 Building and Technology', students are required to design a sustainable, energy-neutral building.

8.2. Minor programmes

The ABE faculty offers eight thematic minors, all of which are taught in English. The minor space in the Architecture, Urbanism and Building Sciences slightly deviates from how most other faculties approach it, in that it isn't unusual for students to fill half of this space with an internship worth 15 ECTS, leaving the remaining 15 ECTS for a smaller minor programme. First, four such comparatively shorter minors are examined.

¹See: <https://www.tudelft.nl/en/architecture-and-the-built-environment/study/bachelors-degree-programme> [cited 2 July 2021]

Architecture Presentation - Visions Reviewed² centres around (visual) communication techniques and how to convey a story. The medium ranges from posters to videos. Environmental sustainability is not an explicit part of the programme.

The **Cities, Migration & Socio-Spatial Inequality**³ minor grapples with the topics of spacial segregation and the consequences thereof. Equality and justice are extremely significant for sustainable development, so in this sense, this minor definitely contributes to sustainability.

In the **Spatial Computing in Architectural Design**⁴ minor programme, students deepen their insight into the mathematics, spatial algorithmic design, and simulations in the context of architectural design. Such skills are vital to increasing the performance efficiency of buildings, thereby furthering sustainability. This relationship is explicitly brought up during the minor, but does not appear to be reflected in its learning goals.

Sustainable Urbanism - The Green-Blue City⁵ is centred around adapting cities to the climate crisis, but touches on multiple SDGs besides climate action. The content of the minor has a significant overlap with the bachelor programme of ABE, and as such is not open to its students.

Furthermore, there are three minor programmes for which ABE students are able to take either both quarters of courses or one of the two (this arrangement does not apply for students from any other faculty). The **Archineering**⁶ minor programme is a very hands-on approach to materialisation, i.e. bringing a design to life as a scale model or a 1:1 prototype. Climate design and sustainability are important themes within this minor, if not at the very centre of the curriculum.

Heritage & Design⁷ does appear to make any explicit link to environmen-

²See: <https://www.tudelft.nl/en/architecture-and-the-built-environment/study/minors-and-electives/architecture-presentation-visions-reviewed> [cited 2 July 2021]

³See: <https://www.tudelft.nl/en/architecture-and-the-built-environment/study/minors-and-electives/cities-migration-socio-spatial-inequality> [cited 2 July 2021]

⁴See: <https://www.tudelft.nl/en/architecture-and-the-built-environment/study/minors-and-electives/spatial-computing-in-architectural-design> [cited 2 July 2021]

⁵See: <https://www.tudelft.nl/en/architecture-and-the-built-environment/study/minors-and-electives/sustainable-urbanism-the-green-blue-city> [cited 2 July 2021]

⁶See: <https://www.tudelft.nl/en/architecture-and-the-built-environment/study/minors-and-electives/archineering> [cited 2 July 2021]

⁷See: <https://www.tudelft.nl/en/architecture-and-the-built-environment/study/minors-and-electives/heritage-design> [cited 2 July 2021]

tal sustainability. However, the core values of the minor – the preservation of sites of historical significance in a modern setting – is relevant for social sustainability.

In **Spaces of Display**⁸, students dive into exhibition design. By acquiring new skills in aesthetics and interior design, students are to communicate the significance of a particular artefact. Environmental sustainability does not addressed.

Finally, the only ABE minor which can only be completed as a full semester of 30 ECTS is **House of the Future**⁹. In this minor, students contemplate the effects that our changing culture, ecology, climate, and technology have on housing design. Among the topics treated are durability and energy consumption, but the focus is primarily placed on skills such as design exploration and communication.

8.3. Master programmes

The Faculty of Architecture and the Built Environment offers several master programmes, the largest of which is **Architecture, Urbanism and Building Sciences**¹⁰. This programme has five tracks:

- Architecture
- Building Technology
- Landscape Architecture
- Management in the Built Environment
- Urbanism

When completing the tracks Architecture, Landscape Architecture, or Urbanism, students are on track to being able to claim the protected title of Architect, Landscape Architect or Urban Designer from the Dutch Register of Architects. In the tracks Building Technology, Landscape Architecture, and Urbanism, nature, environmental sustainability, and sustainable development are all present and – to different degrees – driving factors within the

⁸See: <https://www.tudelft.nl/en/architecture-and-the-built-environment/study/minors-and-electives/spaces-of-display> [cited 2 July 2021]

⁹See: <https://www.tudelft.nl/en/architecture-and-the-built-environment/study/minors-and-electives/house-of-the-future> [cited 2 July 2021]

¹⁰See: <https://www.tudelft.nl/en/education/programmes/masters/architecture-urbanism-and-building-sciences/msc-architecture-urbanism-and-building-sciences> [cited 2 July 2021]

curricula. This is less the case in Architecture, where a student's focus depends what electives and graduation studio they choose. Many of these do place a focus on sustainability, but this is not universal. Finally, Management in the Built Environment does not place any particular focus on sustainable development.

The interdisciplinary master programme **Metropolitan Analysis, Design and Engineering**¹¹ is offered in cooperation with Wageningen University & Research. Sustainable development and environmental sustainability are the foundation of this programme.

Another inter-university programme which ABE contributes to is **Geographical Information Management and Applications**¹², this time as part of the 4TU network of Dutch universities of technology. Remarkable about the programme is its blended learning approach, where students have very few contact hours. The topics treated can be applied to aspects of sustainability, such as the placement of rooftop solar panels, the spatial planning of nature, and other topics of urban sustainability. This means that students can have an extremely sustainability-oriented degree programme, depending on the projects they choose to investigate.

In many ways, the programme **Geomatics**¹³ is comparable to GIMA, introduced above. However, Geomatics is of course not hosted by four universities, but only TU Delft, and does not have the same blended learning approach. Additionally, Geomatics also includes a focus on data gathering techniques. Similarly to GIMA, Geomatics students are able to apply the tools and knowledge they acquire to sustainability challenges, which come up regularly in the curriculum.

¹¹See: <https://www.tudelft.nl/en/education/programmes/masters/made/msc-metropolitan-analysis-design-and-engineering> [cited 2 July 2021]

¹²See: <https://www.msc-gima.nl/> [cited 2 July 2021]

¹³See: <https://www.tudelft.nl/en/education/programmes/masters/geomatics/msc-geomatics> [cited 2 July 2021]

Faculty of Civil Engineering and Geosciences

The Faculty of Civil Engineering and Geosciences (CEG) deals with a variety of disciplines in which knowledge of the Earth is essential. As can be intuited from the faculty's name, the educational programmes of CEG are largely divided between either civil engineering or applied earth sciences.

9.1. Bachelor programmes

The Faculty of Civil Engineering and Geosciences offers two bachelor programmes. Civil Engineering (working language Dutch) and Applied Earth Sciences (working language English). Both of these fields have a significant overlap with areas of sustainable development, which is reflected in the curricula to various extents.

In the **Civil Engineering** (CE) bachelor programme, students are taught about the foundational concepts of a range of infrastructural elements. With a changing climate, challenges in civil engineering also change, something the faculty tries to reflect in the curriculum¹.

Sustainability is an explicit part of the programme in courses such as CTB1320-17: 'Construction Materials and Sustainability' and CTB2320-17: 'Design of Structures and Foundations 2' [2]. Here, how to consider sustainability and the environment is taught alongside material science and how to approach construction, respectively.

Applied Earth Sciences (AES) at TU Delft focuses on the geological and engineering sciences needed to identify, work with, and exploit all subterranean materials of interest. This includes the mining of minerals and the extraction of petroleum. From the start of the programme, in AESB1242: 'Grand Challenges and Applied Earth Sciences', students are taught about

¹See: <https://www.tudelft.nl/en/education/programmes/bachelors/ct/bachelor-of-civil-engineering> [cited 30 June 2021]

how to mitigate the destruction of these industries and to become competent applied earth sciences engineers. In this course, the UN SDGs form an explicit basis for understanding the challenges of this field. Sustainability is also integrated in later stages of the curriculum, notably including the final field project [2].

9.2. Minor programmes

The CEG faculty is the primary coordinator of eight thematic minors and hosts an additional two together with Leiden University and Erasmus University Rotterdam (LDE – where the D of course stands for TU Delft)².

These two LDE minors both centre around sustainable development. These are **African Dynamics**³ and **Geo-resources for the Future**⁴. In addition to the engineering typical of a TU Delft minor, these minors place dive into the social, economic, and political factors at play.

The CEG faculty hosts the minor **Climate Change, Adaptation and Mitigation**⁵, which is centred around engineering solutions to the evolving impacts and causes of climate change. Additionally, concepts of recycling materials and circularity are core to the minors **Environmental Engineering and Sustainable Design**⁶ and **Bend and Break**⁷.

Minors in which sustainability is explicitly mentioned, but not the main focus of the minor, are **Delta Expert, Water for the Future**⁸, **Integrated Infrastructure Design**⁹, and the Dutch language minors **Transport, Infrastructuur en Logistiek**¹⁰ and **Research Project Applied Earth Sciences**¹¹. Finally,

²See: <https://www.tudelft.nl/en/education/programmes/minor/thematic-minor-overview> [cited 30 June 2021]

³See: <https://www.tudelft.nl/en/ceg/education/minors/african-dynamics-lde> [cited 30 June 2021]

⁴See: <https://www.tudelft.nl/en/ceg/education/minors/geo-resources-for-the-future> [cited 30 June 2021]

⁵See: <https://www.tudelft.nl/en/ceg/education/minors/climate-change-adaptation-and-mitigation> [cited 30 June 2021]

⁶See: <https://www.tudelft.nl/en/ceg/education/minors/environmental-engineering> [cited 30 June 2021]

⁷See: <https://www.tudelft.nl/en/ceg/education/minors/bend-and-break> [cited 30 June 2021]

⁸See: <https://www.tudelft.nl/en/ceg/education/minors/delta-expert-water-for-the-future> [cited 30 June 2021]

⁹See: <https://www.tudelft.nl/en/ceg/education/minors/integrated-infrastructure-design> [cited 30 June 2021]

¹⁰See: <https://www.tudelft.nl/citg/onderwijs/minors/transport-infrastructuur-en-logistiek> [cited 30 June 2021]

¹¹See: <https://www.tudelft.nl/citg/onderwijs/minors/research-project-applied-earth-sciences>

the CEG minor **Project Management: from Nano to Mega**¹² does not appear to feature sustainability to any considerable extent.

9.3. Master programmes

The Faculty of Civil Engineering and Geosciences is involved in five master programmes. It is the sole organiser of the programmes **Civil Engineering**¹³ and **Applied Earth Sciences**¹⁴. Civil Engineering is divided along eight tracks, while Applied Earth Sciences has six. However, it is also the case that there is an overlap in possible specialisations between these two masters, e.g. Geo-Engineering can be chosen from either degree programme. It is also the case that the Applied Earth Sciences programme is currently being restructured: from the 2022-2023 academic year, it will have different tracks, as well as the track Environmental Engineering becoming a separate programme.

Speaking on these two expansive programmes as they currently are, it is the case that sustainability is integrated in a number of courses [2]. Interesting to point out are the tracks Water Management and Environmental Engineering, where sustainability is deeply embedded in the goals of the tracks [2].

Besides these two expansive programmes, the CEG faculty also co-coordinates three interdisciplinary masters. These are organised together with one or two additional TU Delft faculties to provide a comprehensive programme.

Together with the Faculty of Architecture & the Built Environment and the Faculty of Technology, Policy and Management, CEG organises **Construction Management and Engineering**¹⁵. In the core curriculum of this programme, sustainability can only clearly be recognised in the ethics module. However, within the recommended electives, sustainability is a significant topic, both as a goal in itself or through a function of renewable energy or ecological materials.

The **Offshore & Dredging Engineering**¹⁶ programme is organised together with the Faculty of Mechanical, Maritime and Materials Engineering. The

d-earth-sciences [cited 30 June 2021]

¹²See: <https://www.tudelft.nl/en/ceg/education/minors/project-management-from-nano-to-mega> [cited 30 June 2021]

¹³See: <https://www.tudelft.nl/en/education/programmes/masters/civil-engineering/msc-civil-engineering> [cited 30 June 2021]

¹⁴See: <https://www.tudelft.nl/en/education/programmes/masters/applied-earth-sciences/msc-applied-earth-sciences> [cited 30 June 2021]

¹⁵See: <https://www.tudelft.nl/en/education/programmes/masters/construction-management-and-engineering/msc-construction-management-and-engineering> [cited 30 June 2021]

¹⁶See: <https://www.tudelft.nl/en/education/programmes/masters/offshore-dredging-engineering/msc-offshore-dredging-engineering> [cited 30 June 2021]

possibilities of dredging and offshore engineering are still being explored, with an area of note of course being offshore wind energy. This field is can be explored here in the track Offshore Renewable Energy, but such installations also come up many of the other tracks.

The interdisciplinary master **Transport, Infrastructure and Logistics**¹⁷ is organised in cooperation with the Faculty of Mechanical, Maritime and Materials Engineering and the Faculty of Technology, Policy and Management. It does not appear that sustainability is an explicit aim in this programme, other than when it relates to environmental regulations. Rather, the goal lies with designing and controlling efficient transportation networks and supply chains.

¹⁷See: <https://www.tudelft.nl/en/education/programmes/masters/transport-infrastructure-and-logistics/msc-transport-infrastructure-and-logistics> [cited 30 June 2021]

Faculty of Electrical Engineering, Mathematics & Computer Science

The Faculty of Electrical Engineering, Mathematics & Computer Science (EEMCS) is one of the biggest faculty at TU Delft and its buildings is one of the most iconic on campus. From a survey of EEMCS students conducted by GreenTeam-EEMCS, over 80% of respondents believed that their faculty should do much more to contribute to sustainability [7].

10.1. Bachelor programmes

EEMCS holds three bachelor programmes, each focused on a distinct field within the faculty's expertise. Since 2018, there is no longer a Dutch requirement on the Computer Science and Engineering bachelor programme, resulting in a strong internationalisation. The other two bachelor programmes, Electrical Engineering and Applied Mathematics, are still (partially) in Dutch.

Electrical Engineering¹ is a broad field with a wide range of applications, both in scale and purpose. In the second-year introductory course to power systems, EE2E21: 'Sustainable Energy Supply', sustainability plays an outspoken role. This is currently the only course in the programme which includes such a focus, but several other courses are relevant for applications of sustainability as well [7].

The bachelor programme **Applied Mathematics**² is not only characterised by advanced mathematical theories, but also in what its practical applications are. Developing mathematical models to better understand real-world situations is a core aspect of the curriculum. This has already been applied

¹See: <https://www.tudelft.nl/en/education/programmes/bachelors/ee/bsc-electrical-engineering> [cited 4 July 2021]

²See: <https://www.tudelft.nl/en/education/programmes/bachelors/tw/bachelor-of-applied-mathematics> [cited 4 July 2021]

in, for example, topics of environmental science, letting students experience the significance they can have in sustainable development [7].

The **Computer Science and Engineering**³ bachelor programme focuses on teaching students the necessary mathematics and knowledge about algorithms to become good computer scientists. The courses in the programme definitely has a bearing on sustainability but a direct link to the sustainability was missing in these courses [7].

10.2. Minor programmes

Typical to the thematic minors hosted by the EEMCS faculty is a strong focus on theory and science. While for many minors, understanding social impacts is part of the learning goals, this is not the case for EEMCS minors, which rather focus on technology itself.

Of the seven minors hosted at EEMCS, one focuses directly on sustainability, but again from a predominantly technological perspective. This is the minor **Electrical Sustainable Energy Systems**⁴. The other six minors are **Computational Science and Engineering**⁵, **Computer Science**⁶, **Electronics for Robotics**⁷, **Engineering with AI**⁸, **Finance**⁹, and **Physics for Electronics**¹⁰. These do not have any explicit link with sustainability in the programme, although the related fields of course do contribute to sustainable development in various capacities.

10.3. Master programmes

The EEMCS faculty organises several master programmes. The majority of these fall somewhere on a range relating to electrical engineering and computer science engineering. Figure 10.1 illustrates where the four master pro-

³See: <https://www.tudelft.nl/en/education/programmes/bachelors/cse/bachelor-of-computer-science-and-engineering> [cited 4 July 2021]

⁴See: <https://www.tudelft.nl/en/eemcs/study/minors/electrical-sustainable-energy-systems> [cited 4 July 2021]

⁵See: <https://www.tudelft.nl/en/eemcs/study/minors/computational-science-and-engineering> [cited 4 July 2021]

⁶See: <https://www.tudelft.nl/en/eemcs/study/minors/computer-science> [cited 4 July 2021]

⁷See: <https://www.tudelft.nl/en/eemcs/study/minors/electronics-for-robotics> [cited 4 July 2021]

⁸See: <https://www.tudelft.nl/en/eemcs/study/minors/engineering-with-ai> [cited 4 July 2021]

⁹See: <https://www.tudelft.nl/en/eemcs/study/minors/finance> [cited 4 July 2021]

¹⁰See: <https://www.tudelft.nl/en/eemcs/study/minors/physics-for-electronics> [cited 4 July 2021]

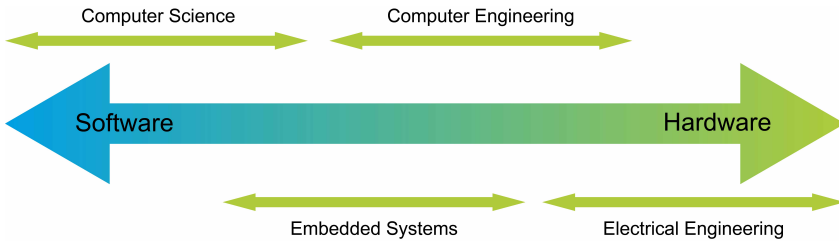


Figure 10.1: Illustration of how four of the master programmes at EEMCS differ in terms of their relation to their teaching of hardware- and software-related topics.

grammes **Computer Science**¹¹, **Embedded Systems**¹², **Computer Engineering**¹³, and **Electrical Engineering**¹⁴ fall on this range.

Each of these four fields is of great significance to the energy transition and innovation for sustainability (such as can be offered through Industry 4.0), but how and to what degree students are able to reflect this in their curriculum varies. Generally, students must consciously compose their programme to include electives and a thesis topic on sustainability if they want to deepen their knowledge in these areas; the pre-defined specialisations generally do not include sustainability. An interesting exception to point out is that, in the Electrical Engineering programme, the Electrical Power Engineering track includes the profile Solar Energy.

The **Applied Mathematics**¹⁵ programme is in a similar situation as these previous four. Its areas are closely linked to efforts towards sustainability, but students in the programme's tracks focus on the strictly technical and theoretical aspects.

The master programme **Sustainable Energy Technology**¹⁶ focuses on a wide array of aspects of the energy transition and sustainable energy. Op-

¹¹See: <https://www.tudelft.nl/en/education/programmes/masters/computer-science/msc-computer-science> [cited 4 July 2021]

¹²See: <https://www.tudelft.nl/en/education/programmes/masters/embedded-systems/msc-embedded-systems> [cited 4 July 2021]

¹³See: <https://www.tudelft.nl/en/education/programmes/masters/computer-engineering/msc-computer-engineering> [cited 4 July 2021]

¹⁴See: <https://www.tudelft.nl/en/education/programmes/masters/electrical-engineering/msc-electrical-engineering> [cited 4 July 2021]

¹⁵See: <https://www.tudelft.nl/en/education/programmes/masters/applied-mathematics/msc-applied-mathematics> [cited 4 July 2021]

¹⁶See: <https://www.tudelft.nl/en/education/programmes/masters/sustainable-energy-technology/msc-sustainable-energy-technology> [cited 4 July 2021]

tional specialisations not only include the generation of energy, but also its storage, and aspects of economic and societal impact. Although this master programme is organised by EEMCS, the specialities in which students can graduate are almost as broad as to cover each of TU Delft's faculties. Only the Faculty of Industrial Design Engineering is not associated with any of Sustainable Energy Technology's specialisations.

Additionally, EEMCS is involved in several master programmes which are collaborative efforts with other organisers. As mentioned in section 6.3, the **European Wind Energy Master** also has a track partially hosted by EEMCS, namely Electrical Power Systems. The other master programmes currently do not have any courses specifically related to sustainability. Finally, **BioMedical Engineering** is a master programme coordinated primarily by the Faculty of Mechanical, Maritime and Materials Engineering. As such, it will be elaborated on in section 12.3.

Faculty of Industrial Design Engineering

The Faculty of Industrial Design Engineering (IDE) is concerned with design engineering sciences. With the motto “Design for our Future”, the faculty indicating an explicit attention to sustainability. This is reflected in the faculty’s research and education in various ways.

11.1. Bachelor programme

The IDE faculty has one bachelor programme, **Industrial Design Engineering**¹. This programme is a special case in the context of this report, as it has undergone a renewal process which will first be implemented in the 2021-2022 academic year [3]. For the purpose of this report, both programmes will be treated with some detail.

The bachelor programme at present already pays some attention to sustainability. A primary example of this are the first- and second-year courses IO1070: ‘Engineering for Design’ and IO2070: ‘Design for Sustainability’ [3]. Sustainability is also integrated well into the bachelor capstone project. A final course relevant to mention is an elective for IDE bachelor students, IO3075: ‘Towards Circular Product Design’. It should be noted that a student survey [3] concluded that the mandatory elements of sustainability offered in the current programme are not sufficient to allow for students to confidently consider sustainability in their design choices.

In the programme starting in 2021-2022, a stronger focus will be put on being able to consider and integrate complex problems before, after, and throughout the design process. Additionally, systems thinking and ethics will become more important parts of the programme, as will working with data, professional development, and interaction design [3]. Analogues to the above-mentioned courses will be present, while sustainability is integrated

¹See: <https://www.tudelft.nl/en/ide/education/bsc-industrial-design-engineering> [cited 7 July 2021]

further into the curriculum with the course ‘Understanding Product Engineering’ and the project course ‘Design Project 3’ [3].

11.2. Minor programmes

There are five thematic minors coordinated by the Faculty of Industrial Design Engineering, all of which are taught in English. Several of these minors make some link to sustainability, but only one can be argued to place a focus on sustainability [3].

The **Designing Sustainable Transitions**² minor programme examines both environmental and social sustainability. Goals such as enacting social change and imagining sustainability through different perspectives play important roles. Students are also taught to think critically about designing for sustainability and the methods and considerations they use.

Within the minor programme **People in Transit**³, the future of mobility is explored, with a focus on automotive technology. The minor presumes that the mobility of the future will be electric, but does not appear to include any learning goals relating to sustainability [3].

Advanced Prototyping⁴ does not appear to make any link with sustainability, but on knowledge and skills needed for prototyping itself. Sustainability also does not play a significant role in the minors **Connected Creativity**⁵ or **Interactive Environments**⁶. However, students are encouraged to reflect on the potential applications the knowledge and skills they acquire can have, including those relating to ecological and social responsibility.

11.3. Master programmes

The Faculty of Industrial Design Engineering coordinates three master programmes, which all approach design from a different entry point. Additionally, five master electives from the IDE faculty have been identified as relating closely to sustainability [3]. These relate to a range of topics influencing sus-

²See: <https://www.tudelft.nl/en/ide/education/minors/designing-sustainability-transitions> [cited 7 July 2021]

³See: <https://www.tudelft.nl/en/ide/education/minors/people-in-transit> [cited 7 July 2021]

⁴See: <https://www.tudelft.nl/en/ide/education/minors/advanced-prototyping> [cited 7 July 2021]

⁵See: <https://www.tudelft.nl/en/ide/education/minors/connected-creativity> [cited 7 July 2021]

⁶See: <https://www.tudelft.nl/en/ide/education/minors/interactive-environments> [cited 7 July 2021]

tainability, from business models to (product) design strategies for sustainability.

