Technische Universiteit Delft

Inventory Report

Sustainability within EEMCS

GreenTeam EEMCS

TU Delft

TU Delft GreenTU

Inventory Report

Sustainability within EEMCS

by

GreenTeam EEMCS

Inventory report on sustainability within the faculty of EEMCS
at the Delft University of Technology.

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About the 2020 EEMCS GreenTeam

The GreenTeams are faculty-specific sustainability offices operating in the Delft University of Technology [1]. The first GreenTeams were founded by students in 2015 and 2017 on the 3mE and BK-Green faculties. GreenTU, the main body in charge of sustainability within the TU Delft, leads the initiative to expand the number of GreenTeams in the academic year of 2019-2020 [3]. This first generation of GreenTeams was co-commissioned by GreenTU and the faculty management, and was additionally supported by the TU Delft's executive board. At the moment of writing the GreenTeams are present at all TU Delft faculties, with the current exception of the Industrial Design Engineering faculty. Making a total of eight active GreenTeams, all of which are organized and run by students in coordination with GreenTU and faculty specific staff-coordinators.

The goal of this first EEMCS GreenTeam is to make an analysis on the state–of-affairs of sustainability within the faculty on four different fronts: operations, education, research, and communication; as well as to propose plausible solutions to improve them. This report presents the findings of the GreenTeam in their examination of sustainability within the EEMCS faculty.

The exact role of future GreenTeams is still open, as it is still a young institution, but what remains clear is that the GreenTeams represent a step forward in TU Delft's efforts to being a more sustainable university and its commitment to educate new generations to build a better future for all.

A note of the authors

Hi there! We are Shea, Wouter and Maria - the very first GreenTeam of the EEMCS faculty. We are all students of this faculty, and although we all have different backgrounds, we are joined by our goal to make EEMCS an example for what modern sustainability look like. We believe that, as one of the highest rated technical universities in the world, TU Delft has the privilege and duty to lead the way in building a better future for everyone. Altogether, we are very excited to be part of the journey that lies ahead for EEMCS.

Not all people have the luxury to think about the big problems facing humankind. The potential sacrifices that would have to be made in wealthy nations like the Netherlands are small in comparison to the harmful consequences that the global south will suffer if wealthy nations choose to neglect their duty. Many institutions, the TU Delft included [1], acknowledge that even the measures outlined in the Paris Climate Agreement might not be sufficient to advert the worst dangers. A form of haste is thus to be made and we believe the TU Delft has a major potential to be an agent for good in this regard.

This report you are reading now is the result of many hours of passionate work we have put into researching how our faculty addresses sustainability, as well as coming up with interesting solutions to make it better. We hope you will enjoy reading it and find is as engaging as we did.

[1] From here onwards referred to as the TU Delft.

Introduction

As a leading research institution, the TU Delft has formulated its stance on sustainability in a clear manner. In line with the United Nations' Sustainable Development goal of Climate Action [2] it has stated the following:

TU Delft sets out to build upon its intellectual and innovative power for safeguarding the world population against the risks of climate change, by developing technologies and methods as described above – in close collaboration with those companies and organizations that need to implement such measures in practice. The problem is complex and urgent – but we have no other choice than to be optimistic and use all of our capacity to face the challenge, through our education programs and our research. TU Delft takes its social responsibility. [1]

It is in this spirit of determination that the EEMCS GreenTeam operates, contributing to the changes that need to be made at the TU Delft to implement its vision and limit further harmful contribution to climate change and other environmental damages. Details regarding the general TU Delft wide implications of this vision have been formulated in documents such as the CO2-Roadmap [17] and the TU Delft Strategic Framework 2018-2024 [4]. On the scale of the EEMCS faculty, the goal of this first EEMCS GreenTeam is as mentioned before: to make an analysis of the state-of-affairs of sustainability within the faculty on four different fronts: operations, education, research, and communication. To further specify the framework for how this research has been conducted, a brief conceptual overview of the four different portfolios is given below.

- Education: this portfolio focuses on how sustainability is integrated into the current curriculum of all bachelor and master courses. What percentage of the courses already include sustainability teachings and in what form? What kind of positive examples do already exist? And what could the future role of sustainability be in EEMCS' education?
- Research: this portfolio focuses on what number of researches done by people at the faculty of EEMCS has sustainability as the main point and how this number can be increased.
- Operational: this portfolio looks at how all material processes are handled at the faculty. Think of waste, the use of water, what foods are consumed and thrown away, and if for instance promotional materials are re-used.
- Communications: this portfolio focuses on how the faculty communicates its beliefs and points of view towards the outside world.

The evaluation of these four portfolios happened in different ways and by different people. The Education chapter was written by Wouter Maas, the operational chapter by Shea Haggerty and the Communication and Research chapters by Maria de Eusebio.

It is important to note here that all the research took place during the pandemic of Covid-19, heavily influencing the opportunities for the team to talk to staff, as much of the staff was (understandably) very busy with making sure daily life could continue as much as possible. Much of the first initial research for this report was therefore done online. Consecutively, a survey on the EEMCS' students opinions on sustainability was conducted, to which almost a 100 students responded. Results of this survey have been integrated into the report where relevant. Finally, much of the research was done by interviewing members of staff, both educational and operational. Listening to the advice and integrating the information they provided has been vital for the creation of this report.