The master programme **Design for Interaction**⁷ looks at design from a user perspective, looking at factors such as user motivation, behaviour, and experience. At present, none of the core courses of the programme relate to sustainability [3].

Integrated Product Design⁸ approaches design from the challenges involved with creating a product. A successful product must tick several boxes, one of which is its role in societal challenges. In this programme, sustainability is a core theme for the courses ID4185: 'Strategic & Sustainable Design' and ID4175: 'Advanced Embodiment Design', while it is also a topic integrated into ID4170: 'Advanced Concept Design' [3]. This programme is listed as a circular economy master programme within the Leiden-Delft-Erasmus Centre for Sustainability⁹

In the **Strategic Product Design**¹⁰ programme, the market aspects of design are at the forefront. Here, the only course identified in which sustainability is integrated is ID4355: 'SPD Research' [3]. This is a project-based courses, in which students have the possibility to work around a topic focused on sustainability. However, it has been indicated that the amount of options focusing on this topic is not enough for every student that is interested [3].

⁷See: <https://www.tudelft.nl/en/education/programmes/masters/design-for-interaction/msc-design-for-interaction> [cited 7 July 2021]

⁸See: <https://www.tudelft.nl/en/io/studeren/masteropleidingen/msc-integrated-product-design> [cited 7 July 2021]

⁹See: <https://www.centre-for-sustainability.nl/education/circular-economy-masters-programmes> [cited 7 July 2021]

¹⁰See: <https://www.tudelft.nl/en/io/studeren/masteropleidingen/msc-strategic-product-design> [cited 7 July 2021]

12

Faculty of Mechanical, Maritime and Materials Engineering

The Faculty of Mechanical, Maritime and Materials Engineering (3mE) hosts a wide range of fields relating to these three branches of engineering. By student population, it is the largest faculty of TU Delft, hosting about 20% of all students. This is mostly due to the high concentration of students in the field of mechanical engineering.

12.1. Bachelor programmes

There are three bachelor programmes at 3mE, the working language for all of which is Dutch. By far the largest of these three is Mechanical Engineering, also making it TU Delft's largest bachelor programme in terms of enrolled students. Next is Clinical Technology, this is a joint degree between TU Delft, Leiden University, and Erasmus University Rotterdam. The third programme is Marine Technology.

Mechanical Engineering is a broad field – it is present in most engineering problems typically imagined. Coming up with sustainable solutions to such engineering challenges is a stated goal of the programme¹. Sustainability is a returning topic in project courses in particular. On top of that, GreenmE – TU Delft's first GreenTeam – provides students with instructions and methods to improve the sustainability of their designs during the first-year project courses WB1642: 'Design Engineering Project 2' and WB1643A: 'Design Engineering Project 3A'². Social responsibility is also a part of the third-year curriculum, where sustainability is of course included [4].

¹See: <https://www.tudelft.nl/en/education/programmes/bachelors/wb/bsc-mechanical-engineering> [cited 1 July 2021]

²See: <https://project.3me.tudelft.nl/Duurzaam-ontwerpen/green-me/en/> [cited 1 July 2021]

Technology is ubiquitous in today's hospitals. **Clinical Technology** students are able to bridge the gap between those with a strictly medical or technical background³. As such, healthcare is central to this programme, which is a topic on-par with (if not more important than) climate for the UN SDGs. In terms of environmental sustainability, this is a growing subject area within clinical technology, but does not play a significant role in this programme at the moment. The programme is co-organised with two medical faculties through the Leiden-Delft-Erasmus network.

The **Marine Technology** bachelor programme is focused on all types of structures built for aquatic use, but has a particular focus on the design, manufacturing, and use of ships⁴. A good example of how sustainability is integrated into the programme can be found in the second-year group-based project course 'MT2434: Second Integration Project'. In this course, students are to design a ship, while taking into account its climate effects, safety, and other ethical considerations.

12.2. Minor programmes

Of the three minors for which 3mE is the primary coordinator, **Engineering for Large-scale Energy Conversion and Storage (ELECS)**⁵ places sustainability front and centre. Here, a major challenge of the energy transition is treated, namely, the storage of energy to bridge the gap between periods of peak production (when renewable sources experience favourable conditions) and peak consumption (when industry/households need the most energy).

It does not appear that the faculty's other two minors, **Biomedical Engineering**⁶ and **Robotics**⁷, place a particular focus on sustainability.

12.3. Master programmes

The Faculty of Mechanical, Maritime and Materials Engineering organises many master programmes and is involved as co-host in several more. A num-

³See: <https://www.tudelft.nl/en/education/programmes/bachelors/kt/bachelor-of-clinical-technology> [cited 1 July 2021]

⁴See: <https://www.tudelft.nl/en/education/programmes/bachelors/mt/bsc-marine-technology> [cited 1 July 2021]

⁵See: <https://www.tudelft.nl/en/3me/education/minors-and-electives/engineering-for-large-scale-energy-conversion-and-storage-elecs> [cited 1 July 2021]

⁶See: <https://www.tudelft.nl/en/3me/education/minors-and-electives/biomedical-engineering> [cited 1 July 2021]

⁷See: <https://www.tudelft.nl/en/3me/education/minors-and-electives/robotics> [cited 1 July 2021]

ber of these are closely connected to sustainability. The programme most heavily geared towards sustainability is **Materials Science & Engineering**⁸. This is one of the circular economy master programmes of the Leiden-Delft-Erasmus Centre of Sustainability⁹. One of the possible focuses of the programme, depending on where students' interests lie, is in the use of material science for circularity. For example, students must choose a specialisation, one of which is Materials for Sustainable Development.

In the remaining master programmes of 3mE, sustainability can be sought out by interested students, but does not appear to be an integrated part of the curriculum. For example, it is also optional for students in the Marine Technology programme to deepen themselves in aspects of sustainability relevant to ships or offshore wind energy¹⁰. The situation is similar for **Systems & Control**¹¹, **Technical Medicine**¹², and **Robotics**¹³.

The inter-faculty masters **Offshore & Dredging Engineering** and **Transport, Infrastructure and Logistics**, for which 3mE is not the only organising faculty, were previously discussed in section 9.3. 3mE is also involved in the **European Wind Energy Master**, previously discussed in section 6.3, for which they co-host the track Offshore Engineering.

BioMedical Engineering¹⁴ is another inter-faculty master, not discussed in detail so far yet, as 3mE is the primary host. This programme is hosted together with the Faculty of Applied Sciences and the Faculty of Electrical Engineering, Mathematics and Computer Sciences. The programme is relatively restrictive in the type and amount of electives students choose, when compared to other TU Delft programmes. It appears that the only ways for a student to integrate environmental sustainability into their curriculum is to choose the BM41070 'Medical Device Prototyping' elective and/or to complete a JIP (as will be discussed in section 20.4) or sustainability-oriented internship.

⁸See: <https://www.tudelft.nl/en/education/programmes/masters/materials-science-engineering/msc-materials-science-engineering> [cited 1 July 2021]

⁹See: <https://www.centre-for-sustainability.nl/education/circular-economy-masters-programmes> [cited 1 July 2021]

¹⁰See: <https://www.tudelft.nl/en/education/programmes/masters/marine-technology/msc-marine-technology> [cited 1 July 2021]

¹¹See: <https://www.tudelft.nl/en/education/programmes/masters/systems-control/msc-systems-control> [cited 1 July 2021]

¹²See: <https://www.tudelft.nl/en/education/programmes/masters/technical-medicine/msc-technical-medicine> [cited 1 July 2021]

¹³See: <https://www.tudelft.nl/en/education/programmes/masters/robotics/msc-robotics> [cited 1 July 2021]

¹⁴See: <https://www.tudelft.nl/en/education/programmes/masters/biomedical-engineering/msc-biomedical-engineering> [cited 1 July 2021]

There is also the broad **Mechanical Engineering**¹⁵ master programme, which is divided into six tracks:

1. BioMedical Design
2. Energy, Flow and Process Technology
3. High-Tech Engineering
4. Opto-Mechatronics
5. Multi-Machine Engineering
6. Vehicle Engineering

Of these tracks, sustainability comes forward the most in Energy, Flow and Process Technology (specifically the specialisations Energy Technology and Process Technology), Multi-Machine Engineering, and Vehicle Engineering.

¹⁵See: <https://www.tudelft.nl/en/education/programmes/masters/mechanical-engineering/msc-mechanical-engineering> [cited 1 July 2021]

Faculty of Technology, Policy and Management

The Faculty of Technology, Policy and Management (TPM) has many the largest influence from the humanities and the social sciences when compared to the engineering sciences of other TU Delft faculties. Here, these disciplines come together to understand and improve the complex relationships technology has with societal challenges.

13.1. Bachelor programme

The **Systems Engineering, Policy Analysis and Management** bachelor programme (in Dutch simply called ‘Technische Bestuurskunde’) provides students with a broad range of tools and methods to assess and design systems of decision making and management.

From the research of the TPM GreenTeam [9], a considerable majority of bachelor students does not identify a need to increase the amount of sustainability in courses. Sustainability is already noticeably present in the programme, although opportunities have been identified to increase this further, such as in the bachelor capstone project.

13.2. Minor programmes

The TPM faculty is the main organiser of four thematic minor, while being a co-host for three more minors organised through the Leiden-Delft-Erasmus network. Most of these minors involve sustainable development or engineering with/for social responsibility, but this is generally not in the form of environmental sustainability.

The LDE minors **Frugal Innovation for Sustainable Global Development**¹,

¹See: <https://www.tudelft.nl/en/tpm/education/minors/frugal-innovation-for-sustainable-global-development-lde> [cited 2 July 2021]

Responsible Innovation², and **Security, Safety & Justice**³ are each deeply invested in the UN SDGs. However, environmental sustainability specifically is not a core focus for any of them, rather social sustainability and sustainable development.

This is also the case for the TPM minors **Companies and innovation**⁴ and **International Entrepreneurship & Development**⁵. In both of these minors, ethics and sustainability in the broad sense are of great importance, but environmental sustainability specifically is not.

Finally, the minors **MedTech-Based Entrepreneurship**⁶ and **Technology-Based Entrepreneurship**⁷ do not appear to have any particular association with sustainability. Apart, of course, the former being centred around health-care.

13.3. Master programmes

The TPM faculty is the sole organiser of three master programmes. Additionally, it co-hosts a programme with Leiden University and one with several other TU Delft faculties.

The **Complex Systems Engineering and Management**⁸ master focuses on the factors required for large-scale operations, such as regulations, logistics, and financial incentives. The programme offers three tracks: Energy, Information & Communication, and Transport & Logistics.

The Energy track has a strong focus on sustainable energy and the ongoing energy transition. The other two tracks also have some integration of sustainability, but research indicates this is still lacking for the Transport & Logistics track [9]. For a field with a significant interface with sustainability, this track could include it more in its curriculum.

Engineering and Policy Analysis is a master programme about “the in-

²See: <https://www.tudelft.nl/en/tpm/education/minors/responsible-innovation-1de> [cited 2 July 2021]

³See: <https://www.tudelft.nl/en/tpm/education/minors/security-safety-justice-1d> [cited 2 July 2021]

⁴See: <https://www.tudelft.nl/en/tpm/education/minors/companies-and-innovation> [cited 2 July 2021]

⁵See: <https://www.tudelft.nl/en/tpm/education/minors/international-entrepreneurship-development> [cited 2 July 2021]

⁶See: <https://www.tudelft.nl/en/tpm/education/minors/ondernemerschap-medtech-based-entrepreneurship> [cited 2 July 2021]

⁷See: <https://www.tudelft.nl/en/tpm/education/minors/ondernemerschap-technology-based-entrepreneurship> [cited 2 July 2021]

⁸See: <https://www.tudelft.nl/en/education/programmes/masters/cosem/msc-complex-systems-engineering-and-management> [cited 2 July 2021]

teraction between nature, society and technology”⁹. The programme spends a lot of time on the global challenges faced in terms of water, food, energy, and safety. Students also indicate that, in their lectures, sustainability challenges are the most common example used when discussing theory [9].

The **Management of Technology**¹⁰ programme is centred around the role technology plays in maximising corporate productivity, profitability and competitiveness. Of the programmes so far, its content is the least concerned with sustainability [9]. Based on student feedback, there is a clear lack of sustainability in this programme as a whole – a straightforward yet impactful change would be for the projects and assignments offered to concern sustainability-related topics [9].

Industrial Ecology is the study of societal processes as they interact with sustainability. It is organised in collaboration with Leiden University: each university hosts a quarter of lectures in the first year, after which students spend time at either university primarily based on their choices of specialisation courses¹¹. This master programme focuses on an interdisciplinary approach, covering engineering, environmental science, and social science. Sustainability is at the core of this programme and the methods taught here can offer interest insight to students for whom sustainability is important, but not their primary focus. In this aspect, Industrial Ecology students have indicated valuable principles to be systems thinking and using a life-cycle approach [9].

Finally, the programmes **Transport, Infrastructure and Logistics** and **Construction Management and Engineering** are co-organised by several TU Delft faculties, among which is the TPM faculty. Both of these programme were already explained in section 9.3, in the chapter of another co-organising faculty.

⁹See: <https://www.tudelft.nl/en/education/programmes/masters/engineering-and-policy-analysis/msc-engineering-and-policy-analysis> [cited 24 June 2020]

¹⁰See: <https://www.tudelft.nl/en/education/programmes/masters/mot/mot> [cited 2 July 2021]

¹¹See: <https://www.universiteitleiden.nl/en/education/study%2Dprogrammes/master/industrial%2Decology/about%2Dthe%2Dprogramme/programme%2Dstructure> [cited 27 June 2021]

Master annotations

It is possible for TU Delft master students to apply for an annotation to their degree. This takes the form of a certificate, which accompanies the MSc degree. To qualify for an annotation, the student must complete their thesis in the theme of the annotation, as well as complete a set amount of elective credits within this theme. Which annotations are available to students depends on their master programme, with different faculties awarding different annotations.

The only annotation among these with an explicit focus on sustainable development is the Technology in Sustainable Development (TiSD) annotation¹. This annotation is one of the few annotations open to students from all faculties.

To be attributed this annotation, students must follow the course 'Engineering for Sustainable Development' (WM0939TU) and have their (sustainability-oriented) electives and thesis topic approved by the sustainable development referent of their faculty². Students following a programme with an inherent focus on sustainable development, such as Sustainable Energy Technology or Industrial Ecology, are not eligible, as the requirements are already part of their degree.

However, in the 2019-2020 academic year, the decision was made to discontinue the issuance of annotation certificated. An exception was made for the TiSD annotation, in that students who started their master degree in 2020-2021 were still able to apply for the annotation and complete WM0939TU. Anyone interested in earning this annotation beyond this academic year is unable to do so.

The reasons cited for this discontinuation include a lack of interest from students, that the current structure of master programmes already allows

¹See: <https://www.tudelft.nl/en/tpm/about-the-faculty/departments/values-technology-and-innovation/sections/economics-of-technology-and-innovation/education/annotation-tido> [cited 30 June 2021]

²See: <https://www.tudelft.nl/en/tpm/about-the-faculty/departments/values-technology-and-innovation/sections/economics-of-technology-and-innovation/education/annotation-tido/the-referents> [cited 30 June 2021]

students to specialise according to their interests, and that the amount of effort required by the department of education and student affairs is therefore too large to justify the continuation of annotations [5]. The value such an annotation adds to the MSc degree of a student was also considered to be too small to warrant the required maintenance [5].

In essence, this does not change the ability of students to pursue courses that interest them, with students still receiving the credits and recognition associated with any (approved) courses they take during their degree programme. However, the removal of annotations does remove a motivator to interest students in the sustainability side of their field. This could be the deciding factor between a student choosing to specialise their electives and thesis towards sustainability or not.

Online learning & MOOCs

TU Delft has been offering online education since 2013 to professionals and students alike. The online learning has become more prominent in the face of corona pandemic. With a history of over 175 years of teaching and with four academic fields ranking amongst the top 10 QS ranking, TU Delft is extensive source of diverse academic fields. At present, TU Delft offers Massive Open Online Courses (MOOCs) to over 3 million online learners worldwide, as well as many courses of Professional Education (ProfEd). The flexibility to follow the course anytime anywhere, availability of course material through a web connection, and guidance from experts are some of the benefits of these online courses.

It is estimated that at the moment, TU Delft provides 185 MOOCs and ProfEd courses centred around sustainability. As sustainability encompasses a huge area, these courses cater to renewable energy, energy markets, climate change policy, data analysis, and circularity, to name only a few examples. A list of all the courses provided by TU Delft is enclosed in appendix B.

Honours Programme Delft

Students interested in an academic challenge which exceeds their bachelor or master programme can join Honours Programme Delft (HPD)¹. Generally, the GPA requirement for this is 7.5, but the precise requirements differ per faculty. Completing the additional programme will increase the student's workload by 20 ECTS and results in a certificate being rewarded upon graduation. When comparing HPD for bachelor and master students, there are similarities in the independence given to students in constructing their personal programme, but in terms of goals and possible content, they differ.

16.1. Honours programme bachelor

Bachelor students following an honours programme must obtain 5-6 ECTS from interdisciplinary projects, with the remaining ECTS being obtained at the faculty of their bachelor programme. There are many ways to obtain the interdisciplinary credits required².

The interdisciplinary credits can be obtained in a variety of ways. For example, students can come up with an independent project, join an international programme³, or follow MOOCs (see chapter 15). There are also specific HPD courses offered. At present, these courses fall into three interdisciplinary subject areas for students to investigate, which are:

- Challenge Modern Society
- Develop 21st-Century Skills
- Awareness & Culture

Here, the 'Challenge Modern Society' subject includes some attention to sustainable development, in the form of an international development course

¹See: <https://www.tudelft.nl/en/education/programmes/honours-programme-delft> [cited 30 June 2021]

²See: <https://www.tudelft.nl/en/education/programmes/honours-programme-delft/honours-programme-bachelor/the-interdisciplinary-part> [cited 30 June 2021]

³See: <https://idealeague.org/> [cited 30 June]

(UD1051: 'Global Engineering') and an environmental engineering course (UD1052: 'Can We Cool the Earth'). A central goal for many of the courses, particularly within 'Awareness & Culture' is to stimulate self-reflection and critical thinking. In these ways, these courses can also be seen as education for sustainability, although the environmental aspect is not a guaranteed part of the curriculum.

As far as the faculty-specific aspect of honours programmes is concerned, students are primarily prompted to discover and explore their own area of interest. The form in which they pursue this changes on a faculty basis⁴, but typically involves a (group-based or individual) research project. Sustainability is a significant research topic at all TU Delft faculties, so students interested in sustainability can certainly pursue this. However, it remains to be investigated to what extent this occurs or is stimulated.

16.2. Honours programme master

The master honours programme generally takes a different approach from a bachelor honours programme. Whereas bachelor students are prompted to explore what interests them, master students have already chosen a specialisation and are assumed to know what field(s) interest them. Therefore, master honours students are expected to expand within and beyond their chosen discipline and to apply for society's benefit⁵.

In contrast to the broad interdisciplinary options HPD offers bachelor students, master students must choose between two courses of 5 ECTS, UD2010: 'Critical Reflection on Technology' or UD2012: 'Business Leadership for Engineers'. Sustainability is stated to be a possible topic for both of these courses, with UD2010 having "ethical or societal issues concerning technology" as central theme.

The faculty-specific aspect is in setup very similar to the for bachelor students. However, because of master students' advanced knowledge, their (re-)research projects are expected to be more in-depth. Further options to meet the faculty-specific workload of 15 ECTS include an additional internship or courses outside of the curriculum that student would otherwise receive⁵. All of these options are inviting to sustainability topics, but the initiative and interests of HPD's students guides what projects are undertaken.

⁴See: <https://www.tudelft.nl/en/education/programmes/honours-programme-delft/honours-programme-bachelor/faculty-programmes-contact> [cited 30 June 2021]

⁵See: <https://www.tudelft.nl/en/education/programmes/honours-programme-delft/honours-programme-master> [cited 30 June 2021]

GreenTU's accomplishments and projects in education

Particularly since the conversion from Delft Green Office to GreenTU, education has been one of the priorities of the board. At TU Delft, education is highly decentralised, so a central body such as GreenTU must work closely with individual faculties to make an impact. This makes the faculty-specific GreenTeams a very valuable addition to the GreenTU community.

To implement GreenTU's vision on education, which will be explained in chapter 18, many projects have been initiated over the past two years. In general, the GreenTU board acts as a catalyst here, setting up projects and looking for support from both central and faculty-specific parties, while GreenTeams are able to manage the execution with some independence.

17.1. Stimulating GreenTeams' work on education: the Green Thread

From the research done by GreenTeams in the 2020-2021 academic year, there was a consistent recommendation for the horizontal integration of sustainability in curricula, by making it relevant to the disciplines students are instructed in. At the same time, there are obvious hurdles when trying to update education. The curricula are dense, meaning an effort must be made to make room for any additions, while the workload of staff must of course also be taken into account.

To achieve the desired results while managing these restrictions, Lijst Bèta and GreenTU have developed an initiative based on the value of student participation to empower students, diversify perspectives, and reduce staff workload. The aim of this initiative is to give sustainability an integral place in all educational programmes, thereby making it a common thread between and in curricula. Thus, the initiative has been given the name of Green Thread Initiative.

Realising the Green Thread is done by reinforcing the activity under the educational portfolio of the existing GreenTeams. Complementing the work they previously accomplished, GreenTeams are now working on sustainability in targeted courses by working with academic staff to replace or extend current teaching materials (case studies, project topics, the tools students are provided, ...) with examples and information centred around environmental sustainability. Academic staff members come up with the outline of the changes they want to see, after which one or more student assistants can work on the implementation.

In the second quarter of 2020-2021, a pilot of this plan was started at the AS and CEG faculties, using the budget of GreenTU and the cooperation of the faculties' GreenTeams. This pilot will be evaluated to further improve the Green Thread for implementation across the whole university. To implement this plan on a wider scale, not dependent on GreenTU funding, the idea is to set up faculty-specific funds with approval of their management: lecturers are then encouraged to send in a proposal to the fund, after which the GreenTeam can allocate hours to making it a reality.

Courses at the Faculty of Civil Engineering & Geosciences which have benefited from this initiative so far are:

- **Introduction to Civil Engineering:** This is one of the first courses Civil Engineering bachelor students follow. Sustainability is being integrated in the activities of the first week, where students receive an introduction to sustainability and a workshop where they assess the impact (positive or negative) of different civil structures in Delft. In the following weeks, each lecture is dedicated to an aspect of civil engineering, in which attention will now also be given to how this aspect interacts with sustainability. This way, students are introduced early on to the overarching challenges they will face in their field.
- **Financial Engineering:** This is a core course for students in the Construction Management & Engineering master programme. The current project being undertaken is to introduce practises of sustainable finance and the circular economy into the course. To this end, a literature study is performed on contemporary education of sustainable finance, in which the students assistant is in contact with several other universities.
- **Environmental Engineering:** Currently still a track of the Applied Earth Sciences master programme, Environmental Engineering is currently being redesigned as a standalone master programme. Through the

Green Thread, a student assistant is helps with the forming of this renewed programme based on feedback gathered and practises of similar programmes. The new programme will kick-off in the 2022-2023 academic year, and plans are being made for maintain student involvement. A knowledge pool is also being created as a tool for Environmental Engineering to draw inspiration from, which has already been expanded to include the Civil Engineering track Structural Engineering, and will eventually be expended to include all disciplines present at the CEG faculty.

After the pilot took off at the CEG faculty, the GreenTeam AS was also approached, as education has been their main focus this academic year. Other GreenTeams have and are also contributing to the education of their faculty in a way that alligns with the Green Thread framework, which is elaborated on in subsection 17.2.1.

The successes experienced with the pilots so far can be attributed for a significant part to the enthusiasm of involved staff members and to the qualities and ambitions already present in TU Delft students. Combined with a diligent selection procedure, a good match is made between the desires for the course and the student(s) that will work on it. A detailed evaluation will take place in August 2021. In the meantime, a main requirement for the continuation of this project is continuing to get additional staff members on board as previous projects come to a close. To this end, Dr. Daan Schraever, who is the lecturer of the Financial Engineering course being worked on, was interviewed for *The Educator*, the newsletter of the TU Delft Teaching Academy¹.

17.2. GreenTeam accomplishments and projects

The projects mentioned previously are or were carried out with extensive involvement of the GreenTU board. However, the seven GreenTeams active at the different faculties of TU Delft also contribute to education in various capacities. Some of these initiatives receive the active support of the GreenTU board, while others are executed with relative independence.

¹See: <https://www.tudelft.nl/teachingacademy/newsletters/the-educator-june-2021/sustainability-in-education-will-increase-the-impact-our-students-can-make> [cited 20 July 2021]

17.2.1. Course adjustments

Even without the additional support made possible through the Green Thread pilot as mentioned in section 17.1, GreenTeams have been able to contribute to improving the integration of sustainability at their faculty. This mostly means providing new examples to work with, based on sustainable technologies, or provide some addition or change to project courses.

Green-mE worked together with Patrick van Delft to include sustainability in his bachelor course on oral presentation for mechanical engineering students. In one of his lectures, the students were directed to give a presentation about a technology. The team proposed to change this to a sustainable technology, rather than any technology. The team proposed a list of topics that the students then could choose from and had to give a three minute presentation of. It was considered that this was an excellent opportunity to teach the students that sustainable technology goes beyond the energy transition. Especially since these students are in the beginning of their academic life, so as to inspire them to consider sustainability in the rest of their (academic) career. It was made sure that there was a rich diversity of sustainable technologies. This way, the entire class could come into contact with sustainable technologies when listening to their classmates' presentations.

In order to make it as easy as possible for teachers to incorporate sustainability into their courses, **GreenTeam TPM** is working to develop a number of different teaching cases with sustainable subjects. The first of these cases, on the subject of waste management, is currently in development and more are to come in the future. These cases will contain useful information like recent literature, statistics and a brief stakeholder analysis which can then easily be adapted by a teacher to fit their course, either as a possible subject for a project, as an example in a lecture or in any other way.

GreenTeam AS focused its efforts on education this year and helped in reviewing the course material in two ways. There is the low hanging fruit, for which the GreenTeam could make qualitative suggestions to the professor that could be directly implemented. The real challenge lay in courses that wanted to fundamentally change course material. For this, the Green Thread came in handy, as explained in section 17.1.

From the start of the academic year, **GreenTeam AE** has been working together with the course coordinator of a second-semester project, Design & Construction, which is mandatory for first-year bachelor students. The course was adapted to incorporate sustainability oriented themes and questions. Additionally, an interactive presentation was created and delivered to the students by team members to give the students insight into the various ways to consider sustainability in engineering design. The presentation was

created to be easily adapted and as a template for future incorporation of sustainability themes into other projects carried out during the BSc.

Furthermore, **GreenTeam AE** is assisting professors of various master courses to implement sustainability-related issues or solutions to their lecture material. The first implementation of this approach will be tested in Q1 of the academic year 2021-2022.

The possibility for such changes are also being investigated by **BKGreen**, who will continue preparing the application of the Green Thread in the following academic year. The plan is to work on redesigning the bachelor courses.

17.2.2. Programme evaluations

In Q4 of the 2020-2021 academic year, **Green-mE** sent out a survey to Clinical Technology (CT) students, both bachelor and master. In this survey, the students were asked about sustainability in their daily life and their studies. Especially whether they think the focus on sustainability in their study is enough and what should improve. The results of this survey will be evaluated and used to provide an insight for the curriculum change that is happening at the moment. The team's goal is to integrate it in the year-long courses where CT students learn basic skills and/or approach teachers who are interested in implementing sustainability in their course. A combination of both would be ideal, especially if coordinated from Green-mE to make sure there is little overlap and that the most relevant ideas get integrated in the curriculum. Ideally, a similar survey is sent to the teachers to investigate who the team's stakeholders can be, also for other projects.

Over the same period, **GreenTeam AE** shared a survey for students at various phases of their education to gather opinions on the integration of sustainability in their programmes and what students experience to be lacking. The results are to be compiled by the end of the academic year. If it turns out that the need for sustainability related courses is significant, these results can also be used to convince the board of education that such courses should be offered.

17.2.3. Highlighting sustainable options in education

A project to highlight sustainability-oriented electives was set up to assist students in finding sustainable courses to follow during their MSc program. Since it can be a rather cumbersome task to find courses of your liking, especially when looking across faculties, **GreenTeam AE** decided to make a comprehensive list of courses that could be interesting to MSc students in Aerospace Engineering. This list can also be used in an adapted form for

other faculties. The inventory for this project started in March 2021 and the list is expected to be complete before the end of the academic year 2020-2021. The AE study association VSV 'Leonardo da Vinci' will be asked to help spreading the document, such that as many students as possible will be aware of it.

Green-mE composed and released a document highlighting how students 3mE students can integrate sustainability into their education. Every type of educational programme relevant to 3mE students is covered, including master electives and MOOCs, even including references to some extracurricular resources. This document can be accessed from the Green-mE website².

17.2.4. Graduate school course on sustainability

GreenTeam CEG came up with the project of introducing **new Graduate School courses focused on sustainability**. These courses would be accessible to all Graduate School students of TU Delft. A survey was conducted across all eight faculties to get an idea of the need, opinion, and the current state of such sustainability-focused courses offered by the Graduate Schools. 119 out of the 170 respondents expressed keen interest about following such a course as part of their curriculum.

When asked what form the course should take, the most popular answer was a two-day interactive workshop, focusing on specific topics. Suggestions for topics included how to apply sustainability in their specific research project, or the basics of using the right keywords for a sustainability-focused research paper. The team is collaborating with the research school SENSE to evaluate the existing courses and to come up with one suited better for TU Delft students in the upcoming year.

17.2.5. Inter-faculty elective on social and ecological responsibility: Blue Engineering

For TU Delft's goal of educating socially responsible engineers to be achieved, GreenTU believes there are many skills still lacking in curricula. Therefore, a master elective is being set up in the style of Blue Engineering³, to make students realise the social and ecological responsibilities associated with engineering, as well as to stimulate skills such as perspective-taking, acting morally, and gaining interdisciplinary knowledge.

Blue Engineering was first set up in 2009 at TU Berlin and has since spread

²See: https://project.3me.tudelft.nl/Duurzaam-ontwerpen/green-me/nl/res/0v_erzicht_Duurzaamheid.pdf [cited 18 May 2021]

³See: <http://www.blue-engineering.org/> [cited 12 May 2021]

to several other German universities. One of the founders of the course, André Baier, was invited to present the interactive course structure to the GreenTU and GreenTeam members working on education. The session inspired some participants to follow the course themselves, at TU Berlin, with the idea also emerging to set up such a course at TU Delft. This is being carried out by the **GreenTeams of AE and CEG**, as well as associated staff members. The current plan is to already start offering a comparable course

TU Delft master students generally follow faculty-specific ethics courses, which relate their field to acting morally. Blue Engineering has a more interdisciplinary character, which is made possible by the interaction between participants. Because of these values, the goal is for any master to have this course as part of their study planning.

17.2.6. Guide to sustainable mechanical engineering

In the past years, **Green-mE** has created a guide for students that collects guidelines and explanation of the main technical and engineering tools for a sustainable design⁴. This booklet is used by first-year students for their final design project. Students have to take into account sustainability in their design. To do so, they make use of the Green-mE guide to learn about the tools to assess the sustainability of their design and they apply them to their final project.

This year, the team has worked on making the guide easier to follow and to read. The introduction of the guide, which aims to define what is sustainability and what is the importance of mechanical engineers to accelerate a sustainable transition, was edited and updated. Moreover, the second chapter “How to use this guide” was enriched with graphical sketches to make it easier to read and to follow. Furthermore, the classification of “Design for” and “Assessment for” tools was further clarified.

⁴See: <https://project.3me.tudelft.nl/Duurzaam-ontwerpen/green-me/nl/> [cited 2 June 2021]

GreenTU's vision on education

Besides research, the primary activity of TU Delft is the education of its students. For TU Delft to fulfil its responsibility to educate socially responsible engineers, it is GreenTU's vision that all students their education must provide them with:

1. The same **basic grammar** concerning sustainability and social issues.
2. Possibilities to **explore** sustainability in their academic life.
3. Possibilities to become **experts** on sustainability-related topics.

This vision and the topics discussed in this chapter relate to education in an academic way. However, GreenTU also recognises that students do not only learn through courses, but also through different experiences, such as symposiums, career days, and social events. For the purpose of this report, these are considered under social engagement, meaning they will be treated in part V.

18.1. Basic grammar

This goal aligns with the idea that every student must have a practical basic grammar in sustainability. Since sustainability is a multidisciplinary problem spanning all industries, it is important for students to not only understand how sustainability plays a role within their own discipline, but also how to communicate across disciplines. This includes understanding concepts such as environmental footprints, circularity, and systems theory.

GreenTU is aware of the workload staff faces and that adding one topic to the curriculum often means removing another to safeguard student workload. It is therefore the shared vision of GreenTU and Lijst Bèta to integrate sustainability as a 'green thread' throughout educational programmes, which

is currently being explored through the Green Thread Initiative, which was highlighted in section 17.1.

18.2. Exploration

The goal of exploration can be seen as a prerequisite to the goal of educating experts in sustainability. Giving students opportunities to find their interest and niche in sustainable development would be the logical step to reach this goal.

The most impactful time to let students explore the sustainability-related opportunities in their field is at the bachelor level, before they have chosen a master degree. Here, a notable choice offered is the minor space in the third year. There is currently already a decent number of sustainability-focused minors across all faculties, meaning that GreenTU's goal in this regard is to improve visibility of these options. This includes ensuring the education webpage¹ of the TU Delft sustainability website is maintained and up to date.

18.3. Expertise

The goal to give students the possibility to become experts in sustainability is grounded in the reality that technical experts working on sustainability are much needed. There are certain qualities which distinguish such expertise from other specialisations.

The academic proficiency of most students culminates in the completion of a master programme. TU Delft has several programmes which are centred around sustainability, with several other programmes including sustainability as a main focus in one or several of their tracks, as made clear in the faculty-specific sections of this chapter. Because of this, the importance of visibility – as described in section 18.2 – is also relevant here.

Additionally, the annotations previously facilitate – at least in spirit – in the idea that students following any of the specialisations present at TU Delft can gain value from an increase in sustainability in their curriculum. The being for them to become something of an expert on sustainability with their expertise. As was mentioned in chapter 14, the previous annotation framework is outdated, but it is GreenTU's view that a system of the same spirit, adapted to the present needs and opportunities present, would be a great addition.

GreenTU takes the approach that sustainability experts are needed in all fields and can take many forms, meaning that developing new electives

¹See: <https://www.tudelft.nl/en/sustainability/education> [cited: 12 May 2021]

and tracks is a priority. Combined with a reintroduction of annotations, this would give students a variety of ways in which to explore and pursue the sustainability-related specialisations. It is being investigated in what ways the Green Thread framework is a viable tool in this regard as well, as was explained in section 17.1. In addition to this, it must be stressed that providing the necessary tools alone is not sufficient. It must also be convenient for students to take the step to integrating these tools into their education.

III

Research

Introduction to research

Dynamic and active research is crucial to achieve impactful and innovative initiatives and projects. Research at TU Delft is performed under the umbrella of four themes, represented by Delft Research-based Initiatives (DRIs):

1. Delft Health Initiative
2. Delft Energy Initiative
3. Delft Global Initiative
4. Delft Deltas, Infrastructure, and Mobility Initiative

Through these initiatives, TU Delft aims to meet societal needs in a sustainable way by tackling problems using a multidisciplinary approach and in partnership with diverse organisations. This is implemented through research institutes, student teams, and start-ups. The university also works on translating the laboratory and small-scale research into a larger scope implementation in real-life conditions. To fulfil these goals, the university seeks to develop a sustainability-related research agenda with the participation of all faculties. Further improvements are required in connecting and involving students in research projects, and in having better communication about research on sustainability within the TU Delft community and to the outside world.

In this report, the diverse initiatives and projects related to TU Delft's research on sustainability will be briefly described, with a focus on the new relevant changes of the year 2021. Beyond 2021 updates, other descriptive details can be found in *GreenTU Delft's Vision on Sustainability: A Review and Strategy 2020-'30*.

19.1. Focused SDGs

The major goal of the Delft research initiatives (DRIs) is to find practical solutions to technical and societal challenges, in accordance with the UN SDGs. The main SDGs which apply to the research themes are:

- Good health and well-being [SDG 3]
- Clean Water and Sanitation [SDG 6]
- Affordable and Clean Energy [SDG 7]
- Industry, Innovation and Infrastructure [SDG 9]
- Sustainable Cities and Communities [SDG 11]
- Responsible Consumption and Production [SDG 12]
- Climate Action [SDG 13]
- Partnership for Goals [SDG 17]

19.2. TU Delft Research Repository

To assess of the amount and general trend of research performed at TU Delft and by TU Delft affiliated researchers, the university research repository was used. The latter is an online repository that stores all the published research from TU Delft. The research repository site is based on a tag system to identify the documents by year of publication, subject and faculty¹.

Based on this data, 1,076 documents (2001-2021) were found using the keyword for the research subject ‘sustainability’ and 99 documents (2001-2021) when using ‘sustainable development’ (table 19.1).

Keyword used	2019-2020	2020-2021
‘sustainability’	167	121
‘sustainable development’	14	14

Table 19.1: Table showing the number of documents per keyword in the academic years 2019-2020 and 2020-2021

A noticeable increase in the sustainability related research performed by TU Delft researchers during the last decade (starting from 2010)¹ can be seen on figures 19.1 and 19.2.

¹See: <https://repository.tudelft.nl/> [cited 31 January 2021]

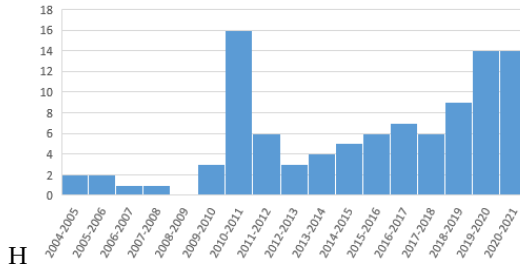


Figure 19.2: Trend of documents published in TU Delft research repository using the search keyword 'sustainability' per academic year

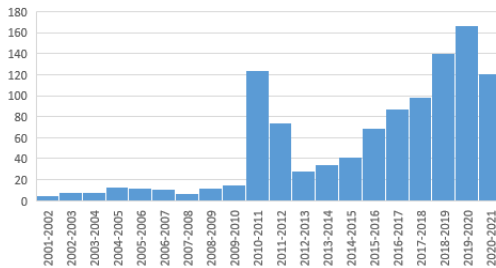


Figure 19.1: Trend of documents published in TU Delft research repository using the search keyword 'sustainable development' per academic year

19.3. Research collaborations and partnerships

To have research that is well connected to institutions and decision-making parties and that is relevant to the needs of society, it is important for the university to collaborate with diverse partners. These include research institutes, national and international universities, governmental organisations, as well as companies. The research partnership of TU Delft can be divided into four categories: cross-faculty, regional, national, and international co-operation. TU Delft has multiple collaborations with partners focused on education, including²:

²Further details can be found in: <https://www.tudelft.nl/teachingacademy/community-network/collaborate-with-partners> [cited 28 July 2021]

- Leiden-Delft-Erasmus Centre for Education & Learning
- 4TU - Centre for Engineering Education (4TU.CEE)
- Virtual Exchange Credits for MOOCs and EdX
- CDIO initiative: Conceive Design Implement Operate
- EDEN: The European Distance and E-learning Network
- AMS: Amsterdam Institute for Advanced Metropolitan Solutions
- SEFI: European Society for Engineering Education
- Open Education Consortium

In addition, TU Delft has agreements with international universities through exchange networks, including Advanced Technology Higher Education Network, Socrates (ATHENS), the Global Engineering Education Exchange (Global E3), the IDEA league, and the NAHSS. Depending on the department, the Innovation and Impact Centre at TU Delft collaborates through expert programmes with centres for entrepreneurship and incubation, as well as industrial partners and institutes, such as TU Delft Climate Institute, and AMS Institute.

19.3.1. International Universities Climate Alliance

After having published its vision on climate action, TU Delft started in April 2021 a new Climate Action Programme³ to have a practical elaboration of this vision. The program is composed of research themes:

1. Climate science
2. Climate change mitigation
3. Climate change adaptation
4. Climate governance

TU Delft has joined in 2020 the International Universities Climate Alliance as a partnership to implement the Climate Action Programme. This alliance forms a network of universities aimed at conducting climate research⁴.

³see: <https://www.tudelft.nl/2021/tu-delft/tu-delft-start-grootschalig-climate-action-programma> [cited 28 July 2021]

⁴See: <https://www.universitiesforclimate.org/> [cited 31 January 2021]

20

Research centres

20.1. Delft Research Initiatives

Sustainability and climate action find their ways in Delft research-based initiatives through theoretical and practical work. As mentioned previously, the four Delft Research-based Initiatives (DRIs) each relate to sustainable development in a profound way.

20.1.1. Delft Health Initiative

The Delft Health Initiative aims to use innovative technologies for the development of sustainable healthcare¹. 30% of TU Delft researchers are involved with health care related research ranging from bionanoscience to sustainable medical technologies. TU Delft partners with the Erasmus Medical Centre offering complementary resources and expertise to various challenges. The research is focused on four main themes:

1. Medical imaging
2. Cure and care
3. Targeted molecular therapy
4. Rising cars

20.1.2. Delft Energy Initiative

Delft Energy Initiative (DEI) is a platform for facilitating education, research and innovation related to advanced and sustainable energy technologies at TU Delft. It acts as a catalyst for various internal and external collaborations for scientists and students working in the field of energy. The initiative consists of four main pillars²:

1. Wind Energy Institute

¹See: <https://www.tudelft.nl/health> [cited 15 February 2021]

²See: <https://www.tudelft.nl/energy> [cited 15 February 2021]

2. Urban Energy Institute

3. Power Web Institute

4. E-Refinery

The research of these institutes are in line with the SDGs related to clean energy, infrastructure, sustainable cities, responsible consumption and production, and climate action.

Wind Energy Institute

TU Delft Wind Energy Institute (DUWIND) works on wind energy education and research with a focus on developing leading technology for sustainable energy with a multi-disciplinary approach. The multiple areas of research of DUWIND include: lighter materials, cost-efficient design, smart operations & management processes, optimal grid operation, and wind farm optimization. The research is carried out by collaborating with various international partners and brings together experts from six different faculties and thirteen research groups in the TU, each with their own expertise. Three major themes are:

- Wind in sustainable power supply
- Wind power stations
- Wind energy convertors

A large number of projects have been initiated by DUWIND in the year 2020, including:

- Fault diagnosis and fault tolerant control of offshore wind farms
- Fieldlab Unmanned Valley Valkenburg
- NEON - Lighting the Way to Zero Emission Energy and Mobility
- Multi-scale numerical modelling of floating offshore wind turbine
- Aerodynamics of floating offshore wind turbines undergoing large motions
- Reduced-order models and machine learning for FOWT analysis and design
- Multidisciplinary design analysis and optimisation framework for FOWT farms
- Automated manufacturing of carbon fibre reinforced composites for offshore wind turbine blades
- WINS50: Winds of the North Sea in 2050
- Ice-induced vibrations of offshore wind turbines (SHIVER)

- Dynamic power management in large-size renewable energy hubs: Understanding the causes of stability threats and development of intelligent control principles
- Aeroelastic wind turbine blade behaviour in field conditions
- Physical Modelling of Service Life Consumption by Pile Driving
- Bubble formation model and physical testing

Urban Energy Institute

The Urban energy institute at TU Delft mainly focuses on facilitating energy transition to a carbon free urban energy system in the Netherlands by 2050. The research is carried out in collaborations with research groups from all the faculties of TU Delft contributing with their own expertise. The research carried out is broadly divided into six themes:

1. Towards zero energy buildings and beyond
2. Fast transition existing building stock
3. Thermal urban energy system
4. Solar urban
5. Smart monitoring, management and control
6. Transforming the cities

The Urban Energy Institute is constantly active with several new projects in the last and current years (2020-2021). Some of these projects are:

- Integrale Energietransitie Bestaande Bouw (MMIP-IEBB)
- Warming-UP (MMIP 4: Sustainable heating and cooling in the built environment)
- Trust PV
- LIFE (Local Inclusive Future Energy) City Platform
- Energy security for energy communities
- Startup on zero energy development- sensors and actuators without batteries

Another new project of the Urban Energy Institute called 'Brains 4 Buildings' was recently initiated on the development of smart buildings to allow for lower energy consumption, and higher respond flexibly to user behaviour and local energy supply and demand. The project will be implemented by a consortium of 40 organizations, ranging from installation companies, energy consultancies, building owners, platform/interface developers, technology suppliers to knowledge institutions. The aim is to "harness big data from building management systems, smart meters, and the Internet of Things devices".

Power Web Institute

The goal of the institute is to design and model future power systems that are robust and can handle the penetration of renewable energy sources. The main areas of research are: the development of solutions to the changing electricity markets with an integral study of underlying physical systems (hardware); the design of smart energy management systems (software); and the study of smart grids in relation to their societal and economic environment (peopleware). MIGRATE is a major EU-wide research project that is facilitated by Power Web institute, with a focus on mitigating the operational challenges of the power system due to integration of massive power electronics by 2040.

E-Refinery

E-Refinery is a TU Delft research institute with the vision to accelerate the transition towards sustainable production of chemicals and fuels. The institute is supported by five faculties. The researchers focus on converting sustainable electricity to fuels and chemicals. The institute aims at solving three main challenges:

- Carbon-neutral fuel
- Seasonal energy storage
- Defossilized chemical industry

Over the year of 2020, 10 projects were started by E-Refinery:

- Co-PI Electrochemical CO₂ conversion
- SELECTCO₂

- OTP Battolyser
- OTP NH3
- E2C
- E2CB
- TOeLS
- RELEASE
- Safety

- alt raw materials in industrial clusters

20.1.3. Delft Global Initiative

This initiative has a truly global spirit with a societal impact towards sustainable future. The projects are aimed towards achieving the SDGs in developing countries with expert knowledge from TU Delft researchers. Scientists at the TU partner with local experts to realize these projects promoting a strong global partnership in solving global challenges. Projects are implemented in diverse regions, including East Asia and Africa³.

The projects are broadly classified into five themes:

1. Healthcare
2. Water
3. Energy
4. Disaster resilience and response
5. Urbanisation

The multi-disciplinary approach of the Global Initiative encompasses many principles: global challenges, science, co-creation, and local impact.