Through these different methods, the overall presence of sustainability has been attempted to be determined. Where possible, recommendations have been added for implementations on how the level of sustainability could be raised. These recommendations vary in ease of implementation and effectiveness, which is considered and commented on. This report ends with a summary and overall advice from the EEMCS GreenTeam.

Definitions and terms

Reflections on sustainability
Below follows a quick reflection on what can be considered as sustainability and sustainable practices.

A traditional starting point for defining sustainability has been that *people should act in such a way that the practices of current generations allows them to meet their needs without compromising the capability of future generations to meet their own* [24]. Here, sustainability stresses the importance of continuity.

There are however already many front-line communities being affected by the devastating effects of climate change and other environmental damages. Meaning, there are already communities whose present needs are not met. In this sense, a global point of view should be considered, one which stresses the urgency for institutions and people to take action right now and to consider the systematic disproportionate impact of environmental damages on many developing countries [20] [21].

When considering these starting points, sustainability has two important aspects: current action to reduce the direct impact on the environment and creating the appropriate mindset for continuity. A mindset such that individuals and organisations consider the environmental impact of the actions they take.

Frequently used terms
Throughout the report, a number of sustainability/university-related terms are used. Because they might not be completely clear for the reader, they are shortly explained below.

- **Centralized:** In relation to the TU Delft, centralized in this context means when a specific matter concerns the whole TU Delft and is thus dealt with by for instance GreenTU instead of a GreenTeam.
- **Climate change:** Climate change refers to any significant change in the measures of climate lasting for an extended period of time. In other words, climate change includes major changes in temperature, precipitation, or wind patterns, among other effects, that occur over several decades or longer [14].
- **CO_2 neutral:** Making or resulting in no net release of carbon dioxide into the atmosphere.
- **Decentralized:** Opposite of centralized - these matters concern only a smaller part of the TU Delft, for instance, a faculty, and in this context these matters are dealt with by GreenTeams.
- **Horizontal integration:** Used to refer to the integration of educational material throughout the bachelor as opposed to creating a specific/dedicated course for a topic. Similar to how the topics Ethics and Security are integrated into the Computer Science and Engineering bachelor.
- **Recycling:** Recycling is the process of recovering material from waste and turning it into new products. The original product is destroyed in this process, usually through a melting process, but it used to form new products. Examples are aluminium cans, plastic water bottles, most food tubs, bottles and cans [22].
- **Reducing:** The act of reducing our overall consumption of "things" in general. This can be as simple as turning off the faucet while brushing our teeth, taking shorter showers with colder water, or pacing the amount of air conditioning we use in the summer or heat in the winter. Carpooling reduces gasoline consumption and reduces the number of cars on the road [22].
- **Refusing:** Sustainability defines refuse as refusing to accept or support products or companies that harm the environment. One way to do this is to refuse items that are over-packaged or packaged in plastic [13].
- **Reusing:** Reusing a certain material means to use it again for the same purpose that it was originally made for. Sometimes a product that is being reused is referred to as being refurbished, or pre-owned. The original product is usually not altered in any significant way before being used again. Examples range from pre-owned cars and golf clubs to clothing and footwear [22].

1 Education

1.1. Introduction

The topic of education with regards to sustainability brings to light some important discussions on what should be included in a university's engineering degree. From one point of view, it could be argued that sustainability has little place in most of EEMCS' education (the exception being the Sustainable Energy Technology master) as its focus is on teaching students to be good engineers in their respective academic fields. Sustainability could be seen as an option a student can focus on in the minor or master but should otherwise be left untouched as a topic.

On the other hand, there is a sense of urgency when it comes to handling the environmental damages impacting the earth's environment. Innovation and societal change are needed in many different areas and the academic fields of EEMCS have the potential to play a key role. Mathematicians and Computer Scientists have always used their knowledge not solely for improving mathematics and computer science itself, but always in relation to other fields. Aiding the creation of for instance climate models is in that sense simply one of the latest relevant additions. Additionally, the role of Electrical Engineers for the creation of sustainable energy technology is self-evident.

The EEMCS GreenTeam supports the idea that EEMCS could actively teach its students about the important role they can play in preventing further environmental damages. Teaching students a 'sustainable mindset', which can help them guide their decisions. An idea very much in line with the belief of dean John Schmitz: *"I very much look forward to applying my experience in contributing to the education of new generations of engineers who will be at the forefront of a sustainable technological society. I firmly believe that universities in general and a faculty like EEMCS in particular can and must play an instrumental role in achieving this. EEMCS knowledge will be essential in finding solutions to the major challenges facing society."*[1]

In this chapter, as well as possible, it is considered where this teaching could be integrated. When done so, hopefully leaving all engineers graduating from EEMCS with more knowledge about the implications their engineering decisions have with regards to the global environment and human society.