³See: <https://www.tudelft.nl/global> [cited 15 February 2021]

20.1.4. Delft Deltas, Infrastructure, and Mobility Initiative

Delft Deltas, Infrastructure, and Mobility Initiative works on developing solutions for societal problems related to infrastructure for water safety and smart mobility ⁴. This initiative includes multiple disciplines which work together in developing integral solutions, following the 'Integral, Innovative and Down to earth' approach. There are currently three areas of focus:

1. Urban Infrastructure
2. Deltas of the future
3. Airports of the future

20.2. TU Delft Climate Institute

Through data-based climate knowledge, the TU Delft Climate Institute aims to be an authority on mitigation, adaptation, and policy. In doing so, a focus is put on initiating interdisciplinary research programs and national infrastructure programs. The institute is active across all eight faculties of the university.

The Climate Institute is currently structured along the research themes:

- Urban climate
- Radiation balance
- Ice & sea level change
- Water cycle
- Geo-engineering

Urban climate

Under this theme, the Institute works on solving problems related to water scarcity, increasing temperatures, and rainfall. The aim is to develop climate-resilient cities.

Radiation balance

⁴See: <https://www.tudelft.nl/infrastructures> [cited 15 February 2021]

Climate Institute works as well on climate models to understand the system formed by the Earth's atmosphere in interaction with its surface. The behaviour and lifecycle of clouds are studied using special airplanes, radar and models using supercomputers and advanced 3D visualisation techniques.

Ice and sea level change

Another focus of the Institute is to study the several factors causing changes in sea level and glacial mass. Orbiting satellites directed to the Earth's surface are used. TU Delft researchers work on diverse aspects of this science, including data processing and sensors.

Water cycle

The availability of water is one of the most critical topics in relation with climate change, as it affects a large number of economic sectors. The fluctuations of precipitation patterns, adding to urbanisation and population growth makes water management more difficult to tackle. At TU Delft, many elements of the water cycle are studied. This includes precipitation, run off from cities, rivers, condensation, and cloud formation.

Geo-engineering

TU Delft supports research focused along two geo-engineering topics: solar radiation management and the capture/use of CO_2 emissions.

20.3. Sustainability-related departments

Electrical Sustainable Energy

The main goal of the Electrical Sustainable Energy department is to accelerate energy transition through research in renewables energy production, transmission, distribution and storage. Amongst the topics are photovoltaics, wind energy, power electronics, high voltage DC transmission and improving energy efficiency. Additionally, technical, economic and social issues of the future power systems are addressed as well.

Delft Subsurface Storage

Subsurface storage is multidisciplinary theme of the department of Geosciences

and Engineering working on societal challenges related to energy, water and environment. The current focus is to develop solutions for storing renewable energy in compressed air, hot fluids and in subsurface formations in the form of green fuels. The research work includes modelling, characterisation, simulation, monitoring and assessing subsurface formations.

Climate Design and Sustainability - Architectural engineering and technology

This department focus on the design of comfortable and healthy climate, in and around the buildings. Sustainable climate concepts are integrated into architectural design and urban planning. The research performed by Climate Design and Sustainability department is divided into three areas:

1. Comfortable and healthy environments
2. Climate integrated design
3. Low energy design

Sustainable Aviation

The Sustainable Aviation department is focused on three areas: reducing energy consumption, sustainable energy, and sustainable aviation operations. One of the prominent projects performed by this department is the Flying-V aircraft concept, which has the potential to save 20% of fuel consumption. The production of green aviation fuels and development of electric aircraft are being worked on as well.

20.4. Joint Interdisciplinary Projects



Figure 20.1: The JIP logo⁵

Research activities are implemented at different levels and from multiple actors, such as students, professors, professionals, as well as other contributors. Students have the opportunity to be involved in research on sustainability in diverse ways: by performing projects and theses as part of one of the Delft Initiatives, by being involved in Dream Teams, by initiating or working in start ups, amongst other possibilities. In addition, one of the research contributions is the Joint Interdisciplinary Project (JIP).

JIP is a research project performed as part of a Master curriculum. It is implemented in collaboration with various departments at TU Delft. Students work as teams on a business case, along with companies. The research performed deal with various sustainability topics such as urbanism/delta, health, industry and society, energy transition & biobased, and aerospace⁵.

JIP allows the students to work on projects with a systemic vision and integrated effort of various academic departments. Another advantage of JIP is the opportunity to collaborate with various companies, including TNO, Delft Imaging, Tahmo, Arcadis, Airbus, Embraer, Tennet and many others.

⁵See: <https://www.jointinterdisciplinaryproject.nl/> [cited 08 February 2021]

20.5. Centre for sustainability

The Centre for sustainability is an interdisciplinary research centre that combines three universities: Leiden University, Erasmus University Rotterdam and Delft University of Technology. The centre has developed open research programmes called "knowledge and innovation hubs" that allow researchers to work together on the transition towards circular economy. The hubs allow for master students to work on research projects that are relevant to the province of Zuid-Holland in collaboration with external stakeholders, including municipalities, companies and researchers. The topics are centralised on cities, industry and horticulture ⁶.

The 'Circular Industries Hub' includes research fields such as 'Industrial Design Engineering', 'Industrial Ecology', and 'Supply Chain Management'. Moreover, the main themes are ⁶:

- Electronics
- Automation
- Healthcare
- Bio-economy
- Renewable energy

In addition, the 'Agrifood Hub' works on the implementation of sustainable food production through big horticultural clusters (including plants, trees, flowers) called 'greenports'. The research performed by the hub aims at enhancing the horticulture sector in innovative ways through digitalisation and bio-based economy ⁶.

20.6. Clean Tech Start ups at Yes! Delft

YES!Delft is a leading technology incubator in Europe. Located at the university campus, it allows students to translate innovative ideas into business enterprises, focusing on sustainability. Four of the currently running startups are mentioned in this report.

Physee

⁶See: <https://www.centre-for-sustainability.nl/home> [cited 02 June 2021]

PHYSEE is a startup working on clean building facades. To contribute in the development of energy neutral buildings, the company provides Smart-Skin that controls the building climate and saves energy use while producing energy.

Kitepower

Kitepower focuses on airborne wind energy, developing innovative and cost-effective substitutes to existing wind turbines through the use of kites for generating electricity. Its patented technology uses 90% less material while being twice as efficient as existing technology. Contrary to conventional wind turbines, Kitepower system does not require resource-intensive towers or heavy foundations, making it easier for transport and deploy. It connects stronger and more tenacious winds at higher altitudes, allowing for capacity factors greater than 0.5 and in return cost-effective electricity generation.

Solar Monkey

Founded in 2014, Solar Money was founded by master students at TU Delft, for enabling installers to grow faster using solar panel software. The software has the potential to design a full system remotely within a minute, improving efficiency and boosting the market.

Circularise

Circularise works with leading industrial corporates, government and research organizations to bring transparent and trusted data sharing to global supply chains. The company works on the acceleration of the transition to a circular economy. It aids reliable and standardised flow of information about materials and components within the supply chain using a blockchain technology.

20.7. Student Teams

In addition to the work done by the researchers, various student teams at TU Delft are working on diverse projects focused on sustainable applications including mobility and energy. Within this framework, the students have the opportunity to work on projects for the aim of turning them into commercial technologies. The student teams working in the D: Dream Hall on

campus are officially known as 'Dream Teams'. The current Dream teams of 2021/2022 are:

- Eco-Runner Team Delft
- Delft Hyperloop
- TU Delft Solar boat team
- Project MARCH

Living lab

Implementing the lab research work at the university into real-life projects is a very important step into the application of sustainability. This allows the campus to be a 'living laboratory', which is one of the standards set by STARS in terms of academics.

21.1. The Green Village

As a living lab for the implementation of sustainable projects at TU Delft, Green Village helps to accelerate the development of several green innovations ¹. It provides a platform for scientists, corporations and the government to experiment and collaborate in a real-life setting. This allows for small lab research to be implemented on a large-scale. The projects at the Green Village are supported by the European Regional Development Fund, the Province of South-Holland, the municipality of Delft.

In the years 2020-2021, new projects have been initiated by The Green Village, contributing in diverse areas, including water, electricity management (AC/DC), buildings, smart mobility, smart technologies (outsmart) and circular economy.

The main new projects are ¹:

Buildings projects:

- DeZONNET This project works on the development and installation of residential solar heating network to provide hot water, as well as heating and cooling. The system includes photovoltaic thermal (PVT) panels, an underground heat storage facility and a heat pump. The group of companies working on the project aims to have an efficient system while being affordable for the average resident in the Netherlands.
- HeatCycle 'HeatCycle' project is also working residential hot water supply and heating through the recycle of heat from drainage water. Con-

¹See: <https://thegreenvillage.org/> [cited 10 February 2021]

sidering the different sources of the latter, drainage water can provide around 40% of the total heat requirement of a residence.

- Supersola "Supersola makes plug & play solar panels to lower the threshold for generating sustainable solar energy. Their panels are an affordable alternative for installations of up to six panels and easy to transport in case of a possible move."
- Isolatiekorrels

Water projects:

- **Bluebloqs** The aim of Bluebloqs is to have a circular water system by making rainwater available for urban uses through rain gardens and ponds. This also allows the prevention of flooding and drought.
- **RainRoad** Rainroad project works on the concept of storing rainwater in reservoirs under street pavements for providing cooling when water evaporates.
- **ZOAK** bestrating ZOAK project works on ceramic pavement that have the capacity to quickly and efficiently absorb rain water, which can then distributed in the soil.

Open access research

To ensure the free of charge accessibility of its publications, TU Delft has committed itself to Open Access publishing policies, as part of the Open Science Programme. As defined by TU Delft, Open Science means "as wide as possible dissemination of scientific knowledge, free of charges to all users and online accessible" [8]. More specifically, open access is defined in the Dutch National website for open access as having "no financial, legal or technical barriers" to access a publication. In other words, it is "when anyone can read, download, copy, distribute, print, search for and search within the information, or use it in education or in any other way within the legal agreements"¹.

The Open Science 2020-2024 Strategic Plan was set to loosen the restrictions on the access of academic knowledge. The pillars (interrelated projects) of this plan (called *Research and Education in the Open Era*) are [10]:

- Open Education
- Open Access
- Open Publishing Platform
- Fair Data
- Fair Software
- Citizen Science
- Open Hardware

These projects allow for the making and development of resources, such as software and educational materials, to benefit TU Delft teachers, researchers and students. The programme aims at having academic knowledge: findable,

¹See: <https://www.openaccess.nl/en> [cited 2 June 2021]

accessible, interoperable and reusable, which abbreviates as 'FAIR'. The evaluation of the programme in the year 2020 and the budget and workplan of 2021 are available in [10].

22.1. TU Delft's Policy on Open Access Publishing

Starting from May 2016, TU Delft has taken the 'Green Road' towards open access by making the uploading of publication on the research repository obligatory to all (co)authors affiliated to TU Delft. Accordingly, following the official publication of a paper in a journal, researchers are required to submit their publication to "TU Delft's research information system" PURE (previously METIS) [8]. Managed by TU Delft Library, the publication will then be made available on TU Delft Institutional Repository. The step towards the mandatory policy of open access publishing was a follow-up of Berlin Declaration on Knowledge in the Sciences and Humanities in October 2003 [8].

As mandated by TU Delft's executive board, the facilitation of open access publishing through diverse instruments and measures is one of the tasks of TU Delft Library. Open Access is promoted by TU Delft Open Publishing, TU Delft Repository, 4TU ResearchData, as well as bilateral and national agreements with publishers, The Dutch National website for Open Access² contains further details about the national agreements. Furthermore, TU Delft has special open access deals with ACM, Copernicus, IEEE, IWA, Frontiers, MDPI, PeerJ, PLoS, Royal Society, RSC, and SciPost³.

Through the implementation of these policies, the percentage of all peer reviewed articles published as open access increased from 30% in 2015 to 81% in 2020.

Open access publications are available in several sources:

- TU Delft Research Repositories
- The Directory of Open Access Journals (DOAJ)
- The Directory of Open Access Books (DOAB)
- The Dutch portal for research information NARCIS
- The European science platform OpenAire
- CORE

²See: <https://www.openaccess.nl/> [cited 2 June 2021]

³See: <https://www.tudelft.nl/en/library/library-for-researchers/library-for-researchers/publishing-outreach/open-access-publishing> [cited 2 June 2021]

- Unpaywall
- ArXiv

22.1.1. Open Access Financing

Open access research is financed in diverse ways³:

1. **National agreements:** It is possible for researchers to publish with no costs in journals that are part of national agreements.
2. **Bilateral agreements:** TU Delft library has bilateral agreements with publishers
3. **TU Delft Open Access Fund:** Open access publications can be financed by funding bodies such as the European Union (through the European program Horizon2020), the Dutch Research Council (NWO), and the European Research Council (ERC).

22.1.2. Plan S

New requirements have been set by research funders (the funding bodies of TU Delft Open Access Fund) in 2021. All research funded by NWO needs to be open access. In order to facilitate this change, the open access funders have formed an international consortium called 'Plan S', which includes the European Commission and NWO³.

GreenTU's accomplishments and projects in research

Within the scope of GreenTU's activities, research plays a minor role. GreenTU primarily interacts with bachelor and master students and with operational and educational staff. Its influence in research has always been limited. However, there are a few projects from the past year that are interesting to point out.

23.1. GreenTeam accomplishments and projects

As mentioned, the GreenTU board has not been directly involved in research. The projects described here are thought up by and implemented primarily by GreenTeams.

23.1.1. Sustainability Journal

To inspire students who will be writing their master thesis in the future, the **GreenTeam TPM** aims to set up the GreenTeam **thesis journal**. This journal will include summaries of theses by students who have chosen a topic related to sustainability or energy transition, including their suggestions for further research. For the graduating students, this will be a nice way of displaying their hard work to a bigger crowd. For aspiring thesis candidates, this will be a way to get inspired about interesting topics or research gaps to follow up on.

23.1.2. Graduate school course on sustainability

As could be read about in detail in chapter 17, **GreenTeam CEG** is working to introduce introducing **new Graduate School courses focused on sustainability**. This would improve the ability of the Graduate School students of TU Delft to account for sustainability in their research.

GreenTU's vision on research

A major part of TU Delft's research initiatives is linked to the SDGs. The research departments are always the frontier of their field's publishing content every year. This can be seen from the Elsevier's ranking based on SDGs. TU Delft is ranked first in the Netherlands for research contribution towards the SDG 6, 9 and 11.

Nevertheless, there are great potentials for the university to have a better performance and ranking in research. Taking into consideration that this report is on behalf of a student organization, the authors would like to clarify that any advice in this report is based on collected data and literature, STARS assessment criteria, as well as our experience in facilitating sustainability-related activities.

The vision for Research is:

- Explore new interdisciplinary research areas related to sustainability and to all SDGs.
- Establish better communication of research projects on sustainability and encourage students and researchers towards contributing to them.
- Develop a clear and elaborate research agenda focused on the implementation of sustainability goals in a multidisciplinary approach.
- Promote the concept of campus as a living lab connecting researcher, operations team and students.

To achieve these goals, the authors recommend the following a set of action points.

24.1. Interdisciplinary collaboration and better communication

TU Delft has multiple research departments and a large number of researchers who work on different dimensions of sustainability. Hence, there is a need to

facilitate the accessibility and the possibility of contribution in the research projects by students. Joining the efforts with the Centre for Sustainability and other institutes, better communication of the projects can be achieved to spread awareness on the activities performed by the university. This also gives a fertile ground for collaboration between researchers, students and diverse partners, while enhancing the multidisciplinary aspect of the research performed. Having a strong network can be a great asset for the university to improve its contributions towards climate action. This can be achieved with the help of Green Village and GreenTU, who have already been active and effective in connecting with various stakeholders working on sustainability.

24.2. Comprehensive study on the current progress and research agenda

As TU Delft has committed itself to the Climate Action Programme in 2021, it needs to have a clear plan and agenda of its sustainability-related research projects. For this, the progress and development of activities of researchers in all faculties should be assessed to identify to what extent the research work is in line with sustainability goals. Moreover, this assessment is crucial for being aware of the potential topics in which more research is to be performed.

Moreover, applying this to all the different faculties allows to recognise the possible areas of interdisciplinary research as some projects can be applied in collaboration with more than one faculty. This approach helps to contribute in the SDG of 'partnership for the goals' (SDG 17). Having a clearly set agenda gives the opportunity for a better organization of the research projects, as well as a more efficient partnership within and outside the university.

24.3. Vision for living lab

The Green Village at TU Delft has been serving as the Living Lab with many exciting projects related to sustainable development. From energy to architecture, Green Village has become a test bed for many innovations in TU Delft. In spite of the success, there is much more potential that can be explored.

One of the directions that has not been explored until now is student contributions to the Green Village. With lots of great minds graduating every year, many students are eager and interested to work on practical projects which can include sustainability. Providing a direct channel between the Green Village and students can open many opportunities for developing the

projects performed. To encourage innovation and to promote student interests, offering funds through competitions or grant applications for students would greatly motivate the students to work towards sustainable projects. This can potentially be done by allowing students to perform internships with companies involved in the Green Village or by linking graduation work to the ongoing practical projects.

Another important aspect that needs attention is establishing collaborations between the Green Village, researchers and TU Delft operations team. The university has great resources to test the various innovations happening on campus. For instance, TU Delft owns its own power grid and power plant. This could be a benefit for testing new innovations for future power systems. Establishing these connections can accelerate the feasibility and scalability of the projects.

Hence, expanding the Green Village by extending its reach to all the stakeholders of the university could further promote the research contributions of TU Delft towards sustainable development. The means to implement this could be the settling up of the Centre of Sustainability.

IV

Operations

Introduction to operations

With TU Delft's ambition to be a carbon neutral and circular campus by the year 2030, it is important that sustainability starts in the campus and its operations. In the vision and action plan 2020 co authored by different stakeholders, the first objectives for a circular campus can be achieved through the following C's:

- Carbon neutral
- Circular
- Climate adaptive
- Contributing to quality of life

To facilitate the journey to sustainable campus operations by 2030, twelve specialised teams have been formed to focus on a specific theme of sustainability. Each team is comprised of employees of influential service departments, academics from different faculties with expertise in the respective subject, and (not least) students from GreenTU or one of the faculty Green-Teams. The specialised themes for operations have been described below:

- The **EcoCampus team** works on plans for a greener campus that has a better water management, aiming for increased biodiversity and improved climate adaptivity.
- The **Energy System team** focuses on a sustainable energy system with renewable power generation, thermal energy, sustainable fuels and energy storage.
- The **Construction & Renovation team** looks into the current building stock and the possibility to renovate these buildings on the one hand and into sustainable new construction on the other hand. Its focus is to reduce the carbon footprint of buildings on campus, old and new, and to incorporate circularity.

- The **Mobility team** works on a sustainable mobility policy and focuses on commuter, business and student travel. Furthermore, this team looks at employee and student services, as well as sustainable facilities at the campus, for example electric charging points, bike storage and safe infrastructure.
- The **Food & Beverage team** focuses on the catering at the campus, the environmental footprint of food and sustainable food policy.
- The **Procurement & Waste Management team** is dedicated to a system of circular resource management, through procurement through preferred and contracted suppliers and the avoidance of waste, or sustainable processing thereof.
- The **ICT, AI & Data Management team** concentrates on reducing the negative carbon impact of ICT and the positive potential of using ICT and AI in energy efficiency in creating a smart campus.

The report contains the data available and the initiatives and proposed strategies for the following thematic areas of operations: (i) Energy, (ii) Catering, (iii) Biodiversity, (iv) Mobility, (v) Waste and (vi) Procurement. The chapter also provides a detailed description of the energy and carbon footprint model developed by the GreenTU team.

26

Energy

TU Delft is taking major steps to achieve the 2030 carbon neutral goal by reducing emissions from all three scopes. Energy consists of scope 1 and 3 emissions.

- **Scope 1 emissions:** These refer to the emissions which directly traced back to the sources owned or controlled by the university.
- **Scope 2 emissions:** These refer to the emissions which are caused by the purchase of heat or electricity from the reporting company.
- **Scope 3 emissions:** These are the indirect emissions that occur due to the university which include wastewater treatment, employees commute and so on.

Currently the share of the electricity consumption on campus is provided by wind, Combined heat and power (CHP) plant and solar energy. Wind constitutes the major share as over 70% of the energy is from this source. The energy is generated by wind farms and is bought by the University through the energy company Eneco. Solar panels installed on the rooftops of buildings contribute less than 2% to the annual consumption but there are plans to accelerate the adoption of solar in the coming years by Campus & Real Estate (CRE). The CHP source is used to generate power during times of high load and not enough generation from the renewable sources. Since the energy from wind is not controllable, there is excess energy being generated at the campus during times of high wind speeds which is sold to third parties in Delft.

Also, the heating requirements of the campus contribute significantly to the overall emissions of the campus. The CHP plant and the Boilers are responsible to supply the heating needs of the campus which is powered by gas. To reduce the emissions, there are plans to utilise geothermal energy as the primary source to supply the heat for all the buildings. The project is set to begin in the next couple of years and it will also be a hub for further research activities into geothermal energy.

The emissions due to electricity and heating were modelled to project future changes. Three possible scenarios were developed to transition towards a campus that is less carbon-intensive and more sustainable. It is explained in detail in chapter 32.

Catering

Food accounts to a large percentage of emissions and one of the main reasons is the meat industry. To counter this, initiatives are being put in place in order to curb these emissions.

27.1. Meat-free canteen

As part of achieving the 2030 carbon neutrality goal, a major step has been taken to reduce the food emissions drastically. The canteens in the university have always been meat centric. It goes without saying that to fight against climate change, a change in food pattern and consumption needs to be incorporated. For this very reason, the restaurants at the Faculty of Architecture and the Built Environment offer an entirely vegetarian menu¹ starting May 3rd 2021. This shift to a fully vegetarian/vegan menu saves more than half of the food related emissions. This pilot initiative has been put in place with the help of the TU Delft caterer CIRFood.

27.2. Waste Separation Pilot

The aim is to reduce the general waste in the campus. Even a small quantity of waste that doesn't need to be incinerated can reduce the carbon emissions.

In June 2020, a pilot project was started at the Faculty of Architecture and the Aula. All general waste bins have been replaced by waste stations where paper, plastic and other waste can be disposed. The waste stations are strategically placed for people to use them conveniently. In the restaurants, a green bin is used for general waste.

The catering facilities in these two buildings also participate in this pilot. The share of general waste is quite high in these catering facilities and has to be brought down².

¹See: <https://www.tudelft.nl/2021/bk/restaurants-faculteit-bouwkunde-als-e-erste-over-op-volledig-vegetarisch-aanbod> [cited May 12 2021]

²See: <https://www.tudelft.nl/en/sustainability/campus/pilot-waste-separation> [cited July 5 2021]

Biodiversity

The well-being of people around the world depends on the provisional services provided by trees like food, shelter and so on. Therefore, trees form a vital part in enhancing biodiversity and the ecosystem. For the well-being of human race and take action against the rapidly regressing climate around the world, it is necessary to enhance the green cover on earth. For this very reason, TU Delft is striving to work on the biodiversity on campus.

28.1. Eco-campus Project

Urban Ecosystem based planning and design is a basic approach to improve the quality of life along with environmental performance in cities around the world. Understanding and intervening at local as well as systemic level via urban ecosystem restoration strategies & design can transform existing cities into Eco-cities. The research fellowship Urban Ecology is based at the **Faculty of Architecture and the Built Environment** in the Urbanism department and is funded by **Bird Life Netherlands, VBN**.

One of the projects by this team of researchers is the Eco-campus project at TU Delft. The campus of TU Delft is to be transformed into an Eco-campus by the year 2050. Unnecessary pavements can be eliminated and place for a new water infrastructure and vegetation that fits the existing ecosystems in this area can be introduced. Three habitats are created from North to South: the forest, the meadow and the swamp into which the campus is aimed to be transformed into¹.

28.1.1. Forest

With more forestry area, the urban heat island effect and air pollution can be curbed. The increased canopy provided by the trees leads to shadow, air filtration and improves the ecosystem housing a varied species of birds and insects. For the people, the forest can act as a place to relax as well as have strolls in and reconnect with nature.

¹See: <https://www.urbanecologytudelft.org/ecocampus/> [cited 1 July 2021]

28.1.2. Meadow

The Mekelpark evolved into a wildflower meadow, which attracts pollinators whilst adding aesthetic value to the place. Many faculties are situated around the park. Eco-friendly furniture is in place for people to gather and use. The park is open and attracts a lot of people on sunny days.

28.1.3. Swamp

The swamp area is enriched by a natural swimming pond for the students to use. Due to the water purification using reeds, the old sports fields turned into the natural environment that provides space for many events of student associations at TU Delft. The Mien Ruys park serves as an escape from the big buildings on campus, for humans as well as for other species. The eco-structures, made of reused tiles, offer a home to a lot of insects, while shaping the atmosphere at this spot.

By the philosophy of **The art of letting g(r)o(w)**, a campus that offers space for students and the university along with increased biodiversity is found to be possible. This philosophy emphasises on increasing the coexistence of people and wildlife².

28.2. Green roof

Most of the roofs of buildings at TU Delft are covered with grass or sedum. The insulation provided in winters and the cooling in summers by these vegetation helps in saving energy costs. One such example which is pretty evident is the TU Delft Library covered with grass. In total, TU Delft has 170,000 square meters of flat roofs of which 13,300 square meters are covered with grass or sedum or a mixture of both³.

²See: <https://www.urbanecologytudelft.org/ecocampus/ecoconcepts/the-art-of-letting-grow/> [cited 1 July 2021]

³See: <https://www.tudelft.nl/en/sustainability/campus/green-roofs> [cited 1 July 2021]

Mobility

The CO2 Roadmap calculated the total carbon emissions from travelling as around 11630 tCO₂-eq. Although majority commuters use bike, high emissions from air travel is a major contributor to the total emissions. Some 27,000 people use the campus every day – students, scientists, visitors and staff of the university and the businesses on campus – and that number is set to increase during the coming years. This means that it is becoming more and more busy on and around the university site. There is also a greater demand for parking spaces and CO₂ emissions are increasing. Keeping in mind the aim to make operations carbon neutral, initiatives to make mobility operations more sustainable and accessible is the need of the hour. Consequently the Campus and Real Estate team (CRE) aims to create a campus that is both easy and safe to reach – now and in the future: a green, park-like environment that can be explored on foot and is carbon-neutral while encouraging use of public transport. The following measures are being proposed by CRE :

- **By bike and on foot:** Attention will be paid to the network of cycle paths and pedestrian routes on campus and leading to and from the university. To improve road safety and traffic flow, bicycle and car traffic will be separated as much as possible. We will tackle safety bottlenecks by installing traffic lights, for example. We will also create more greenery and space on our campus in areas where there are currently a lot of cars and smaller car parks.
- **By public transport:** We are also improving accessibility to the campus by public transport. Delft Zuid station will be renamed Delft TU Campus station and will be served by more trains in both directions. A tunnel will also be built under the tracks. A new cycle bridge, the Gelatine Bridge, will also be built over the Schie, which will provide a direct connection between the campus and this station. Tram 19 from The Hague Leidschendam-Voorburg will be extended from Delft Central Station to the south of the campus.

- **By car:** Car drivers will soon be able to find their way quickly and safely from the campus ring road to the car parks (located at the edge of the campus) using dynamic parking signage. They will no longer have to search for a parking space. All campus destinations will be accessible on foot from the car parks.

The Annual report from GreenTU for the academic year 2019-2020 identified and reported sustainable mobility initiatives undertaken on campus. Noteworthy were the Mobility pilot program and P-Sports car park. As part of the mobility program, staff and students had the opportunity to try an e-bike free of charge, use public transport in combination with a public transport bike or a folding electric scooter, or work from home. The pilot provided valuable information on keeping the campus accessible, influencing travel behaviour and on how we can encourage the use of sustainable transport. Over 500 staff and students took part. Researchers from the Transport and Planning department of the Faculty of CEG led the research into travel behaviour. The initial results showed that 49% of the participants used cars less after the pilot, 12% switched completely from cars to sustainable modes of transport, and 22% of the e-bike testers bought themselves an e-bike. TU Delft is replacing various parking areas scattered throughout the campus with larger easily accessible parking facilities close to the campus ring in stages. The car park will be built using a modular system with prefabricated concrete and steel elements. It can eventually be completely dismantled and re-erected elsewhere, making it an example of circular and sustainable construction.

Consultant Mobycon were hired by TU Delft to assess mobility management measures on campus. By analyzing commuter census and postal code data they gained valuable insights into multimodal travel behaviours (bike, e-bike, public transit, car). Additional data were obtained through an online survey. The following suggestions were made: (i) E-bike trial programme: The e-bike is an attractive mode for distances up to 15 kilometers (10 miles). The programme creates opportunities for people to travel to the university by e-bike for free for a week. By doing so, they experience a new way to commute to the university, (ii) Dockless bike sharing: Bike sharing is a great last-mile solution from the two train stations serving the campus. We approached Mobike and they placed hundreds of bikes in the city, (iii) Travel information: Provide commuters with information on how to time their trip to and from the campus to avoid the inconveniences of rush hour, (iv) Ridesharing: The University introduced a match-making app to link people on campus who are interested in ride sharing. As an incentive, people who used the app got better parking facilities.

The results of the e-bike trial program on campus was reported by Ton and Duives in a recent paper [13]. Data was collected at various moments during and after the trial period to evaluate the long-term changes in commuting behaviour and to identify potential reasons for these changes. A total of 82 participants are included in this study. Overall, car use for commuting decreased from 88% before the pilot to 63% three months after the pilot. E-bike use went up from 2% to 18% in the same time period. The purpose of the study was twofold: (i) to evaluate the long-term changes in car use and e-bike use for commuting to campus, and (ii) to determine which factors result in a participant decreasing their car use or increasing their e-bike use three months after the pilot. They identified that a scheme that allows individuals to purchase an e-bike in several terms, could potentially increase the share of participants that change behaviour on the long-term. Hence, any incentive schemes/ support from the institution can accelerate use of e-bikes.

29.1. Campus mobility dashboard



Figure 29.1: Snapshot of the campus mobility dashboard represented through a digital twin of the campus

In light of COVID, TU Delft campus is a living lab for studying traffic and commuter flows. The development of the Outdoor Mobility Digital twin is led by Dr. Sascha Hoogendoorn of the Mobility Innovation Centre Delft (MICD) and Prof. Serge Hoogendoorn, of the Transport & Planning Department at

the TU Delft Faculty of Civil Engineering and Geosciences. With the help of 30 (camera) sensors around the campus and with the use of openly available public transport and car traffic data, the flows of people and traffic on and around the campus can now be visualised and monitored on a dashboard in (near) real-time. This data will help to predict the location, density and direction of flows of people on campus and can show the effect of implemented safety measures and policies. By combining and enriching all available data about people's locations and movement and the availability of mobility services on and around the campus, the institute can organize the traffic flows much better and make optimal use of existing and new services provided. Although the short term focus of the Outdoor Mobility Digital twin lies on informing campus management about crowd development, critical locations, and whether social distancing can be adhered to, many more future applications for it are foreseen where IoT can play a role. For instance, creating a better connection between the Delft Campus train station and Campus Zuid. Or new algorithms for controlling traffic lights, for example through direct communication with pedestrians and cyclists, offering new transportation services to move to, from and on campus, parking reservation systems, etc. In short: the possibilities for the development of IoT and new sustainable mobility solutions are endless as the communication infrastructure, sensor network and dashboard are intended to grow into a fully-fledged fieldlab for innovation in mobility.

30

Waste

There are a total of 13 different waste flows at TU Delft, all of which are separately collected and processed. Paper, biodegradable waste, wood and metal, for example. But also rubble, building and demolition waste, and organic waste from the catering facilities. General waste accounts for 46% of all waste produced at TU Delft. In the year 2018, TU Delft produced 2,788,757 kg of waste, see figure 30.1 (Source:Renewi 2019).This is 514 kg per fte and 92.6 kg per person. Latest data for the year 2020 was unavailable at the time of writing the report. But given the COVID circumstances, it can be expected that the waste produced on campus was reduced considerably. Almost half of the waste is currently residual waste (47%), which goes to the waste incineration plant in Rozenburg. Separate collection of the waste streams takes hardly place. The current share of VGF consists almost entirely of green waste (pruning waste, maintenance of landscaping). Swill (biomass from catering) is only collected separately at the Sports Center and the Aula . In 2020,there was a waste separation pilot focussing on the separation of paper, PMD, coffee cups, and residual waste at ABE and the Aula. The finance department is calculating the university's carbon footprint annually from 2019,according to the method of the 'CO2-prestatieladder'. This method follows the international Greenhouse Gas Protocol. Waste is also included and falls under scope 3 upstream. To calculation for the CO2 emissions are based on the waste report from Renewi which contains the amount of waste collected from the TU Delft campus in 2019. The carbon impact of waste is 3,242 tCO2 and the carbon impact of radioactive waste is 18 tCO2 (Refer figure 30.2). 45% of the waste in 2019 was residual waste, this is 2% less than the previous year. The table shows that the green waste category has the largest share of emissions, followed by residual waste. The emissions that are released during the transportation of the waste are not yet included. In the year 2020, a waste separation pilot in the Faculty of Architecture and the Buily Environment and the Aula¹. General waste bins were replaced by waste stations for disposal of pa-

¹See: <https://www.tudelft.nl/en/sustainability/campus/waste-separation-pilot> [cited 12 August 2021]

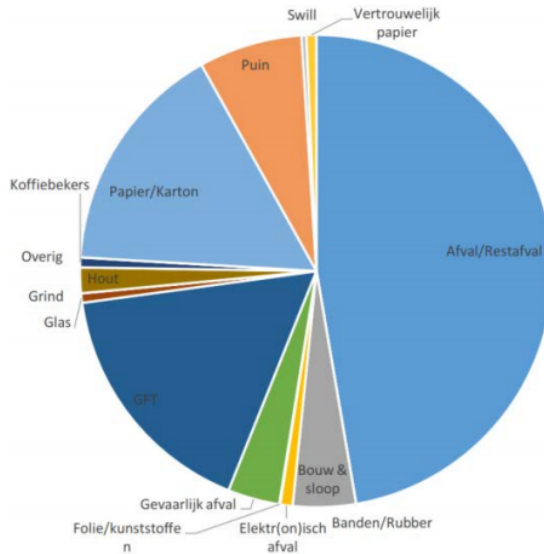


Figure 30.1: Distribution of waste materials at TU Delft campus. (Source: Renewi 2019)

per, PMD (plastic, cans and drink cartons) and other waste. These are located in strategic places, so one can always get to a waste station within about 30 seconds. The catering facilities in the Aula and at the Faculty of Architecture are also participated in this pilot. They also collected food waste and plastic, cans and drink cartons separately from the general waste.

Afval operatie	Eenheid	Volume	Emissiefactor CO ₂	2019 (ton)
Bouw & sloop	kg	137.870	1,00	138
Afval / restafval	kg	950.856	1,00	951
Banden en rubber	kg	151	3,18	0
Elektronisch afval	kg	17.630	2,70	48
Smilt	kg	11.474	4,25	49
Groenafval	kg	367.370	4,25	1561
Papier / karton	kg	261.652	1,10	288
Glas	kg	23.330	0,85	20
Gevaarlijk afval	kg	81.676	1,00	82
Hout	kg	48.850	0,63	31
Koffiebekers	kg	20.916	1,10	23
Kunststoffen / folie	kg	604	1,74	1
Puin	kg	193.890	0,18	35
Vertrouwelijk papier	kg	14.541	1,10	16
Transport afval	liter		3,23	-
Totaal	ton			3.242

Kernafval	Eenheid	Volume	Emissiefactor CO ₂	2019 (ton)
Radioactief afval	stukks	1	18.000	18
Totaal	ton			18

Figure 30.2: Emissions from waste

Procurement

The term 'procurement' includes the purchase of many different products and services namely:

- **Food & Beverage:** The university buys food and drink for its students, employees, and visitors. Food & beverage includes vending machines, hot beverage machines, unmanned catering facilities, faculty corner, salad bar, sandwich corner, marketplace, on-location catering, and food trucks.
- **Furniture & other hardware:** Furniture can be found in each building on the campus. The faculties and services are responsible for their furniture and use them solely in their own building. It is unclear which and how much furniture is in each of the building.
- **Office supplies:** Office supplies are traditional office items as pens, staplers, paper clips, printer ink cartridges, etc. It also includes products like paper towels, bathroom tissues, and plastic utensils. Printer ink/cartridges and printing paper is under contract management with the ICT department (central purchasing). All other office supplies are handled within FM (decentralized purchasing)
- **Office expenses:** Office expenses are for example website services, computer software, domain names, computers, laptops, printers, office phone systems, internet fees, etc.
- **Labs:** There are several laboratories at TU Delft, each with special needs to be able to carry out their research. Some examples of basic lab equipment are pipette, test tube (rack), beaker, flask, syringe, thermometer, stethoscope, scale, magnifier, level, barometer, etc.
- **Services:** Services are also purchased; an agreement is established between the university and the service provider. Maintenance services, consultants, accountants, legal services, and flexwork forces are all examples of this.

In the last academic year, the Projects Committee of GreenTU has drafted sustainable procurement guidelines aimed to serve the Transforming Education Spaces (TES) team of TU Delft. In the future, this can help the educational spaces of TUDelft to move towards sustainability in a fair and structured manner and concisely evaluate sustainability in future tenders.

At the moment, the document is drafted to provide a grading scheme for furniture suppliers. A rigorous comparison is made between the most relevant sustainability certificates. Some of the salient features of the report are:

- The documents provides a framework for evaluating the sustainability on a company and product level. Certifications such as PAS2060, Lean & Green, GreenGuard and CO2 Prestatieladder were found to indicate some level of sustainable achievement at the company level. EMS (Energy and/or Environmental Management Systems) have been suggested to resolve a tie-break situation when suppliers have the same product certificates.



Figure 31.1: The product life cycle with relevant sustainability certificates indicated.

The product life cycle consists of 5 stages and the document identifies appropriate sustainability certificates during certain phases of the product life cycle.

- The guidelines also identify the most impactful stages of the life cycle of furniture. The findings collected through an extensive review of rel-

evant literature will help identify and reward certificates for the most impactful stages of the product life cycle.

- One of the most important value addition from the report is the rigorous comparison of sustainable certificates supported by a grading scheme that uses a point system to determine the final sustainability score of a company.

The Sustainable certificate study for furniture is a first step towards drafting sustainable procurement guidelines for other utilities such as electronics as well. Such a qualitative comparison can serve as a blueprint for other procurement frameworks and be expanded further.

GreenTU's energy and heat model

In this section, the model that was developed for the assessment of the carbon footprint will be presented. The carbon footprint was analysed for two sectors, namely the consumption of electricity and heat on the campus.

32.1. Electricity consumption

The electricity requirements for the campus is powered by three sources currently, they are:

- Solar energy
- Wind energy
- Combined heat and power plant (CHP)

Over 70% of the electricity is powered by wind. The CHP plant is used at peak loads and when there is insufficient generation from wind to support the load. Solar accounts for less than 2% of the total electricity consumption and during 2016 most of the PV systems were installed. During periods of high generation from the wind source that is greater than consumption, the excess is sold. The percentage of total energy that was sold over the entire year was about 14% for 2019 and 2020 and this was not considered in estimating the carbon footprint of the campus as the energy is not utilised on campus.

The data for the model was obtained from the campus and real estate department (CRE) regarding the energy consumption for the past 5 years, i.e. 2016 to 2020. This data was utilised to model the carbon footprint and few assumptions had to be made regarding the rate of change of each parameter to develop future scenarios to project the status in the year 2030. The rates of change is shown in table 32.1. For each scenario the rationale behind the change is as follows:

- In the current scenario, the rate of change over 2016-20 was averaged to obtain the change for the electricity consumption which is expected to increase by 0.61% every year. The growth in solar and wind energy was averaged for the last 2 years, i.e. 2019 and 2020. A moderate increase in CHP of 0.3% was considered to support the increasing load every year.
- For the business as usual case, no further increase in the renewable energy sources was considered. The increase in electricity consumption of 1% would be supported by only the CHP source.
- An optimistic scenario was also developed to look at more ambitious reductions in carbon emissions at the campus. Here, a drop in electricity consumption by 0.5% every year was taken. The increase in solar and wind energy was taken at 10% and 1.5 % respectively. As solar accounts for a smaller share of total consumption, the potential for growth is higher. A reduction in CHP by 8% per year was considered to support the expected load.

Scenarios	Annual rate of change (%)			
	Electricity consumption	Solar	Wind	CHP
Current	0.61	8.94	1.086	0.3
Business as usual	1	0	0	3
Optimistic	-0.5	10	1.5	-8

Table 32.1: Rate of change regarding electricity consumption for each transition scenarios.

The data in the above table was modelled to project the electricity consumption for the year 2030 as shown in figure 32.1. As expected, the optimistic case results in the least electricity consumption in the year 2030 and the business as usual resulting in the highest.

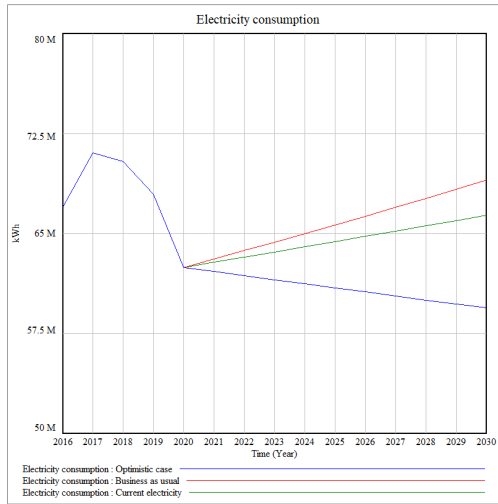


Figure 32.1: Electricity consumption on campus

The carbon footprint was estimated from the above data by considering an emission factor for wind, solar and CHP. The emission factor was multiplied with the quantity of electricity produced from the respective source to obtain the total emissions. The considered emission factors are as follows:

- Solar - 0.32 tons/MWh
- Wind - 0.01 tons/MWh
- CHP - 0.443 tons/MWh

The carbon footprint for the above calculations is shown in figure 32.2.

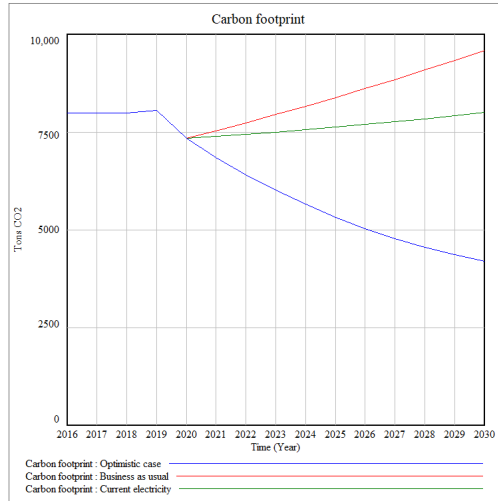


Figure 32.2: Carbon footprint of electricity consumption

32.2. Heating requirements

The heating for the campus buildings is supplied by 2 sources, they are:

- CHP
- Boilers

The CHP plant is capable of producing both electrical power and heat by utilising natural gas as the fuel. The CHP and the boilers work in conjunction to support the heating requirements of the buildings on campus with boilers contributing about 60% and CHP contributing the remaining 40%. The heating requirement data was obtained for the last 5 years and was accordingly utilised in the model.

Similar to electricity consumption, three scenarios were developed to project the carbon footprint due to heating for 2030. Table 32.2 summarises the annual rates of change for each scenario. The rates of change for CHP for each scenario was taken the same as for electricity consumption scenarios. The annual change in Boilers is not considered as it is a function of CHP, it is modelled to meet the deficit heat demand not supplied by CHP.

- In the current scenario, the average change in the heating requirements

for the years 2016-20 was taken. It was observed that there was an average drop in the consumption by 2.27% annually.

- The business as usual considers that there are no improvements in the heating infrastructure. Therefore, there is no change in the annual rate of change for heat consumption in this scenario.
- For the optimistic scenario, a 3% decrease in heat consumption was considered which is slightly better than the current scenario. This can be largely brought about through better heating infrastructure in the buildings.

Scenarios	Annual rate of change (%)	
	Heat consumption	Heat from CHP
Current	-2.27	0.3
Business as usual	0	3
Optimistic	-3	-8

Table 32.2: Rate of change regarding heating requirements for each transition scenarios.

In figure 32.3, the effects of the factors in table 32.2 are visualised. The average annual heating requirements is expected to continue dropping in the next years till 2030.

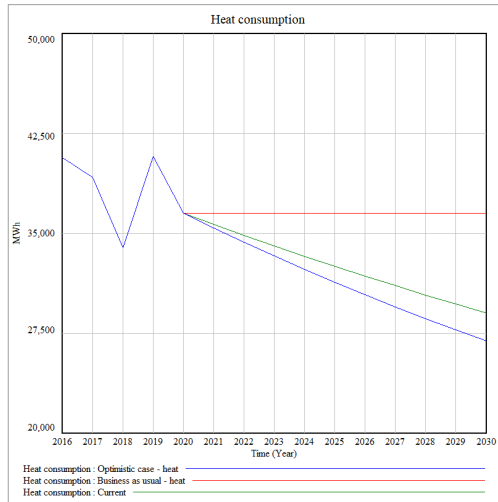


Figure 32.3: Heat consumption on campus

The heating requirements from the above figure is translated to emissions. This is calculated similarly to electricity consumption by considering the emission factors for each source of heat generation:

- CHP - 0.252 tons/MWh
- Boilers - 0.149 tons/MWh

The total carbon footprint is represented in tons of carbon dioxide for each year in Figure 32.4.

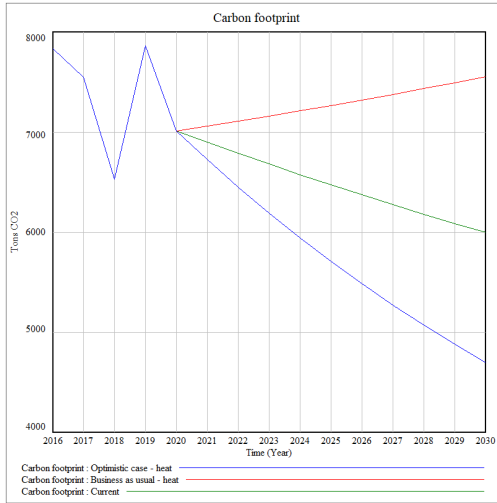


Figure 32.4: Carbon footprint of heat consumption

32.3. Assumptions and future scope

There are multiple assumptions that are involved in the estimates shown in this chapter. These assumptions had to be made due to the data that was used and also to make the projections for the year 2030 as the annual changes in the future cannot be known with certainty. Some key assumptions are as follows:

- A constant rate of change for the years up to 2030 was taken. This is unlikely to be the case as there are usually multiple variations for each due to multitude of factors. This was carried out to simplify the model.
- Electricity consumption and heating of the campus buildings saw a drop in the year 2020. A major factor for this can be the COVID-19 pandemic as significantly fewer students and university staff were visiting the campus. This factor was not considered in the estimates.
- Due to lack of solar and wind data for the years 2016-18, assumptions had to be made based on the available data for 2019-20.
- There is plans for implementing geothermal energy as the primary source of heating in the next few years. However, the year of implementation

is not known and was not considered in the model. Geothermal energy can significantly reduce the emissions due to heating on the campus, so the actual emissions can be lower by 2030 than even the optimistic case.