Approach

The extent to which sustainability is present in an educational program was evaluated in the following manner. Firstly, every degree's courses were researched online with the information available, investigating whether and to what extent sustainability was already present in these courses. Presence can come in different forms, a course can be directly focused on topics related to the environment or human environmental impact, but it can also be that it is simply mentioned in the course as a relevant example of the application of the material at hand.

Based on this evaluation, courses were divided into four different categories [2].

Course categories

1. Courses that are already integrating sustainability into their curriculum

[1] https://www.tudelft.nl/en/eemcs/the-faculty/dean/

[2] A divide inspired by the AS GreenTeam

2. Courses with a 'hands-on' nature where sustainability could become a more integral part of the course
3. Courses in which it is possible to make relevant examples about sustainability
4. Courses that do not relate to sustainable topics

Consecutively, different members of staff connected to courses belonging to the first three categories were interviewed. Giving them an opportunity to express their ideas about how sustainability could be integrated into EEMCS' education. Originally the GreenTeam would also have liked to have interviewed the directors of studies of the different programs, but they were, understandably, very busy with managing the effects of Covid-19.

The information found through these different research methodologies (the survey included) was summarised and synthesised into overall recommendations and ideas on possible courses of action.

Student opinions regarding sustainability and EEMCS

An important factor that would influence any changes regarding the education present at EEMCS, is the opinion of students. An important finding that came forward from the conducted survey was the worry students expressed with regards to climate change 38.2% of the students indicated to be extremely worried about the issue of climate change, whilst 52.8% indicated to be very worried. Less than 3.3% of the students indicated to be not worried at all, or only a little worried.

More importantly, students were even more unanimously convinced that EEMCS could and should do more with regards to sustainability. The question *"Do you think EEMCS, in general, should take more active measures to be more sustainable?"*, which had a 1 to 5 scale, 1 being: "*No, we are fine the way it is"* and 5 being: *"Yes, the EEMCS faculty should do much more for sustainability"*, was answered with a 5 by 43.8% of the students and with a 4 by another 33.7% of the students. Only 4.4% of the students replied with a value equal or less than 2.

More specific findings with regards to the importance of sustainability in the EEMCS education were that an overwhelming majority of the students (88%) found it at least somewhat important that sustainability would be present in their education. With 32.6% of the students even indicating that they found it "very important", and another 33.7% marking it plainly as just "important".

For how sustainability could then be integrated three main ideas came forward. Firstly, 72% of the students indicated that *"... a specific course dedicated to showing the relevant parts of sustainability in your field of study"* could potentially be valuable.

Secondly, more non-mandatory education could be provided. When asked *"How else would you like to see sustainability integrated within your education?"*, the majority of students (57.3%) replied with *"more elective courses"*, closely followed by *"More lunch lectures"* (47.2%), *"More other non-mandatory events, such as as symposiums"* (43.8%), and *"More minors"* (25.8%). Other suggestions had a negligible amount of votes.

Lastly, whilst adding a course on sustainability could be tremendously valuable for degrees that currently lack this, time in curricula is also scarce and adding one topic, or course often means removing another. What the GreenTeam, therefore, believes to be the most significant, approach which was also valued and highlighted by both students and staff, is the possible '*horizontal integration*' of sustainability throughout the curricula. Some topics, like sustainability, can be important enough to have a presence, but to dedicate an entire course to it might simply not even be the best teaching method. Examples of horizontally integrated topics can be found in the Computer Science and Engineering bachelor, where the topics Ethics and Security are present throughout the bachelor program.

65.1% of the students in the survey answered with a clear "yes" to the question: *"Would you be in favour of sustainability being more integrated into existing courses in your degree (for instance: learning about the environmental impact of a certain part of engineering, or calculations being done with sustainability-relevant examples)"*. An additional 22.5% replied with "maybe", and only 12.4% was opposed. Another form of this horizontal integration could be to integrate sustainability as a topic in project courses, including 'projects' like the bachelor thesis. 48.1% of the students indicated to be directly in favour of this, with another 28.1% indicating that this could be potentially interesting. This was also mentioned by multiple members of staff, who for instance mentioned the relevance of tackling socially relevant issues in a project that could be done by teams made up of students from different faculties[3].

[3] As mentioned in the conducted interview with Christoph Lofi, Assistant Professor at the Web Information Systems group of EEMCS

1.2. Overview of sustainability in the bachelor education

The faculty currently hosts 3 bachelors programs. This section goes over each of the different bachelor's education programs, enumerating relevant courses and to which category they could potentially belong if small adaptations are made. Additionally, a general introduction with comments and relevant observations is presented per bachelor degree.

1.2.1. Computer Science and Engineering

As the Computer Science and Engineering degree's website describes: "Computer science engineers work on software for web applications, mobile apps, route planners, robots, healthcare systems, financial services and much more."[4] What this uncovers is that CS as a field is much more connected to other fields rather than being self-focused. There are simply few fields that are untouched by computers in the 21st century. Assistant Professor Christoph Lofi describes this situation in the following way: "[computer science] is a little bit like a helper discipline ... allowing other people to their job more efficiently and effectively". Continuing with the observation that for most of the solutions regarding sustainability, computer scientists will be needed[5].

Computer Science students noted the possible relevance of the connection between Computer Science and sustainability, with 84.4% of the Computer Science students indicating that "not enough attention to sustainability is given in their educational program". This is interesting in comparison to for instance Electrical Engineering students, who gave similar high ratings for their concerns regarding climate change, but who were much more satisfied with the current level of attention regarding sustainability in their degree. This, as noted by the Electrical Engineering students, probably because the Electrical Engineering bachelor currently already holds a course specifically dedicated to showing how Electrical Engineering can be used in a sustainable fashion, for more on this see the section on Electrical Engineering.

As mentioned earlier, based on the responses of staff and students sustainability could probably best be integrated into the Computer Science bachelor as a horizontal topic, in a similar fashion as the topics Ethics and Security.

Examples of how this could be done were given by interviewed staff: for instance in a course like CSE1500 Web- and Database Technology comments could be made on the energy costs of data-farms. Another suggestion was to comment on the tremendous amount of waste in terms of computer hardware due to the rapid progress at which computers have developed in the past century. A comment like this could be placed in the course CSE1400 Computer Organisation[6]. Examples would not have to be in-depth, dedicated lectures but rather a few extra slides in existing lectures, there to show the implications of engineering decisions, and adding to the awareness regarding the relevance of Computer Science in terms of contributing to solutions for environmental problems.

As mentioned before, many students were also in favour of having sustainability becoming a more integral part of project courses. The interviewed staff also indicated that this would be a good possibility. An example of how this could be done has already occurred, in 2019 the OOP project course (CSE1105) assigned students to "Go Green" by developing software that could be used to track the environmental impact of its users. In this course, students already need to reflect on the ethical implications of software engineering as part of the "Responsible Engineering" marking criteria. Making sustainability structurally part of a course like this could thus be done with relative ease, maybe only adding a small criterion which has students also write a small reflection on the sustainable impact of their developed product.

The rest of this sub-chapter will comment on specific courses, mentioning where ideas like the ones described above could be implemented. *Cursive text is used to mark recommendations.* Sometimes it is mentioned explicitly, but further elaborations or help with implementing these recommendations could come from future GreenTeams.

Computer Science Courses

1. Category 1 courses: The bachelor Computer Science and Engineering currently has no courses which could be classified as category 1. In the third year of the bachelor, there is already space for three elective courses within computer science. Here, *a Green IT course could be added.* Existing examples of this are: Sustainability and Assistive Computing by Eric Eaton at Bryn Mawr College: `https://`

[4] https://www.tudelft.nl/en/education/programmes/bachelors/cse/bachelor-of-computer-science-and-engineering/field-of-study/
[5] As mentioned in the conducted interview with Christoph Lofi, Assistant Professor at the Web Information Systems group of EEMCS
[6] As mentioned in the conducted interview with Bart Gerritsen, Associate Professor TU Delft, Industrial Design Engineering

cs.brynmawr.edu/Courses/cs380/fall2010/, Artificial Intelligence for Health and Sustainability by Emma Brunskill and Manuela Veloso at Carnegie Mellon University: (opens pdf) http://www.cs.cmu.edu/~ebrun/spring2012_ai.pdf and Computing and the Environment by Doug Fisher at Vanderbilt University: (opens pdf) http://www.vuse.vanderbilt.edu/~dfisher/socially-engaged-computation ComputingEnvironment.pdf.

2. Category 2 courses: Currently none of the project courses in the Computer Science and Engineering bachelor focus on sustainability. The integration of sustainability could be done as a project topic with the addition of a small marking criterion regarding the ethics of sustainability.

   (a) CSE1105 OOP Project: *focus on topics related to sustainability for the to be developed software*

   Although the aim of the OOP project is to improve students' software engineering workflow, sustainability could become a passive, secondary study goal. Students will need to educate themselves on the topic of their application that they developing regardless of what that topic is. Making this topic be connected to sustainability could be interesting as it has so much current relevance. Additionally, to connect to the ethics component already present in the course, students could be asked to also reflect on the potential environmental impact of their application. Example topics could be: building a footprint calculator, a simple climate modelling tool or a database query tool which can compare the impact different product suppliers have.

   (b) CSE2115 Software Engineering Methods: *similar to the recommendation for CSE1105*

   (c) CSE2000 Software Project: *actively invite companies working on sustainability to submit proposals for software projects*

   In the Software Project 5 bachelor students work full-time for two and a half months to solve a software issue for an actual client. Companies from different fields working on sustainability could be actively invited to submit proposals to which students could then apply. Giving students the possibility to work first hand with sustainability and contributing to the development of products that could have a positive effect on the environment. Companies like Triodos and the sustainability department of Unilever are examples. The EEMCS GreenTeam could be asked to do research, draw up a list for the course coordinators and help with contacting such companies.

   (d) CSE3000 Research Project: *highlight topics related to sustainable research*

   There are several examples of researchers at the EEMCS faculty that are developing technology that is directly related to a positive societal or ecological impact. These could be the researchers that students are coupled with when doing the Research Project. Since students are responsible for finding a suitable research project, a possibility could be to give the students a list of researchers that are developing technology that is directly related to a positive and societal or ecological impact.