- The infrastructure at the campus is constantly improved towards more efficiency in electricity and heating. These future changes are challenging to accommodate in the model, but accounting these parameters can significantly improve the quality of the model.
- The emission factor for the various sources were taken based on research in the previous year. These factors can vary due to many factors. For example, emission factor of solar is dependent on the annual irradiance. A more in-depth analysis can be carried for the upcoming model to accommodate these effects.
- There are other sectors that contribute to emissions which have not been considered, like procurement, food related emissions, waste, etc. These parameters can be included in the upcoming models. But, these emissions fall in the category of scope 2 and 3 emissions which can make it challenging to find the necessary data.

Nevertheless, the model is an attempt at showing the possible pathways for creating a campus that is less carbon-intensive. The assumptions that are mentioned above can be validated and overcome in the next iterations of the model to improve the accuracy and drive the change towards a more sustainable campus.

GreenTU's accomplishments and projects in operations

With TU Delft's ambitious goals to make campus operations sustainable, many projects are being set up, covering a wide array of topics. GreenTU is involved in many of these, at times being a primary organiser, but always providing feedback and insight from students' perspectives. This chapter highlights the main projects that have been active in the 2020-2021 academic year.

33.1. Catering

Due to the pandemic, progress made in previous years towards more sustainable catering slowed down, and there were few projects. However, the canteen of the Faculty of Architecture and the Built Environment became entirely meat-free in May 2021¹. Additionally, the implementation of a carbon tax is on the agenda, which would financially incentivise more sustainable consumption patterns.

33.2. Mobility

Several pilots concerning mobility – initiated in the 2020-2021 academic year or previously – are being developed and executed at TU Delft. GreenTU has a significant coordinating presence in all of these. A new introduction is the mobility theme team within the sustainable TU Delft project, which was introduced in chapter 4.

33.2.1. Staff mobility

This project, also known as the 'Mobility Pilot' – being GreenTU's first project concerned with reducing the environmental footprint of mobility – is primar-

¹See: <https://www.tudelft.nl/en/2021/bk/restaurants-at-the-faculty-of-architecture-and-the-built-environment-are-the-first-to-offer-fully-vegetarian-menu> [cited 25 May 2021]

ily concerned with non-commuting university-related travel of staff members. For example, travel to conferences. The goal of these pilots is to encourage, and in some cases make mandatory, more sustainable means of travel, such as trains. This is done through policies which divide possible journeys into a variety of categories, to determine which mode of transportation makes sense, logistically, while burdening the environment the least.

The project was started in 2020 by Sarah van Amerongen, at the time operations coordinator of GreenTU, in cooperation with **GreenTeam AE**. Since then, **GreenTeam CEG** has become a significant contributor, setting up their own pilot at the CEG faculty. During February 2021, the GreenTeams focused on analyzing data concerning business trips of faculty members with the help of Koen Flapper (Projectmanager of Procurement at TUDelft), Jessy van Eesteren (GreenTU Operations Coordinator).

In March, the results of this analysis were presented to the Management Team of the Faculty of Aerospace Engineering, along with suggestions on effective ways to reduce carbon emissions connected with these activities. The Management Team responded enthusiastically to the proposal, and prompted that GreenTeam AE prepare a draft of possible measures to be implemented in the academic year 2021/2022. GreenTeam AE is currently working with their supervisor (Irene Fernandez Villegas, Sustainability Officer of the Faculty of Aerospace Engineering) and other members of the faculty to review these suggestions and prepare a more detailed plan on how to present the project and promote it to the public. This additional document is planned to be reviewed by the Management Team at the end of the current academic year, or at the beginning of the next (i.e., by the end of 2021).

The proposal for the Faculty of Civil Engineering & Geosciences is also being discussed with their Management Team and received well. The hope is that this pilot will be approved by the end of the academic year.

Both GreenTeam AE and GreenTeam CEG are also participating in the Mobility Theme Team created by Andy van den Dobbelsteen to share their work on the Mobility Pilot and keep updated with the future plans on Mobility for the whole campus.

33.2.2. Student mobility

During their studies, many students travel abroad to complete their minor at another university or to complete courses or a thesis project abroad. This year, plans were set up to provide students with the funds necessary to travel sustainability in Europe. If these plans are approved, students will be able to subsidise their journeys by bus or rail when aviation would otherwise

have been the go-to option.

33.2.3. Waste separation

As was explained in chapter 30, there is an ongoing pilot to improve waste sorting and decrease general waste, in which GreenTU is involved. The pandemic has thrown a spanner in the works for the waste pilot which started in the 2019-2020 academic year, as university operations drastically changed, including the generation of on-site waste. Still, the pilot was able to continue. From the few buildings it started at, the pilot is expanding and is expected to cover the entire university by the end of the 2021-2022 academic year.

33.2.4. Procurement

One of the main topics which GreenTU's project committee dedicated themselves to in 2020-2021 is the creation of a procurement manual to be used by the Transforming Education Spaces (TES) group, the details of which can be found in chapter 31. The aim of this manual is to allow for informed decisions to be made in the procurement of equipment for educational spaces. The manual consists of a certificate system and a standardised calculation to rank design choices.

33.3. GreenTeam accomplishments and projects

In the projects mentioned previously, it is not uncommon for GreenTeams to be involved when the project concerns their own faculty. As mentioned, the GreenTeams of CEG and AE are closely involved in their respective staff mobility projects. Additionally, GreenTeam TPM was involved in the expansion of the waste separation pilot to their faculty building and BK-Green was involved in the introduction of A&BE's meat-free canteen.

It is also within the ambitions of GreenTeams to introduce their own projects to make their faculty's operations more sustainable. However, students have had restricted access to the TU Delft campus during this academic year, leading this pillar to be de-emphasised.

GreenTU's vision on operations

The vision of GreenTU is for TU Delft to play a leading role in sustainability by reflecting the presence of expertise and innovative resources on campus through practice. To this end, three goals have been identified:

1. to maintain **consistency** in terms of operations throughout the university;
2. to achieve a **CO₂ neutral** university by 2030;
3. to strive for **circularity** on campus.

34.1. Operational areas

The vision of the TU Delft and therefore the property manager CRE is a climate-neutral campus by 2030. From the CO₂ roadmap of the TU Delft can be concluded that there are four main areas where a great impact on CO₂ emissions can be made. The areas food, waste, mobility and energy and buildings are therefore the four main areas the operations department will focus on. Supporting and stimulating sustainable initiatives, creating a circular campus and creating consistency in terms of sustainable operations are the methods that will be used.

Creating a circular campus is a part of reaching a carbon-neutral campus. The operations of GreenTU will focus on circularity by creating operations concerning this in bigger scales such as the project management in the TU Delft and on a smaller scale by creating alternatives to single use products for students and employees. Consistency is another pillar of GreenTU's vision. Impact is made by TU Delft wide projects instead of local projects per faculty. University wide implementations will impact the large campus and society of the TU Delft instead of small fractions.

These goals will be achieved within four areas:

1. **Energy & Buildings:** Firstly, we aim to minimise the use of energy, through the use of smart systems, the renovation of existing buildings and the procurement of energy neutral buildings. Secondly, we want to be a forerunner in the promotion of fossil-free energy and the reduction of the use of natural gas.
2. **Mobility:** A major cause of emissions by the university is mobility, ranging from daily commute to international flights. We aim to reduce this emission by promoting alternatives; like public transport or cycling for daily commute and public transport and video conferencing for long-distance flights.
3. **Waste:** The reduction of material wastage and loss of product life cycle is an important step towards a circular campus. We aim to achieve this goal by the introduction of pilots, which after positive results can be extended to the rest of the campus.
4. **Food:** The food consumed on campus is one of the largest causes of greenhouse gas emission associated with university operations. We seek to reduce this emission by promoting a plant-based diet, sourcing food locally and reducing food waste.

34.2. Consistency and the scales of initiatives

Supporting and stimulating sustainable initiatives will be executed from top-to-bottom and bottom-to-top, which we can see as scales. These scales are important because change can be made by working together with the people implementing, executing and/or effected by operations, instead of only using one group. GreenTU can support and stimulate operations through facilitating and creating pilots, connections within the TU Delft and create a support base under students.

The scales GreenTU works with, and their distinguishing characteristics, are:

1. **Guardian angel** (top-down): Hold TU Delft accountable for realising their set goals; by providing and collecting data on the four areas, creating roadmaps based on the given data and prioritising its execution.
2. **Execute:** Perform as much as is in our own power.
3. **Inspire** (bottom-up): Inspire, finance and consult on sustainable initiatives by students and staff.

For the operations of the campus to be manageable throughout the shift to a circular campus, consistency must be safeguarded. To this end, operations will be tested and implemented through pilots in a step-by-step process, as shown in figure 34.1.



Figure 34.1: Roadmap to bringing pilot projects to full implementations

34.3. Food

Carbon emissions from the Agriculture, forestry, and other land use (AFOLU) sector represents around 24% of global GHG emissions (10-12 GtCO₂-eq/yr). The emissions from the food and catering sector constitute an important part of the scope 3 emissions. As a university and an organisation with large resources, TU Delft can play a considerable role in moulding the cultural and behavioural aspects of its stakeholders towards responsible consumption and reducing the negative impact on the environment.

In the year 2020, the CO₂ roadmap has shown that according to the standard Dutch diet and several other assumptions, TU Delft is currently responsible for 13,800 tCO₂ equivalent of emissions from food consumption. This is the highest amount of emissions compared to other operations related activities. Most of these emissions are related to meat consumption on campus.

Vision for sustainable catering and food consumption

- Reduce scope 3 emissions due to meat, dairy, cutlery, packaging and food waste,
- Define healthy and sustainable food standards for the caterers and campus restaurants.
- Increase awareness among consumers towards alternative options

With this vision, the authors define the following goals to be achieved in the next ten years:

- perform a study on the impact of food on carbon emissions based on accurate data form the caterers and restaurants.

- In addition to the environmental impact, focus on personal wellbeing and healthy lifestyle.
- Take measures towards reducing the meat consumption and increase vegetarian options.
- Reduce the use of disposable cutlery and plastic packaging
- Expand the current pilots such as 'no meat week' to all faculty cafeterias and make it an annual and biannual tradition.
- Define healthy and sustainable standards for caterers and restaurants for procurement, menus, preparation and waste disposal.
- Study business cases focusing on sustainable food options to support the restaurant owners and assure that it is economically feasible and profitable.
- Define guidelines for catering large meetings and events by applying sustainable menus, reducing food wastage and avoiding disposable cutlery.
- Create awareness among the stakeholders about the emissions from food.

34.4. Strategy

The reduction of emissions from the food and catering sector is a critical task that needs a collective participation of all stakeholders. It is important that top down initiatives come to light from the university and the caterers. Achieving this depends on the commitments, policies and social responsibility.

In the current strategy, we approach sustainability in food based on various initiatives that are achievable in a time span of 10 years and presenting what each stakeholder can contribute to. This includes TU Delft campus operations, caterers, restaurants, food truck owners, student organisations and consumers. The main student organisations working on the sustainability of this sector are Food and More, Foodsharing Delft and GreenTU.

Standards for procurement

As part of the credits allocated to the operations of an academic institution, STARS has two types of credits related to Food & Dining, namely: 'Food and beverage purchasing' and 'sustainable dining'. The standards and terms under each credit type are aimed to recognise institutions that supports a sustainable food system.

Food and beverage purchasing

"As an academic institution, TU Delft has the capacity, through its purchasing power, to demand for transparency on the source and quality of food from producers and distributors. This purchasing power, if applied properly, can be translated into a positive contribution and encouragement to have humane, environmentally friendly and sustainable farming techniques. This is important as well for reducing poverty amongst farmers and unsafe working conditions [12].

The criteria proposed for 'Food and beverage purchasing' require food in the university's restaurants and caterers to be sustainably or ethically produced, through the following standards and terms:

- **Short food supply chain (SFSCs):** SFSCs are supply chains with a minimal number of intermediaries between farmers, harvesters, distributors and the institution. Examples of SFSCs are regional food hubs, regional farm-to-institution programs, direct sales, contract production, organic farms cooperatives, and community-supported fishery programs. The measures taken for the implementation of SFSCs has been briefed by the European Parliamentary Research Service under the name 'Short food supply chains and local food systems in the EU'.
- **Small producers:** In accordance with the World Fair Trade Organization (WFTO) and Fairtrade International, a small-scale produced is one that is "not structurally dependent on permanent hired labour", by managing production activity mainly with a family or owner-operator workforce.

Other criteria for an ethically and sustainably produced food include: sustainable agriculture techniques, sustainable seafood practices, fair trade and fair labor, as well as humane animal care. One possible and recommended tool for meeting these criteria is the requirement of international and/or regional verification standards and certificates from producers. However, this may not be always possible and affordable for small farmers to get

these standards and certificates. Amongst the verification programs recommended by STARS is the 'Real Food Challenge' (RFC) . RFC is an organisation that collaborates with schools and universities in the United States of America to have a sustainable food system by spreading awareness and providing 'real food' certifications. Although their work area is only in the U.S., TU Delft can benefit from their elaborated standards. Focused on the level of production, Real Food standards request food products to be [6]:

- **Local and community based:** This includes prioritising small- and mid-size farms and food businesses, diversified ownership and control, reduced distance between consumers and producers, and traceability.
- **Fair:** Fair work translates into work with dignity, worker bargaining and advocacy, fair compensation, safe working environment, non-discrimination, gender equity and gender justice, and job security.
- **Ecologically sound:** This includes ecologically sound pest management, soil conservation, biodiversity and habitat protection, water conservation, and sustainable waste and energy management.
- **Humane:** This focuses on humane animal treatment through: nutritious feed free of non-therapeutic antibiotics and hormones, low stress environment, limited physical alterations, careful handling, minimise transportation, and humane slaughter.

V

Social engagement

Introduction to social engagement

The fourth and final pillar of TU Delft to achieve sustainability is social engagement. Social engagement is essential to achieving sustainability for several fundamental reasons. Of course, the desired shift in the functioning of TU Delft described so far cannot be achieved by GreenTU or even the wider sustainable TU Delft framework, as long as it lacks support from university staff and students. Bottom-up initiatives have proven to be received well. Furthermore, many changes, such as those in operations, require active individual participation, something impossible to achieve without social engagement and awareness about the mission of GreenTU. Additionally, TU Delft should do its part in creating a fair and just world by embodying these values in its campus community.

Across TU Delft, there are many groups which have similar goals when it comes to social engagement. These will be elaborated on. When linking this to sustainability, the events and career committees of GreenTU play a part, as do other student initiatives. This chapter focuses on three main areas on which the pillar of social engagement stands on: communication, stakeholder engagement & events, and diversity & inclusion. This is followed by the projects undertaken and accomplished by GreenTU, as well as the vision for social engagement. The vision is to focus on raising the importance of this aspect engaging with various associations and individuals that work towards this goal to reduce lack of awareness of the issue of climate change and help people take the right steps to mitigate it.

Communication

The Information Age, which has been on the rise over the past few decades thanks to the internet has revolutionised the mode of communication. Using this to the advantage, a sustainability website has been put in place by the university to keep track of the various initiatives and events that happen in and around the campus. GreenTU, on the other hand keeps its own section in this sustainability website updated with all the work done by the board, Green Teams as well as the committees¹. Social media platforms like LinkedIn², Facebook³ and Instagram⁴ are used by GreenTU to provide information from time to time in an engaging way.

The Instagram account is handled mostly by the communication & events coordinator of GreenTU and the events committee. All the updates on different kind of sustainability activities on campus of GreenTU as well as other related organisations are posted here. For example, the **#mondayinitiatives** hashtag is used to highlight different initiatives in and around Delft. The **#gettinggreener** hashtag represented different actions to make your daily life more sustainable. Next to these, there was a weekly story update about all upcoming events.

The career committee also has a **#careerfriday**, where various careers regarding sustainability are updated weekly on the LinkedIn, Facebook and Instagram pages of GreenTU. All the separate GreenTeams have their own Instagram channels through which they are connected with the students of their respective faculties. This helps in delivering information to the students and also get their feedback in the form of surveys organised.

The annual sustainability report of GreenTU is another means of giving updates on the different aspects covered by the university in terms of sustainability and this very report is the second edition in that series. This full-length

¹See: <https://www.tudelft.nl/sustainability/get-involved/greentu--although-notethat,atthetimeofwriting,thiswebsiteisunderconstruction>. [cited: 1 July 2021]

²See: <https://nl.linkedin.com/company/tu-delft-green-office> [cited: 1 July 2021]

³See: <https://www.facebook.com/GreenTUDelft/> [cited: 1 July 2021]

⁴See: <https://www.instagram.com/greentu.delft/?hl=en> [cited: 1 July 2021]

report, summaries of each of the chapters and their visions is incorporated along with the executive summary of in GreenTU's website⁵. All this information is public and can be accessed by anyone.

⁵See: <https://www.tudelft.nl/sustainability/get-involved/greentupillars/research/review-and-strategy-report> [cited: 1 July 2021]

Stakeholder engagement & events

In this chapter, stakeholder engagement reflects on encouraging and facilitating interest at TU Delft (in the first instance of students) in sustainability and climate action. There are many (student lead) organisations active in Delft which contribute to this goal, often times by organising social events, individually as well as collaboratively. This chapter aims to provide an introduction to some of these organisations and their activities.

37.1. Delft Climate Coalition

In January 2021, many organisations active in Delft came together to discuss setting up a climate march prior to the Dutch general election that would follow in March. With the broad network created, the march (which was stationary, to keep in line with covid-19 restrictions) was organised and promoted to great success. Since then, the Climate Coalition has remained active to strengthen bonds between organisations.

The Delft branch of **Extinction Rebellion** has so far played an important coordinating role in the Climate Coalition, which has also set up the group **University Rebellion Delft**. Other participating organisations¹ are **Stichting Delft Bloeit**, **Delft4GlobalGoals**, **Luchtwachters Delft**, **Milieudefensie Delft**, **Natuurlijk Delfland**, **Platform Energietransitie Delft**, **Scientists4Future Delft**, **Stichting Kindertuinen Delft**, **Students4Sustainability**, and **GreenTU**. Several of these organisations are elaborated on slightly in the coming sections. GreenTU has not played an active role in the coalition since the march, due to time constraints, but this could change in the coming academic year.

¹See: <https://www.klimaatcoalitiedelft.com/organisaties> [cited 8 July 2021]

37.2. Students4Sustainability (S4S)

The mission of S4S is to stimulate sustainability in various areas, both on a small scale and globally. S4S wants to inform and inspire students about the possibilities that sustainable techniques have to offer, through activities such as lunch lectures and workshops. This organisation is run by the students of Delft and is currently focused on implementing sustainable projects in Africa.

The **Students4Sustainability (S4S)** has conducted plenty of events over the last year, the most notable being their yearly symposium **Biomimicry** which was conducted online due to the pandemic and the restrictions imposed. Biomimicry is a practice that learns from and mimics the strategies found in nature. This practice generally occurs in design but could also be implemented in business structures. During the symposium, biomimicry was introduced by the speakers and its potential has been discussed².

A lunch lecture was conducted with the speaker from **MilieuDefensie**, the first company to hold Shell responsible for carbon emissions. A music festival with a theme of sustainability called **Festable** was also organised. Many other events including a photo contest was also held this year³.

37.3. Energy Club

The Energy Club was founded in the year 2009 by the Delft Energy Initiative and is committed to providing opportunities to sustainability enthusiasts. The vision of the club is to act as a platform to connect students with key policy makers as well as researchers in the sustainability industry and facilitate in energy transition.

The **Energy Club** organised few lunch lectures over the past year in collaboration with various companies like Guidehouse, Deloitte, Eneco, McKinsey & Company, and so on. Guidehouse provided an insight into how to transition into a consulting career in energy and sustainability. A senior expert from McKinsey & Company presented a report on how the European Union can cut down the carbon emissions to net zero with net zero costs. The Deloitte event comprised of a lunch lecture about the future of energy and a follow up event on how to transition into careers in consulting related to energy. A lunch lecture by Eneco was held where the company's work on offshore wind turbines has been discussed. Similarly plenty of other events

²See: <https://www.students4sustainability.nl/en/evenementen/online-symposium-biomimicry-19> [cited 29 June 2021]

³See: <https://www.students4sustainability.nl/en/evenementen/archive> [cited 29 June 2021]

have been organised by Energy Club⁴ and also helped organise **Days of Sustainability 2020** along with many other associations, including GreenTU.

37.4. Centre for Sustainability Students

The Centre for Sustainability (CfS) is an interdisciplinary research centre of the three universities in the LDE network: TU Delft, Leiden University, and Erasmus University Rotterdam. The centre is focused on interdisciplinary cooperation to work towards environmental sustainability and a circular economy. Researchers contribute following an open research format called Knowledge & Innovation Hubs.

Knowledge and innovation hubs form the core of this group's centre⁵. A hub is an open research programme that connect master students, researchers, municipalities and businesses and the focus is on the province of Zuid-Holland covering three areas: cities, horticulture and industry. Each hub is open to master students from the universities Leiden, Delft and Erasmus. Through the student board associated with the CfS – CfS Students – helps connect master students to these hubs for their thesis projects. The main aims of the hub are:

- Formulate research topics that are demand-driven in collaboration with external stakeholders.
- Providing master students with the connections and resources to go about their research with impact.
- Develop and promote interdisciplinary research among the three universities.

Every hub has its own coordinator who reaches out to partners and formulate the scientific research themes together.

Additionally, CfS Students has organised many events over the past year, which mainly comprised of online lectures by various professionals, from both academia and industry, relating to sustainability⁶.

37.5. Scientists4Future Delft

This is a group of concerned scientists in and around Delft which is a part of a bigger organisation Scientists4Future NL whose main focus is to raise aware-

⁴See: <https://www.energyclub.nl/past-events> [cited 29 June 2021]

⁵See: <https://www.centre-for-sustainability.nl/about-us> [cited 29 June 2021]

⁶See: <https://www.centre-for-sustainability.nl/calendar> [cited 29 June 2021]

ness and promote change for the well-being of Netherlands and the rest of the world. Even though the group is highly concerned about climate change and find ways to prevent it, most of the group are not experts in climate science and are from very diverse backgrounds⁷.

Scientists4Future Delft collected mandates from various researchers to participate in a physical protest at Delft municipality office which was organised by Delft Climate Coalition on 14 March 2021. Apart from this, the group is quite active with regular posts related to sustainability and have regular meetings to discuss this aspect as well as attend and conduct keynote lectures.

37.6. Foodsharing Delft

Foodsharing Delft is an organisation that aims to reduce food waste around Delft and accelerate the transition towards a food-waste-free society. The aim of this organisation is to increase sustainability and reduce planetary emissions by decreasing the wastage of food. Social media is used in order to spread awareness about food wastage and the events organised.

IChange⁸, a foundation dedicated to reducing food waste which is currently established near Delft station, also hosts a community fridge and pantry, which is stocked by Foodsharing Delft. The Foodsharing community organises weekly pickups to distribute the 'wasted' food that can no longer be sold in shops and cannot be accepted by Voedselbank (Food Bank). A goal currently being worked towards is to create an app where TU Delft and similar parties can indicate whenever there is leftover food, such as after a catered event, so that it can be picked up and distributed through the community. This would increase the amount of food waste saved even further. The organisation aims to collaborate with other organisations in the future and raise awareness in the local government and student representatives at TU Delft for their cause of reducing food waste.