3. Category 3 courses: Many courses in the computer science bachelor hold relevant connections with sustainability which could be mentioned.

   (a) CSE1400 Computer Organisation: *mention the environmental impact of the resources needed to build computers*

   This course gives an in-depth overview of the inner workings of computers. Learning about processors, the working of transistors and the general development computers have gone through in the past century is an integral part. In this respect comments could be made about the rareness of quality silicon, the environmental impact of mining the lithium needed to power smartphones, and the amount hardware waste (e.g. the number of devices that are yearly thrown away) due to the rapid development of hardware.

   (b) CSE1500 Web- and Database technology: *explain the energy cost of running the internet and large data-farms*

   This course gives a first introduction to web- and database technology. When talking about the World Wide Web, comments can be made about the energy cost of connecting such a global network of computers. Additionally, interesting questions that can be raised are regarding instantaneous retrievability of data stored in the cloud. Creating awareness that a slower yet more environmentally friendly storage system could be preferred.

(c) CSE1405 Computer Networks: *show the effects of more or less efficient communication protocols in term of electricity usage*

In this course, students are thought about the fundamental protocols used for communication between computers. Similar to CSE1500 comments could be made about the energy costs of connecting a global network of computers. Interesting sample calculations could be outlining the different energy costs of more or less efficient communication protocols.

(d) CSE2520 Big Data Processing: *mention the importance of Big Data for tackling environmental issues*

Big Data analysis is a field which plays an important role in tackling the environmental issues faced by society. In the lectures, many examples could be given, for instance, the importance of Big Data for accurate climate models could be mentioned, but also the fact that Big Data can with locating harmful emission sources or identifying pressure points along supply chains. Additionally, in the practical lab aspect of the course, a dataset containing whether data could be used. Letting students query this data for different time spans, showing them the increase in extreme weather events. See this website of the UN on Big Data and sustainable development, which contains many resources (including a WorldBank database): `https://www.un.org/en/sections/issues-depth/big-data-sustainable-development/index.html`

(e) CSE2525 Data Mining: *similar to the recommendation for CSE2520*

This course follows directly after CSE2520 and could in that sense continue with examples given in the previous course.

4. Category 4 courses: Most other courses in the bachelor focus on teaching students the necessary mathematics and knowledge about algorithms to become good computer scientists. These courses could consider changing some examples to be more related to sustainability, but a more direct link would be missing.

A resource that could be used for further inspiration and with resources for integrating sustainability in computer science is: `https://serc.carleton.edu/sisl/sustain_in_cs.html`

1.2.2. Electrical Engineering

As described on the Electrical Engineering website: "[Electrical Engineering] is a broad and diverse field, with everything from solar cells to computer chips and medical implants."[7]. This immediately touches upon the relevance of Electrical Engineering in sustainability: it has created some of the most important technology needed in the energy transition (e.g. solar panels).

As mentioned in the *Student opinions regarding sustainability and EEMCS* and *Computer Science and Engineering* sections, many of the Electrical Engineering students already indicated to be happy with the presence of a course directly focused on sustainability in their bachelor curriculum and only pointed out that sustainability could be more integrated horizontally or in project courses.

Electrical Engineering in this regards stands out from the other bachelor programs at EEMCS as it has already integrated sustainability as a direct topic of study in three courses. However, none of these courses are project courses and there are other courses too where the connection could be made.

The rest of this sub-chapter will comment on specific courses, mentioning where ideas like the ones described above could be implemented. *Cursive text is used to mark recommendations.* Sometimes it is mentioned explicitly, but further elaborations or help with implementing these recommendations could come from future GreenTeams.

Electrical Engineering Courses

1. Category 1 courses:

(a) EE2E21 Sustainable Energy Supply:

The best example within the EEMCS bachelor programs that demonstrates how the respective academic field is relevant with regards to sustainability.

[7] `https://www.tudelft.nl/en/education/programmes/bachelors/ee/bsc-electrical-engineering/field-of-study/`

2. Category 2 courses: Currently none of the four project courses in the Electrical Engineering bachelor focuses on sustainability. The integration of sustainability could be done as a project topic with the addition of a small marking criterion regarding the ethics of sustainability.

   (a) EE2L11 Design a Chip: *stimulate students to build something which solves a small problem with regards to sustainability*

   In the Design a Chip project students have to build a chip and are currently entirely free to decide the function of this chip. Instead, the topic of the project could be to solve a small, real problem in sustainability. For instance an energy monitoring system of electric devices.

   (b) EE3L11 Bachelor Graduation Project: *set up a number of project assignments related to sustainability*

   The department could create a list of project assignments related to sustainability. The project already has an important focus on ethics (see quote), which could be further extended to also include sustainability. "In view of the prime importance of the societal awareness for the future engineers, the students will be also involved in an “Ethics and technique” module that will discuss responsibility, ethical theories, ethical dilemmas in companies, taking decisions in an environment of uncertainty, ethics and law etc."[8]

3. Category 3 courses:

   (a) EE1L11 Booming Bass: *include comments on the environmental and societal concerns regarding the used materials*

   EE1L11 is the first project course in the Electrical Engineering Bachelor. Currently, it is mostly focused on the design and creation of a sound system. Relevant comments about resource management, the scarcity of resources such as copper and the environmental impact of mining such resources could be added to stimulate students' critical thinking.

   (b) EE2L11 Design a Chip: *similar to the recommendation for EE1L11 + earlier comment*

   (c) EE2E11 Electrical Energy Conversion: *relate the importance of energy efficiency to environmental impact*

   "This course is all about one central concept: power. There are many different kinds of power. Electric power can be supplied that will vary according to the current and voltage. Mechanical power is also vital to machines where force, rotational speed and acceleration are determining factors. Energy loss, for example, due to heat dissipating in a resistance or due to friction between two cogs, will affect the efficiency of a system." [9] In this regard comments can be made about the importance of for efficient power conversion in large power-plants, also showing calculations of the environmental implications of low efficiency.

   (d) EE2S21 Systems and Control: *mention in the introduction lecture how systems, control and feedback loops are important for environmental impact models and resource management*

   Whilst this course focus, in general, more on smaller systems, system analysis and control is an integral part of modelling important processes in sustainability such as: climate change models and waste stream analysis. In the introductory lecture of this course, it can be mentioned how the concepts taught in the lectures to come are also relevant for understanding and managing these large processes.

   (e) EE3D11 Computer Architecture and Organisation: *mention the environmental impact of the resources needed to build computers/computer chips*

   This course explains how a microprocessor works, how the processor uses its memory, and how that memory is configured. In this respect comments could be made about the rareness of quality silicon, the environmental impact of mining silicon or the lithium needed to power smartphones, and the amount hardware waste (e.g. the number of devices that are yearly thrown away) due to the rapid development of hardware.

4. Category 4 courses: Most other courses in the bachelor focus on teaching students other relevant knowledge to become good Electrical Engineers. These courses could consider changing some examples to be more related to sustainability, but a more direct link would probably be missing.

[8] From the studyguide, accessed via `https://studiegids.tudelft.nl/a101_displayCourse.do?course_id=55097`
[9] https://www.tudelft.nl/en/education/programmes/bachelors/ee/bsc-electrical-engineering/curriculum/

1.2.3. Applied Mathematics

From the different bachelor programs taught at EEMCS, Applied Mathematics might have the oldest connection to sustainability. Processes such as global warming, climate change would never have been understood if mathematical models had not been used to study these processes. A fundamental component of Applied Mathematics is optimisation and efficiency, also an integral part of sustainability.

Similar to Computer Science, in Mathematics sustainability could mostly be integrated into the application side of this academic field. Marleen Keijzer, course instructor of the course AM1050-B Modeling B, explained in an interview that Applied Mathematics is always looking for issues which have current relevance, sustainability naturally being part of this. In that sense, courses with a project component could let students solve small mathematical problems related to sustainability and environmental issues. A precedent of this was mentioned by Kees Vuik, responsible instructor of course AM1050-A Modelling A, who explained how in earlier versions of the course students had to work with models regarding the pollution level of a lake. Doing calculations on the developments of this pollution. This serves as a perfect illustration of how sustainability could be integrated horizontally into the Applied Mathematics bachelor.

The rest of this sub-chapter will comment on specific courses, mentioning where ideas like the ones described above could be implemented. *Cursive text is used to mark recommendations.* Sometimes it is mentioned explicitly, but further elaborations or help with implementing these recommendations could come from future GreenTeams.

Applied Mathematics Courses

1. Category 1 courses: The bachelor Applied Mathematics currently has no courses which could be classified as category 1. Currently, however, there are four spaces in the bachelor where students can choose an elective. *An elective course dedicated to teaching about the role of Mathematics in sustainability could be added.* Inspiration for how to integrate sustainability in mathematics courses could be found papers like "Sustainability Education: The What and How for Mathematics" [15].

2. Category 2 courses: The more direct integration of sustainability could probably best be done as a project topic with the addition of a small marking criterion regarding the ethics of sustainability.

   (a) AM1050-A Modelling A: *explicitly incorporate the modelling of environmental issues and problems in sustainability as exercises*

   As mentioned before, examples of modelling issues related to sustainability have already been part of the modelling courses in Applied Mathematics. This could be further extended, making explicitly a certain number of the project about environmental issues and sustainability issues. Besides the importance of larger models such as climate and environmental models could be mentioned and explained.

   (b) AM1050-B Modelling B: *similar to AM1050-A Modelling A*

   (c) AM2050-A Modelling 2A: *similar to AM1050-A Modelling A*

   (d) AM2050-B Modelling 2B: *similar to AM1050-A Modelling A*

   (e) AM3000 Bachelor Project: *highlight topics related to sustainable research*

   In the Bachelor Project students have the ability to choose from a range of different mathematical topics. A specific list indicating topics connected to sustainability could be drawn up and presented alongside the current list of topics.

3. Category 3 courses:

   (a) AM2520-H History of Mathematics: *include a section regarding the role mathematical models have played in sustainability*

   This course gives an overview of parts of the history of mathematics. When focusing on modern history, a section could be dedicated to the role mathematical climate models have played in the development of the societal discourse regarding climate change. Additionally, the accuracy of projections made outlined in historically significant works like the Club of Rome's "The Limits to Growth" (published in 1972) could be compared to empirically observed measurements. Creating space for discussions about the influence mathematical models have on such processes.