37.7. IESA Shift

This is a study association for industrial ecology students at TU Delft and Leiden University. Besides organising events for their own students to get to know each other, the association organises events to spread awareness on sustainability. Shift aims to enrich student life by providing opportunities for networking with other students as well as companies to gain knowledge

⁷See: <http://delft.scientists4future.nl/about/> [cited 29 June 2021]

⁸See: <https://i-change.nu/> [cited 29 June 2021]

about different relevant topics in the field of industrial ecology and developing professional skills based on the three pillars⁹:

- **Educational:** Help and motivate students in their thesis research and future career.
- **Social:** Create connections with alumni and everyone involved with industrial ecology.
- **Professional:** Equip students with the right skills and information needed for their careers.

Various online lectures have been organised over the year. Also events related to Student Well-being have been organised. A scavenger hunt event has been organised in the cities of Delft and Hague which was one of the first in-person events after the restrictions eased. Many other activities have also been conducted over the past year and ensured interaction among students¹⁰.

37.8. Delft Sustainable Energy Association

This is the study association of Sustainable Energy Technology (SET) master track and organise events in collaboration with industries focusing on the sustainability aspect. The association aims to help the students and alumni of SET with following points¹¹:

- **Academic:** Promote interaction among the students and alumni as well as the professors.
- **Social:** Create connections with alumni and students of SET.
- **Career:** Connect students with organisations and companies in renewable energy and sustainability.
- **Cultural:** Bridging the gap for the students of different backgrounds in the university.

The **Delft Sustainable Energy Association** has conducted plenty of events over the last year with sustainability as its theme. Few of them are the Sustainable Startup Event in collaboration with YES!Delft. A lunch lecture was

⁹See: <https://www.iesashift.nl/about-shift/> [cited 29 June 2021]

¹⁰See: <https://www.iesashift.nl/events/> [cited 29 June 2021]

¹¹See: <https://delftsea.nl/about-us/> [cited 29 June 2021]

organised with Sunrock in November 2020 which was followed by a case study in April 2021. Sunrock is the largest company in the Netherlands for roof-top solar PV installations. Similarly, many other events including a CLASP Webinar have been conducted¹².

¹²See: <https://delftsea.nl/events/> [cited 29 June 2021]

Diversity & inclusion

To achieve a sustainable campus community, virtues such as justice, equality, and inclusion are essential. TU Delft, being a global university, has a lot of diversity and this concept of inclusion is addressed in the UN SDGs **Gender Equality** and **Partnership for the Goals**. This diversity expresses itself in many ways, from race and ethnicity, to gender, personal limitations, financial position, and religious and cultural background, to name a few.

38.1. Diversity & Inclusion Office

The **Diversity & Inclusion (D&I) Office** at TU Delft ensures that everyone as part of the university feel at home regardless of their sex, age, background, sexual orientation or disability. At TU Delft, people are central and it so happens that a very diverse community exists to build a good foundation for knowledge sharing. Inclusion helps improve ability of all the parties involved ; the scientists, support staff, students and so on to participate in the university life actively. D&I office focuses on seven themes and are subject to change over time to keep TU Delft community vibrant and inclusive¹:

- Gender equality
- Gendered Research & Innovation (GRI)
- Study and work success and representation
- Institutional support & well-being of students and staff
- Further professionalisation of recruitment with regard to diversity and inclusion
- Religion and spirituality
- Supportive services for employees and students with disabilities

¹See: <https://www.tudelft.nl/over-tu-delft/strategie/strategiedocumenten-tu-delft/diversiteitsbeleid/zeven-themas> [cited 29 June 2021]

38.2. DEWIS

Another network within the university called **DEWIS** comprising of women scientists help in attracting more women and grow in the academic field. Another important goal for DEWIS is to reach a male-female ratio that more accurately reflects the society. The board of DEWIS has a mission to advance, attract and retain academic women within TU Delft. DEWIS formulated a strategy to organise activities which will help reach the objective of a gender-diverse TU Delft with equal opportunities for all around the three themes²:

- Creating Awareness
- Influencing policy
- Connecting

DEWIS offers peer-to-peer learning which helps to work on improvement in the quality of work and teaches to approach situations better as well as improve the creativity in finding solutions³. Every year DEWIS also conducts a symposium inviting women from prominent fields of academia and industries⁴.

38.3. True U

True U⁵ is the lesbian, gay, bisexual, and transgender (LGBT) network for TU Delft employees. It is dedicated to a working environment in which everyone can feel safe and accepted, regardless of sexual orientation or gender expression. One way in which True U contributes to this is by giving LGBT staff members opportunities to connect with each other and exchange experiences and knowledge. By giving the LGBT community at TU Delft a face, the network also serves as a sounding board in decisions of university management.

²See: <https://www.tudelft.nl/over-tu-delft/strategie/strategiedocumenten-tu-delft/diversiteitsbeleid/dewis/activities-dewis> [cited 29 June 2021]

³See: <https://www.tudelft.nl/over-tu-delft/strategie/strategiedocumenten-tu-delft/diversiteitsbeleid/dewis/activities-dewis/peer-to-peer-learning> [cited 29 June 2021]

⁴<https://www.tudelft.nl/over-tu-delft/strategie/strategiedocumenten-tu-delft/diversiteitsbeleid/dewis/activities-dewis/dewis-symposium> [cited 29 June 2021]

⁵See: <https://www.tudelft.nl/en/about-tu-delft/strategy/strategy-documents-tu-delft/diversity-policy/true-u> [cited 29 June 2021]

True U is also in contact with DHW⁶ (Delft Working Group Homosexuality). The youth branch of DHW, Outsite⁷, is open to anyone under 29 years old who identifies as LGBT+. They offer students a variety of ways to explore and expand their network among fellow LGBT+ people.

⁶See: <https://dwhdelft.nl/> [cited 29 June 2021]

⁷See: <https://outside.nl/> [cited 29 June 2021]

GreenTU's accomplishments and projects in social engagement

A large part of GreenTU's activities, and particularly those activities that students are aware of, relates to social engagement. The main reason of most events that GreenTU sets up throughout the year, relates to social engagement. This chapter provides an overview of these. Within GreenTU, the events and career committees are largely responsible for conducting various kind of events, but many events are also conducted in cooperation with other organisations, in aspiration of becoming the umbrella organisation that GreenTU aims to be.

39.1. Day of Sustainability Symposium

Since 2015, a yearly symposium has been organised for the Dutch 'Dag van de Duurzaamheid' (Day of Sustainability) on 10 October. This is a collaborative event of all sustainable organisations in and around Delft.

In 2020, the theme was the event was Doughnut Economy. A keynote speaker from the Ellen McArthur foundation presented and had a Q&A session, which was followed by several lectures and workshops. Topics ranged from the energy transition, to indigenous knowledge, to DIY projects for at home. This was the first online edition, to which there were many positive responses. The symposium as a whole had around 300 participants.

In 2021, the theme will be 'The Roaring Twenties?' in which the need for change in the coming decade is addressed. This is compared to the social and economic changes of the 1920s.

39.2. Career days: *Green Maze*

One of the main priorities of the **career committee** was to organise a big event. After brainstorming about the purpose and content of the event a collaboration with S4S was made, because of a shared goal to show TU Delft students perspective in a career in sustainability. Together with S4S, a **two-day career event** was organised, consisting of inspirational lectures, cases and workshops online.

Amidst the COVID-19 pandemic and its challenges, a successful first edition of this online career event was organised, under the title of the Green Maze. The speakers were great and it was well attended, setting a positive precedent for coming editions.

39.3. *A Slow Christmas weeks*

The **events committee** organised two thematic weeks in which people were informed about **celebrating winter holidays sustainability**. In these weeks, the events committee posted regularly on social media on topics such as gift giving and wrapping gifts. Besides to this, two events were organised too: a gift wrapping workshop and an escape game themed around climate refugees.

39.4. *Low Waste Challenge*

This was one of the biggest events by the **events committee** this year! In these weeks, the committee challenged GreenTU's Instagram followers to complete up to nine **methods of reducing household waste** per week, for which they would get a reward. In support of that, a lecture with two restaurants whose aim is to use food that would otherwise be wasted was organised, as well as a clean-up, where litter was collected around Delft.

39.5. *OWee movie nights*

During the orientation week for incoming bachelor students, known in Delft as the OWee, GreenTU organised **two viewings of *An Inconvenient Truth*** on campus. This was an opportunity for new students to learn about GreenTU and the challenges they will face as engineers.

39.6. *Smaller GreenTU events*

Besides the events mentioned so far, GreenTU's events and career committees have also conducted smaller events.

39.6.1. Committee Pubquiz

At the start of the academic year, the **events committee** organised a get-together for all committees (events, career, research and projects) to get to know each other and start a fruitful collaboration.

39.6.2. *Life on Our Planet* movie night

During this movie night, the **events committee** screened David Attenborough's *Life on Our Planet* and discussed the different facets.

39.6.3. Canoe clean-up

After the success of the clean-up during the Low Waste Challenge (section 39.4, the **events committee** decided to organise another clean-up, with a twist: participants canoed along the waters of Abtswoudse Bos, **collecting litter** as they went.

39.6.4. Lunch lectures

The **career committee** has organised several **lunch lectures** with student teams and companies that are at the forefront of sustainable innovations and technologies. They wanted to offer low-threshold opportunities for TU Delft students to get inspired and informed about what pioneers in sustainability are working on. Students can join the lunch lectures online and get the chance to ask their questions to the experts during a Q&A. The committee is extremely satisfied with the number of students attending the lectures of the student team AeroDelft, the start-up Pyropower, and the energy cooperative Deelstroom Delft. This is definitely an initiative to be continued in coming years.

39.7. Smaller partnered events

Apart from organising events on its own, GreenTU collaborated with various third parties to conduct events.

39.7.1. Climate Strike participation

In collaboration with Extinction Rebellion, GreenTU promoted and joined a (small) climate strike which was part of a national initiative. Due to COVID-regulations, the strike was limited in the amount of people allowed to be present.

39.7.2. Composting workshop with X

The first offline event of the year! The **events committee** set up two workshops about composting in the Community Garden of X in which we looked together at the different types of food waste together with composting expert Rutger Spoelstra. The composting workshop was part of the symposium *Food for Thought* that was hosted by **Centre for Sustainability**.

39.7.3. Docubate Collaboration SG

In the context of the **Studium Generale** series of events following the theme of decolonisation, the **events committee** set up a docubate evening in collaboration with **University Rebellion**. Films on the environmental and human costs of the fast fashion industry were viewed and discussed.

39.7.4. Election debate

In collaboration with **Studium Generale** and the **Central Student Council**, a **climate action debate** among the youth factions of most popular Dutch political parties was organised. The factions' positions on several statements concerning climate action were discussed.

39.7.5. Garden community events

After the renovation of the university garden at X, GreenTU was invited to contribute to the events hosted for garden community members. So far, this has included a workshop for composting organic household waste, but more events are to follow.

39.8. Multimedia engagement

For years, the (social) internet has played an increasing role in everyday life. This could not be any more true for the 2020-2021 academic year. Besides the online events mentioned so far – which are optimistically assumed to be outliers in the grand scheme of things – GreenTU has been creating an online presence through social networking platforms such as Instagram and LinkedIn, as well as a sub-domain of the TU Delft sustainability website. Two more productions of GreenTU are the podcast *Sustainable Goalgetters* and the annual sustainability report.

39.8.1. Social media

In order to make the students aware of the various committees in GreenTU and their functions, the **events committee** proposed an idea of various com-

mittees (career, events, research and projects) taking over the Instagram account of GreenTU and familiarise the followers with the team and their contribution within GreenTU. Examples of this include the **#mondayinitiatives** and **#gettinggreener** hashtags.

One of the ways that the **career committee** has tried to motivate and raise awareness has been through creating **#careerfriday**. Almost every Friday of this academic year, there has been a new post on the GreenTU Instagram page about a current vacancy fitting students in the area of sustainability, or a post highlighting a past TU Delft Alumnus currently working in sustainability. With these posts we hope to have raised awareness about all of the possibilities and provided a realistic view of the job-market, giving evidence that there is truly a demand for more sustainable careers. This is an ongoing task which we hope will be carried on by our successors.

Along with **#careerfriday**, the career committee has busy with recording a **series of short interviews** with professionals working in sustainability, in startups or larger companies, which are accessible online¹. These interviews aim to help students gain insight into what it is actually like, and to pass on the wisdom of professionals, almost entirely TU Delft graduates, who have chosen a career in sustainability.

In order to increase awareness on both sustainability in general and the projects of the individual **GreenTeams**, they are publicised on Instagram in their individual accounts and has quite a good reach among the students. Through this social media it has been possible to communicate the events, important milestones and updates in the projects undertaken by the teams, and general sustainability (fun) facts.

39.8.2. Podcast

In cooperation the board of AISEC in Delft – who are dedicated to leadership development and cross-cultural internships – and ORAS – a party on the central student council of TU Delft – GreenTU set up and published a **podcast**, *Sustainable Goalgetters*².

The goal of this podcast is to highlight what is being done to achieve the UN SDGs. Each episode, a particular SDG is discussed, with topics treated including sustainable housing and construction initiatives at TU Delft, student innovation in sustainable transportation, and what the construction of TU Delft's geothermal well means for the surrounding region.

¹See: <https://anchor.fm/greenttu-career> [cited 20 July 2021]

²See: <https://anchor.fm/sustainablegoalgetters> [cited 12 May 2021]

39.8.3. Sustainability report

This topic will need little explaining. You are already reading the 2021 edition of the GreenTU sustainability report. This report is coordinated by the **research committee** was first published in 2020 and attempts to highlight all the ways in which sustainability is relevant to TU Delft. One purpose of this report is to introduce interested parties to these topics, but it is also used to bridge the gap between those who are already intimately familiar with a certain aspect of sustainability at TU Delft, but who are missing a larger picture.

39.8.4. GreenTU website

GreenTU has a website³ which is constantly updated covering various facets of sustainability work done on the campus. The inventory reports of various GreenTeams, as well as the yearly sustainability report along with their summaries, are uploaded here, which can be accessed publicly. The goal of this website is to inform anyone interested to learn about GreenTU's vision and activities.

39.8.5. Sustainable living guides

To provide students with easy and affordable ways to become more sustainable, GreenTU published the series *Guides to Sustainable Living*⁴. The series is authored by a team of Industrial Ecology students. The topics range from food and waste to sustainable travel and setting up events.

39.9. Sustainability label

With the help of the Green Office of the University of Groningen, GreenTU has introduced the Sustainability Label. This idea arose from the acknowledgement that all parties of the university need to take action to tackle the climate crisis. As student initiatives affiliated with the university play a big part in setting an example for the students, it is important that they also strive for a more sustainable university and thus society.

The Sustainability Label is a checklist that can be used to measure how sustainable a student organisation is. All organisations and associations that are located in Delft and focus on students of TU Delft can participate in the Sustainability Label.

³See: <https://www.tudelft.nl/sustainability/get-involved/greentu> [cited 14 June 2021]

⁴See: <https://www.tudelft.nl/sustainability/get-involved/greentu/research> [cited 1 June 2021]

If they decide to fill out the checklist and send it to GreenTU, they might be awarded a label in recognition of their efforts. The labels are categorised as bronze, silver and gold. If you are awarded a Sustainability Label, the logo can be put on your site for members and companies to see. In the following years, the association can further improve its sustainable practices and get a higher label. Associations can apply for a label by sending in a completed checklist.

39.10. Subsidies for student societies and study associations

In support of sustainable initiatives by TU Delft associations or students, GreenTU offers sustainability subsidies. The subsidies are awarded to facilitate concrete ideas that create a positive change with a high impact.

Applying for a subsidy can be done by sending in a short business plan indicating the impact and a clear calculation of the money needed.

39.11. Green Delft network

Delft has a lot of green initiatives, each with their own entourage. To allow for collaborations and promoting each other's events, the Green Delft network has been set up in collaboration with Students4Sustainability. This network consists of a group's chat of the following organisations: GreenTU, Students4Sustainability, Delft Sustainable Energy Club, Extinction Rebellion, Foodsharing, IESA Shift, All Energy day, Centre for Sustainability and Energy-club

39.12. Student Sustainability Council

Several times per year, GreenTU holds plenary meetings for student organisations. Here, topics are discussed such as GreenTU's available subsidies. The core purpose is to inspire associations to improve the sustainability of their activities. This is partially accomplished by allowing them to exchange ideas and experiences, as they often share common goals and methods.

39.13. The Hive

In 2019, GreenTU arrived at an agreement with CRE to use a space on the ground floor of The Fellowship (on the south campus; building 66). This

space, called The Hive⁵ was refurbished, including the acquisition of a range of used furniture and a CO₂-neutral coffee machine.

Due to the pandemic, this space has only been used sparingly, to host meetings in accordance with the 1.5 metre regulations. The imagined purpose of The Hive, once safety considerations allow for a more intensive use, are much wider than a place for meetings. It is to be a meeting place in a broader sense, inviting people interested in sustainability at TU Delft to have a look and be inspired. This is to be accompanied by an exhibition space, a library of relevant publications and textbooks, and a sustainable concept store.

39.14. GreenTeam accomplishments and projects

Social engagement is one of the primary tasks of GreenTeams. They work to embed sustainability into the education and operations of their faculty, but they must of course do this in a way that staff and students can get behind. To engage the members of their faculty in sustainability, GreenTeams have undertaken, and are undertaking, a number of initiatives.

39.14.1. Awareness of sustainability among students

Almost all of the GreenTeams are active on their social media accounts in LinkedIn and Instagram in order to keep the students updated about the steps being taken for sustainability inclusion in their curriculum as well as to gather their opinions regarding the same.

39.14.2. Name recognition among students

GreenTeams are still a young concept, with many GreenTeams celebrating their first anniversary in 2021. Additionally, GreenTeams perform a majority of their work behind the scenes of their faculty, in ways students won't notice if they aren't made aware of these efforts. As such, dedicated efforts are being made to spread information about the GreenTeams' activities. A selection of examples is included here.

Each quarter, the magazine committees of the study associations of 3mE publish a magazine. To increase the awareness of sustainability at their faculty, **Green-mE** filled one page in the Slurf about who they are and what they are doing. In the future, the team hopes to keep writing articles in the magazines to increase awareness and to inspire students about sustainable aspects

⁵See: <https://www.tudelft.nl/sustainability/get-involved/greenttu/the-hive> [cited 29 June 2021]

of engineering.

39.14.3. Civil Engineering & Geosciences career week

In the last week of March, **GreenTeam CEG** collaborated with the study association of Applied Earth Sciences, Mijnbouwkundige Vereniging, to organise an online sustainable career week of the faculty, for the students of the study. Sponsored by Witteveen+ Bos and GreenTU, the event consisted of a series of six talks from industry professionals, as well as academics, that gave the students a glimpse of their projects and the possible career paths after graduation. Companies present included Witteveen+ Bos, Space4Good, Stichting DAP, KNMI, and Aqysta.

The event witnessed an attendance of over 100 students and was received well by the audience. The team further collaborations within the faculty, such as with civil engineering study association Practische Studie, to organise a similar event for students of that study.

39.14.4. Warmetriendag

Green-mE and **GreenTeam CEG** organised a photo contest which was themed around the energy-saving initiative *Warmetriendag* (warm jumper day), that annually takes place in February. The teams have used this national event to create awareness around mitigation of heating usage (in winter) and added a competition element to it. It was a fun, easy, and accessible event. The first 20 participants to share how they stay warm with the heater turned down received a coffee coupon at sustainable coffee places in Delft. The main prize was a 50 euro gift card for a plant. Overall, this was a successful day with quite some entries.

39.14.5. GreenInfo videos

GreenInfo is a series of videos by **GreenTeam AE** aimed to engage both staff and students in Climate Action, and start conversations about this topic. The idea for these videos originated in April, and the first video was shot at the end of May. The team intends to shoot at least two more videos before the end of the academic year and to have them ready to be shared either in June or in September. The topic of these videos will range from food to waste separation, to mobility and the videos will also be a means to communicate the GreenTeam's goals and achievements to the public. The first video has been realized in collaboration with the Online Education Team of the faculty of Aerospace Engineering.

39.14.6. Lunch lectures

In order to create awareness on possible career options that have a focus on sustainability, a lunch lecture was organised by **GreenTeam AE** together with the master societies of the Aerospace Engineering faculty, Englighness, AWEF, and STATO. This lunch lecture was regarding sustainable materials by Christian Rueckerts from Airbus. This lunch lecture was very successful with many participants and many more will be organised in the future.

39.14.7. Social events

The first event **GreenTeam AE** has participated in was a collaboration with one of the committees of VSV 'Leonardo da Vinci'. This committee, DeBaCo (Design Battle Competition), organised an event with the theme of sustainability and recyclable materials. GreenTeam was asked to give a presentation on its projects as well as to present a pubquiz with interesting facts about sustainability in general, at the TU Delft campus, and in the aerospace field.

39.14.8. Career Event at TPM

To inform the students of the TPM faculty about the possibilities in building a career towards sustainability, **GreenTeam TPM** organised a sustainable career on June 11th, 2021 online. GreenTeam TPM assembled four companies to give a lecture or present the students with a case study for this year's edition as well as many potential collaborators in the coming years. The programme ran in different rooms online, allowing students to select the session and company that suits best for them. A lot of channels were used to promote the event by collaborating with the study association, using GreenTeam TPM's Instagram and LinkedIn pages as well as by contacting TU Delft staff.

39.14.9. Online speed dating at Applied Sciences

In order to give students insights into the endless possibilities of putting their technical knowledge into sustainable applications, an online sustainable speed date event was organised by **GreenTeam AS**. In a relatively small and intimate setting, pairs of students could get to know alumni and their career path to a sustainable job, from sustainable entrepreneurs and finance to PhD'ers! In short, a very inspirational and successful evening that could be fun and interesting for the next **GreenTeam AS** to redo.

39.14.10. Themed months at Architecture

BKGreen, owing to the pandemic, decided to focus on digital/social media-based projects. From November to May, different themes related to fashion,

interior/home, education, energy, food, plants and greenery and veggie canteen have been focused upon. The sustainable choices in these themes have been highlighted. As part of the Fashion themed events, a digital thrift shop event has been organised. In the coming board year, a big physical swap event is planned. The way to use groceries sustainably for a longer time has been highlighted and the first vegetarian canteen in the campus has been started at the Faculty of Architecture & Built environment as a pilot project which is a big success.

39.14.11. BK Green Shop

The **BK Green Shop** is permanent at the Faculty of Architecture & Built environment started last year by **BKGreen**. This promotes the idea of waste reduction from model materials being thrown away. The students have the option of bringing back the used materials to **Bouwshop** and get their money back or put the leftover materials in the BK Green cupboard which is stationed in the model hall. This cupboard has been used to a good extent by the first year students. Plans are in place to expand the project and place another cupboard at the **atelier**. At the end of every semester, a big clean-up takes place and useful materials are identified which are restocked into the cupboard.

39.14.12. Green Campus Project

The idea is to increase green spaces on the campus and **BKGreen** is waiting for the update on the project from main coordinator for a green parking space at the Faculty of Architecture and the Built Environment.

GreenTU's vision on social engagement

GreenTU's position within the university lends itself well to playing a not-insignificant role in engaging the TU Delft community on the topic of sustainability. Therefore, GreenTU's vision on social engagement is two-fold: what GreenTU can achieve in its own right, and what it can do to facilitate the wider (TU) Delft community in social engagement.