(b) AM2520-P Philosophy of Mathematics: *include a section about the ethical consequences of Mathematical modelling*

Mathematics plays a huge role in decision-making processes in large organisational structures like companies and countries. One model with slightly different values can lead to vastly different policies. The ethical responsibilities regarding the creation of accurate models can be discussed, examples of where this has gone wrong or the consequences of situations where accurate models were not published for political reasons can also be mentioned.

(c) AM 2530 Systems Theory: *mention the stability of global ecological- and climate systems*

In this course, it can be mentioned how since the Industrial Revolution human behaviour has influenced the global ecological and climate systems. Observations regarding stabilising and destabilising effects can be shared as examples of how the field of Mathematics contributes to raising awareness on this topic.

4. Category 4 courses: Most other courses in the bachelor focus on teaching students other important mathematics in which a link to sustainability is more difficult to make. These courses could consider changing some examples to be more related to sustainability, but a more direct link would be missing.

Resources that could be used for further inspiration and with more examples of integration of sustainability in mathematics can be found at: `https://serc.carleton.edu/sisl/sustain_in_math.html` and `http://sustainabilitymath.org/other-resources/`

1.3. Masters, minors and non-mandatory education

Due to time constraints, a decision had to be made about which program's analysis to prioritise. The bachelor programs were given priority as they serve as the basis for all the other education to come. The master programs were thus not evaluated with the same depth as the bachelor programs.

However, a quick note can be made: there is one master directly focused on sustainability: **MSc Sustainable Energy Technology**, one master which has a dedicated master track on sustainability: **MSc Electrical Engineering, track: European Wind Energy**, and one master which has a track which allows for a specialisation in a sustainable topic: **MSc Electrical Engineering, track: Electrical Power Engineering, specialisation: Solar Energy**. The other masters: Applied Mathematics, MSc Computer Engineering. MSc Computer Science, MSc Electrical Engineering (its other tracks) and MSc Embedded Systems, currently contain no courses directly related to sustainability.

Additionally, there is one minor which presence is important to mention which is: **Minor Electrical Sustainable Energy Systems**. The only minor at EEMCS directly focused on sustainability.

A final note based on the interest of students is that many students seemed to be very interested in EEMCS giving more space in lunch lectures and symposiums to the topic of sustainability or research connected to environmental impact, waste management, climate change, the energy transition, etc. Opportunities allowing students to learn about these topics in a non-mandatory setting or to be introduced to companies working on these topics.

Recommendation: *promote and give extra support to sustainability related events at EEMCS, in a structural manner.*

2

Operational

The TU Delft is currently focused on making the campus more sustainable. The ambitious goal which is set, is to make the campus circular and CO_2 neutral in 2030 [10]. The mindset used for looking at ways to become more sustainable is to critically look at what is actually needed, or in other words, what can be **refused**? Also think of **reducing** energy and water usage for instance. Lastly, there should be looked at ways to incorporate used products back into the campus, thus **recycle**. Everything that is brought as 'new' into the campus, should be as sustainable as possible. This research only focuses on the faculty of EEMCS, but it is extremely helpful to keep the terms **'refuse, reduce, reuse'** in mind in our evaluation.

The operational portfolio was created with the triad mentioned in the previous paragraph kept in mind. In this portfolio, there are many different sub-portfolio's, or aspects, which need evaluation. The aspects can be categorized as follows:

- Waste
- Catering
- Events
- Water, electricity and heating/cooling
- Interior of EEMCS (e.g. furniture, atmosphere)
- Exterior of EEMCS (e.g. parking spaces, spaces to stall your bicycle)

2.1. Waste

With more than 5000 people using EEMCS as a hub for research, studying and working, you can imagine the amount of waste created in a day. If we want to work towards our waste being circular, we have to consider if the waste itself can be reduced, and can the waste be recycled?

2.1.1. Waste reduction

It is of course important to look at how we process waste, but if we can reduce the waste, the battle is half won. There was a petition started by Lijst Beta[1] at the end of the academic year of 2018/2019, which stated that all one-use plastic should be banned on campus. Sadly, this petition was rejected by the TU Delft [2]. However, we can look into other solutions for the reduction of waste which are less impactful on how the catering companies within the EEMCS faculty operate. Waste reduction can be achieved in several ways. This is a list of waste reduction options which are already implemented in the faculty.

[1] One of the two Student Council parties of the TU Delft

[2] Private conversation with Nils Bebelaar, secretary/external affairs of the faction of Lijst Beta (2019/2020).

Figure 2.1: The cutlery recycling bin at the cafeteria of EEMCS.