40.1. Vision for the GreenTU community

Because of its umbrella function, GreenTU aims to raise awareness regarding sustainability on and off-campus. Four crucial aspects of this have been identified:

1. **Branding** GreenTU within and beyond the local community through a constant, distinguishable style.
2. Engaging and inspiring the audience through content that kindles a **personal connection** with GreenTU's vision.
3. Facilitating discussions and **critical awareness** regarding sustainable practices.
4. Showcasing the **'behind the scenes'** of the past and ongoing green initiatives or projects to the community.

Throughout the structure and set-up of the board, we believe that communication serves a great part of its functioning. In order to achieve the central hub that we have in mind for GreenTU, we need to make sure that we are easily accessible and reachable for all (student-)organisations and individuals that are motivated in making a change and joining us on our way to a more sustainable campus.

Besides creating this type of exposure, we need to be *the* platform on-campus that raises awareness on sustainability matters and ongoing research and educational projects around the world. By using the means of social engagement (in events, workshops, but also through social media), we are able to reach a great number of students.

These goals are to be achieved using a fourfold mission:

1. **Branding:** By setting up a distinguishable style which we use in every type of visual promotion, we create recognition among our followers, improving the reach of GreenTU.
2. **Personal connection:** In order to inspire people to do more in their personal sphere of influence, we need to kindle a personal interest. By making the audience relate to our practices, passion and vision, any perceived barrier to entry of joining the movement is lowered.
3. **Critical awareness:** We need to develop a critical awareness among our audience. As part of raising this type of awareness, our platform must facilitate discussions about sustainability of any kind, For example, showing different opinions on nuclear energy or sharing opinionated articles or talks.
4. **Behind the scenes:** Besides showcasing the work of other researchers, it is crucial to highlight what we do ourselves, what is going on 'behind the scenes', on campus and in our own lives.

40.2. Vision for beyond the sustainability bubble

Advocating for sustainability is often a case of preaching to the choir. Most of our communication and events will reach those who are already interested in sustainability. However, it is a necessity that all parties of the university take action to tackle the climate crisis. Therefore, it is important that we also inspire and support those within the wider community on and off campus and reach beyond our bubble.

The Outreach Coordinator is the first point of contact within GreenTU for external parties. As such they support and consult individual students, student and study associations and other student initiatives with sustainable improvements to their daily operations. To establish this several elements are included for our vision beyond the GreenTU community:

- **Networking/personal connection:** The outreach coordinator is the one who reaches outside of the bubble, through collaboration with others

like umbrella organisations SCVR and VeRa. The best way to find the right connections is via-via, thus necessitating informal networking. In addition, it is best to establish personal rapport. In most cases collaboration with an association will be through an early adopter within the organisation itself: someone in a committee or board who is interested in the subject.

- **Continued presence and support:** Establishing more sustainable practices in these organisations is a matter of piecemeal engineering. Though initial contacts within an organisation, initiatives can be set up. These are then able to inspire more individuals and initiatives. Once established these initiatives will slowly become part of an organisation's habits. Most associations are dipped in habits and tradition and cannot be changed overnight. Continued contact and support throughout the years and with every board is important to allow for anything substantial to change.
- **An up to date and topic specific list of possible improvements:** Most associations or individuals will have the intention to improve but have no clue where to start. An up to date and topic specific list of suggestions can provide them with direction. GreenTU's sustainability label is an example of this. At time of writing our list of guides have been expanded with a sustainable event guide. It would be useful to expand and to include e.g. a guide for mobility and acquiring partners.

40.2.1. Career and vacancy awareness

Through the creation of a career committee, awareness among students about career opportunities in sustainability has been increased. This was done through a variety of events and initiatives, including collaboration with S4S, whose mission also aligns with this goal. These activities should continue in coming years to raise awareness surrounding the existing opportunities and to inspire students to pursue them.

In addition to this, the aim is to develop a centralised database that contains a list of vacancies related to a career in sustainability. Through such a vacancy database, the goal is to:

1. create an up-to-date vacancy pool that is easily accessible to provide students with opportunities in the form of internships, part-time jobs, full-time jobs, thesis topics, and academic projects related to a sustainable career;

2. inform students about the vacancies from sustainable student initiatives in TU Delft;
3. expose students to the sustainable options available in the job market.

Several GreenTeams, in addition to GreenTU's career committee, have expressed interest in making this vision a reality. The project will be launched in the 2021-2022 academic year.

VI

Conclusion

Conclusion of each pillar

The main goal of this report is to study and present GreenTU's vision on sustainability at TU Delft from a broader perspective focusing on the UN Sustainable developments Goals. An effort has been made to understand the current state of sustainability at TU Delft in the four portfolios of education, research, operations and social engagement.

41.1. Education

TU Delft is well-known for its education. Over the years, TU Delft has incorporated various facets of sustainability in the bachelor, master and minor programmes it offers. Further through MOOCs, TU Delft aims to spread knowledge about sustainability to the entire world. This report listed these efforts and went further in the assessment of to what degree sustainability has been integrated in other courses and programmes offered by TU Delft.

Each GreenTeam has devised its own perspective on sustainability in education in their respective faculties. Initiatives, notably the Green Thread, are updating the curricula of courses towards a centre-stage inclusion of sustainability. The aim of this report is to evaluate the present status of education at TU Delft with respect to sustainability, document various initiatives implemented by to achieve GreenTU's vision of acquainting each TU delft student with a basic knowledge of sustainability and provide them with options to further explore or become expert in this field.

41.2. Research

In addition to education, research is the university's prime activity. Sustainability-related research is performed at TU Delft through its four research initiatives (Energy, Health, Global and Infrastructure), the Centre for Sustainability as well as departments directly working on sustainability topics. Students have also the opportunity to implement ideas to actual projects and business innovations through YES!Delft startup incubator and through student teams. Moreover, the Green Village at the university constitutes a set of technolog-

ical demonstration and testing projects of sustainable building and infrastructure to develop it later on a larger scale. Beyond the boundaries of the university, partnerships with research institutes, other universities, governmental entities and industries allow to have a more collaborative implementation of its research activities.

Another crucial aspect of research is the open access publishing. The efforts made by the university to widen the application of open access has been translated into the Open Science Programme and the Open Science 2020-2024 Strategic Plan. Furthermore, the years 2020-2021 have witnessed other important improvements in terms of research, such as TU Delft's launching of the Climate Action Programme and its partnership with the International Universities Climate Alliance.

Based on Elsevier's ranking, TU Delft has leading research output in 'Industry, innovation and infrastructure', 'Clean water and sanitation' and 'Sustainable cities and communities'. On the other hand, more advancement needs to be made in the fields of 'Affordable and clean energy', 'Responsible consumption and production' and 'Climate action'. In addition, the authors emphasise on the importance of having more interdisciplinary research between the faculties of TU Delft and with other partners. To expand the prospects of research, the authors recommend to set a clear agenda on the areas to improve on and fields where more research needs to be made. This requires a comprehensive study of the current situation to demarcate the potentials for possible developments. It is also necessary to increase the contribution of students in sustainability-related projects, including living lab applications. A better communication of research activities help to achieve these goals and allow students to be more connected to researchers.

Finally, it is encouraged to have an inventory of all research work related to sustainability to use these resources efficiently and to ease the traceability of the fulfilment of the targets.

41.3. Operations

TU Delft's catering has centred animal protein for quite sometime and it is necessary to decrease the carbon-intensity of catering. Steps are being taken to achieve this by introducing pilot project such as the vegetarian canteen at the Faculty of Architecture and the Built Environment. It is also necessary to focus on increasing biodiversity across the campus, which serves as a positive force for the local climate.

Around 27,000 people use the campus every day and this number is expected to increase. The initiatives from CRE such as improving cycle path

networks and pedestrian routes, public transport accessibility, and an increase in parking lot capacity were discussed. The results of the mobility programme showed a strong inclination of commuters to switch to more sustainable options given the right support. In light of COVID-19, a campus mobility dashboard was also developed to provide real-time data on traffic flows through a digital twin of the campus.

In this report, the main sources of waste streams in the campus were identified. Although data for the year 2020 is not available, it is expected that the quantity of waste generated would be reduced considerably. 2020 also saw the initiation of initiatives such as the ongoing waste separation pilot at certain TU Delft buildings. Within the domain of procurement operations, the last academic year saw the first steps towards drafting a sustainable procurement guideline protocol that will enable greener procurement operations for various utilities.

With quick and decisive measures, it is possible to achieve the 2030 carbon neutral goal at TU Delft and GreenTU will strive to work towards it to help achieve it.

41.4. Social engagement

To achieve sustainability goals, widespread cooperation is of paramount importance. GreenTU is working towards bringing many organisations together, whether these focus on sustainability or other goals, and establish fruitful collaborations. Apart from this, TU Delft has a responsibility to enable a means of communication to the outside world and stakeholders involved.

A

Carbon-footprint model

In this Appendix, more details regarding the model is presented. Figure A.1 presents the change in the electricity generated from solar. In Figure A.2, the generation of electricity from wind is shown. The final source of electricity, that is CHP is presented in Figure A.3. A fraction of the energy that is generated is sold to third parties, it is shown in Figure A.4.

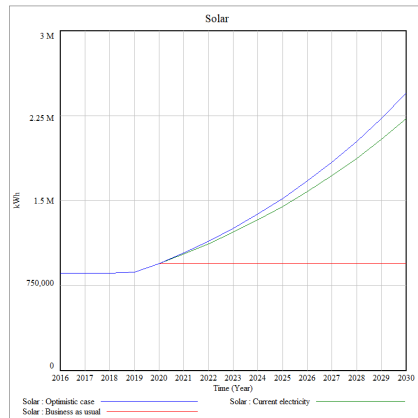


Figure A.1: Electricity generation from solar

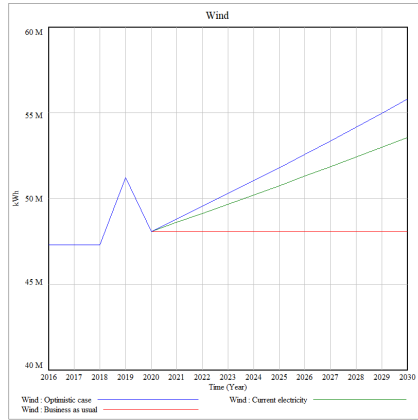


Figure A.2: Electricity generation from wind



Figure A.3: Electricity generation from CHP

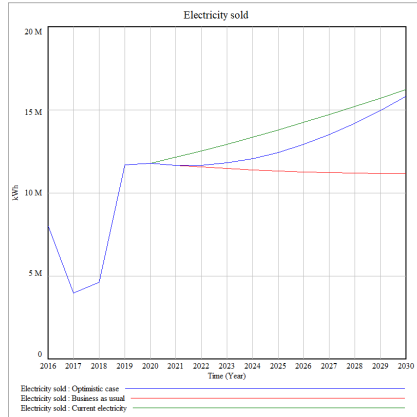


Figure A.4: Electricity sold to third parties

Finally, the second source of emissions that was considered in the report was due to heating requirements on campus. Figure A.5 presents the projections of heat generated from CHP and in Figure A.6 the generation from the Boilers.

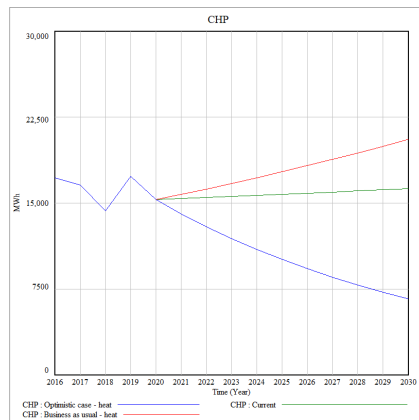


Figure A.5: Heat generation from CHP

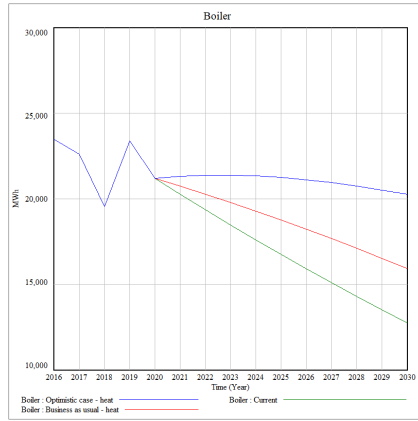


Figure A.6: Heat generation from Boiler

B

List of SDG-related online courses

The following pages contain an overview of all TU Delft online education courses available at any time during July 2020 until July 2021 which are closely related to one or more of the SDGs¹. The courses are indicated as being either a MOOC (massive open online courses) or ProfEd (professional education). MOOCs are large-scale free courses, aimed to be accessible for a wide audience, while ProfEds are aimed at professions who already have experience in a certain field.

¹This list is based on private communication with Bertien Broekhans on 2 February 2021

Name of the course	Type of the course
Beyond Engineering: Building with Nature	MOOC
The Energy Markets of Today	MOOC
The Transition to the Decarbonised Economy of Tomorrow	MOOC
Energy demand in building	MOOC
Energy supply systems in buildings	MOOC
Smart grids - the basis	MOOC
modelling smart grids	MOOC
EUCalc pathwayfinder to a low carbon EU society	MOOC
Decision Making Under Uncertainty: Applying Structured Expert Judgment	ProfEd
Circular Building Products for a Sustainable Built Environment	ProfEd
Circular Product Design Assessment	ProfEd
Virtual Photovoltaic laboratory-light, cells and modules	ProfEd
Advanced Zero-Energy Design: validate your building's performance	ProfEd
Aerobic Granular Sludge for waste water treatment (NEREDA)	ProfEd
Taming Big Data Streams: Real-time Data Processing at Scale	ProfEd
Aeroacoustics: Measurement Techniques	ProfEd
Aeroacoustics: Noise Reduction Strategies for Mechanical Systems	ProfEd
Introduction to functional programming for big data processing	ProfEd
Teaching an online course	ProfEd
AI in practice: applying	MOOC
Global housing design	MOOC
Building inclusive cities	MOOC
Sustainable aviation	MOOC
Adaptive strategies for waterscapes	MOOC
Port cities and urban deltas	MOOC
Dynamic Energy Modelling of Buildings: Thermal Simulation	MOOC
Efficient HVAC systems	MOOC
Thermal comfort in buildings	MOOC
multidisciplinary research methods for engineers	MOOC
Virtual Photovoltaic laboratory-system and electronic components	ProfEd
Urban Air mobility	ProfEd
Engineering Design for a Circular Economy	MOOC
Beyond Engineering: Building with Nature	MOOC
Nature Based Metropolitan Solutions	MOOC
Sustainable Urban Development	MOOC
Treatment of Urban Sewage	MOOC
Urbanism: Design for the Public Good	MOOC
AI in practice: preparing	MOOC
Facade design & engineering complexity: simply explained	MOOC
Mind of the Universe - Robots in Society: Blessing or Curs..	MOOC
Communicating Effectively: How to inspire and convince	MOOC
Creative Problem Solving and Decision Making	MOOC
Decision Making Under Uncertainty	MOOC

Effective Decision Making: dealing with complexity	MOOC
Framing	MOOC
Leadership for Engineers	MOOC
Responsible Innovation: Building Tomorrow's Responsibl..	MOOC
Responsible Innovation: Ethics, Safety and Technology	MOOC
Biobased Products for a Sustainable (Bio)economy	MOOC
Circular Economy	MOOC
Engineering: Building with Nature	MOOC
Sustainable Packaging in a Circular Economy	MOOC
Waste Management and Critical Raw Materials	MOOC
Sustainable Management of Critical Raw Materials	MOOC
Inclusive Energy Systems	MOOC
Solar Energy	MOOC
Solar Energy part 1 (Arabic version)	MOOC
Solar Energy part 2 (Arabic version)	MOOC
Solar Energy: comprehensive exams	MOOC
Solar Energy: PV Conversion	MOOC
Solar Energy: PV in Microgrids	MOOC
Solar Energy: PV Systems	MOOC
Solar Energy: PV Technologies	MOOC
Sustainable Energy	MOOC
Understanding Nuclear Energy	MOOC
Electric Cars: Business	MOOC
Electric Cars: Introduction	MOOC
Electric Cars: Policy	MOOC
Electric Cars: Technology	MOOC
Hyperloop: changing the future of transportation	MOOC
Sustainable Urban Freight Transport	MOOC
Circular Economy for a Sustainable Built Environment	MOOC
Next Generation Infrastructures	MOOC
Zero Energy Building Design	MOOC
Mitigation of Climate Change: An Introduction	MOOC
Mitigation of Climate Change in the Built Environment and Transportation	MOOC
Mitigation of Climate Change in the Industry and the Power Sector	MOOC
Mitigation of Climate Change: Climate Action Perspectives	MOOC
Digitalisation of energy systems	MOOC
Technology for intelligent integration of sustainable energy systems	MOOC
socio-technical energy systems	MOOC
Innovations for Sustainable Business for Integrated Energy Systems	MOOC
upscaling electro conversion systems for industry	MOOC
the energy transition and the challenge for industry	MOOC
Managing Building Adaptation	MOOC
Train Biomed in low-resource settings	MOOC
exoskeleton MARCH	MOOC
Water & Climate	MOOC

Automated Software Testing: Advanced skills for Java De..	MOOC
Cybersecurity Economics	MOOC
Quantum Cryptography	MOOC
Project MARCH: behind the technology of robotic exoskeletons	MOOC
Robotics with ROS	MOOC
The Building Blocks of a Quantum Computer: part 1	MOOC
The Building Blocks of a Quantum Computer: part 2	MOOC
The Quantum Internet and Quantum Computers	MOOC
Design in Healthcare	MOOC
Healthy Aging	MOOC
Aeronautical Engineering	MOOC
Introduction to Aerospace Structures and Materials	MOOC
Railway Engineering: An Integral Approach	MOOC
Co-creating Sustainable Cities	MOOC
Image Ability	MOOC
NGI 1	MOOC
NGI 2	MOOC
Physical & Digital Models in Architecture	MOOC
Rethink the City	MOOC
Engineering walking and cycling networks	MOOC
Pre University Physics	MOOC
Advanced Transport Phenomena	MOOC
Análisis de datos: Diseño y Visualización de Tableros	MOOC
Análisis de datos: Llévelo al MAX()	MOOC
Automated Software Testing: Practical Skills for Java Del..	MOOC
Big Data Strategies to Transform Your Business	MOOC
BM Design	MOOC
BM Implementation	MOOC
BM Metrics and Tools	MOOC
BM Testing	MOOC
Data Analysis EX101	MOOC
Data Analysis EX102	MOOC
Data Analysis EX103	MOOC
Data Analysis: Visualization and Dashboard Design	MOOC
Design Practice in Business	MOOC
Drinking Water Treatment	MOOC
Entrepreneurship for Engineers	MOOC
Entrepreneurship for Global Challenges in Emerging econ..	MOOC
Forensic Engineering	MOOC
Functional Programming	MOOC
Geoscience	MOOC
Global Distributed Software Engineering	MOOC
Industrial Biotechnology	MOOC
Influencing Stakeholders	MOOC
Introduction to Credit Risk Management	MOOC
Mathematical Modelling	MOOC

Observation Theory	MOOC
Open Government	MOOC
Open Science: Sharing Your Research with the World	MOOC
Pre-University Calculus	MOOC
Product Design: The Delft Design Approach	MOOC
Programmeren voor leerkrachten met Scratch	MOOC
Project Finance: Funding Projects Successfully	MOOC
Project Management of Engineering Projects	MOOC
Project Management: Mastering Complexity	MOOC
Scratch: programmeren voor kinderen	MOOC
Scratch: Programming for Kids	MOOC
Scratch: Programming for Teachers	MOOC
Topology	MOOC
Transport Phenomena	MOOC
Unix Tools: Data, Software and Production Engineering	MOOC
Value of BM	MOOC
Adaptive planning for infrastructure and Water management	ProfEd
Dealing with Ethical Dilemmas in Professional Engineering	ProfEd
Multi-stakeholder strategies: analysis for winning coalitions	ProfEd
Strategic Leadership for Responsible Innovation	ProfEd
Offshore Wind Farm Technology: Design, Installation and Operation	ProfEd
PV materials and devices modelling	ProfEd
PV systems modelling	ProfEd
Energy Friendly Renovation Processes	ProfEd
Energy Conversions for green hydrogen utilization	ProfEd
green hydrogen integration	ProfEd
Circular Regional and Metropolitan Solutions	ProfEd
Cybersecurity for Managers and Executives: Taking the Lead	ProfEd
Digital Manufacturing for Industrial Design	ProfEd
Thing-centered design: A New approach to Designing for the IoT	ProfEd
Air Safety Investigation	ProfEd
Aircraft Performance - Physics and Simulation	ProfEd
Assessing and Managing Safety Culture	ProfEd
Improving road safety	ProfEd
Railway Engineering: Capstone Project	ProfEd
Railway Engineering: Performance over Time	ProfEd
Railway Engineering: Real Time Operations	ProfEd
Railway Engineering: Track and Train Interaction	ProfEd
Advanced Credit Risk Management	ProfEd
Culture Sensitive Design	ProfEd
Design Leadership and Innovation	ProfEd
Design your Next Career Move	ProfEd
Designing an online course	ProfEd
Designing an Online Course – TU Delft style	ProfEd
Fiber Reinforced Polymer (FRP) Composites in Structural Engineering	ProfEd
High-rate Anaerobic Wastewater Treatment	ProfEd

Nanofiltration and Reverse Osmosis in Water Treatment	ProfEd
New Product Marketing: how to commercialize innovation	ProfEd
ROS industrial in the factory floor	ProfEd
Smart Structures	ProfEd
Vision in Product Design	ProfEd

Bibliography

- [1] T.P.S. Arblaster, M.J. Mandl, and M. Segeren. *Inventory Report*. GreenTeam AE, 2020.
- [2] T. Barbuntoiu, S. Nawar, and K. Rudraraju. *Inventory Report*. GreenTeam CEG, 2020.
- [3] E. Bloem, N. Buijsman, N. Douenburg, and R. Swinkels. *Inventory Report*. GreenTeam IDE, 2021.
- [4] M. Bussemakers, B. Ruiter, W. Treurniet, M. Mager, L. Kaptein, and T. van Essen. *Onderzoeksverslag*. Green-mE, 2017.
- [5] Central Student Council. Minutes overlegvergadering 224, 2019.
- [6] Real Food Challenge. Real food standards 2.1. Technical report, 2018.
- [7] M. de Eusebio, S. Haggerty, and W. Maas. *Inventory Report*. GreenTeam EEMCS, 2020.
- [8] TU Delft. TU Delft Policy on Open Access Publishing. Technical report, 2016.
- [9] M. Groot, P. Munters, and V. Vipin. *Inventory Report*. GreenTeam TPM, 2020.
- [10] I. Haslinger and A. Versteeg. TU Delft Strategic Plan Open Science 2020-2024: Research and Education in the Open Era. Technical report, 2019.
- [11] T. Kaasjager, E. Wezenberg, P. Wijnia, and M. Wissink. *Inventory Report*. GreenTeam AS, 2020.
- [12] STARS. Stars technical manual. Technical report, 2019.
- [13] Danique Ton and Dorine Duives. Understanding long-term changes in commuter mode use of a pilot featuring free e-bike trials. *Transport Policy*, 105:134–144, 2021.
- [14] A. van den Dobbelsteen and D. van Gameren. *Sustainable TU Delft: Vision, ambition and action plan*. TU Delft, 2021.