Regarding catering:

- Coffeestar offers a 25 cent discount if you bring your own cup. Furthermore, they never give you a plastic cup lid - you have to get it yourself. This reduces the amount of plastic lids used, because in stead of all customers receiving a plastic lid, only the specific customer who wants a lid will use one.
- The cafeteria offers a 30% discount on the final price if you buy snacks/lunch in the last twenty minutes of the lunch break. This measure is taken with the goal that people will buy food which is left after the lunch break, and thus reduce the amount of food which they have to throw away. However, a troubling fact is that the cafeteria offers free utensils for everyone. They are biodegradable, but because they do not ask a fee for the utensils, people are not inclined to bring their own cutlery, which would reduce the waste. There is a possibility to separately throw away the cutlery, and there is a designated bin for it in the cafeteria (shown in the Figure 2.1).

Regarding practicals, lab sessions and research:

- In some projects, the electronic elements which are used in the projects are reused in other projects. This is done by the professors/lab assistants, and is very time consuming and can be tricky - all of the components need to be soldered in order to be removed. These electrical elements are often the larger and more expensive elements. The possibility of making students take apart their work has been thought of, however, due to the high workload and deadlines of the projects it is not feasible. All of the electronic waste which cannot be reused is collected separately [3].

Regarding paper, promotional material etc:

- Throughout the entire faculty, there are net presenters which display promotional material. This way, the use of posters and flyers are less necessary.
- Flyering in EEMCS is forbidden.
- There are designated spaces to hang up posters. This keeps the number of posters printed more or less limited.
- Printing documents as a student costs money. This makes it less attractive to print a lot of paper.

[3] Private conversation with Ton Slats, Electrical Engineering Education (EEE), Department of Microelectronics.

Recommendation 2.1: It would be preferable not to give away the biodegradable cutlery at the cafeteria for free, but to ask a small fee for using them (think of 10 or 20 cents). This way, people will become more aware of them having to buy cutlery with every single meal they eat. They will become more inclined to bring their own cutlery.

Recommendation 2.2: Because it does happen that people forget their water bottles or cutlery from home, a small shop or vending machine selling reusable items would be of great benefit for EEMCS. This shop would sell reusable cutlery, water bottles, food containers etc. To optimize the store for students, it could also sell pencils, pens and notepads which are all sustainably resourced. 66.7% of the EEMCS sustainability survey participants wishes for a reduced use of plastic at the Faculty - the implementation of a reusable utensil shop could be a step in the right direction.

Recommendation 2.3: The printers are not set to default mode on double sided printing/black and white printing (the more sustainable settings). This results in a lot of people printing more paper than they necessarily need. What also often occurs, is that students print a large document single-sided by accident, and end up printing the whole document again for it to be double-sided. It is highly recommended to set the default mode for all of the printers in EEMCS to double sided printing and black and white printing. This makes it a conscious choice whenever you want to print a document single sided or in colour, in stead of the other way around. To support this idea, 48.9% of survey participants wish for less paper waste at EEMCS, and 68.9% would like to see the default setting of printers to double-sided black and white printing.

2.1.2. Recycling waste

How clever a waste reduction scheme may be, there will always exist waste in a building which hosts more than a thousand people a day. This is why is it worthwhile to look at ways to recycle our waste.

The waste management at the faculty is not managed from there- it is a centralized scheme which is implemented on the whole campus. A new pilot is newly implemented (June, 2020) at the faculty of Architecture and the Aula, which will focus more on reducing the amount of residual waste, by creating more waste streams [4] (seperate collection of PET-bottles, paper, cardboard and PMD). The experiences which are going to be gained in this pilot, both in front of and behind the scenes, will be used for a campus-wide roll-out of waste separation [23]. At the moment however, the waste is centrally managed, no individual changes can be made to the faculty of EEMCS. Even though EEMCS cannot make individual changes regarding waste, the staff members/students are mostly ready for more recycling options - 55,6% of the survey participants would like to see more recycling options in the Faculty. In total, there are thirteen separate waste compartments defined on campus. Think of paper, VFG [5], wood, and metal [9].

In the ideal situation, students and staff members would be aware of the situation of waste management, and are informed enough to be aware of the importance of recycling their waste at EEMCS. But are people currently aware that the Faculty already recycles some sorts of waste? 12,2% of our survey participants did not know that the TU Delft recycles at all. Not all waste categories are relevant for in public spaces in the building (for instance, electronic and dangerous waste would be for in labs). Two kinds of waste which can be recycled in the current scheme and are relevant for visitors, students and staff members are paper, and the carton coffee cups. The coffee cups can be thrown away in special designated bins, which are positioned throughout EEMCS (see figure 2.2). The paper part of the cup is recycled into toilet paper, the plastic coating is used for making plastic syringes, and the paint on the paper cups is recycled to corrugated sheets. This is all done by a company called Renewi [9]. Although this information is stated on the TU Delft website, 38,9% of the survey participants did not know where to recycle, and 54,4% where unsure about if their waste was recyclable. This raises the question if information like the coffe cup recycling scheme are made clear enough to EEMCS visitors.

As can be seen in Figure 2.2, there are two types of bins for the coffee cups: a large container (mainly for the CoffeeStar cups), and a smaller version. Throughout EEMCS, the number of coffee bins is not evenly distributed. On the ground floor, you will find eight bins, while on the first floor (the cafeteria) there is only

[4] All loose waste bins in the faculty and the Aula will be replaced by waste stations at central locations where paper, PMD (plastic, metal, drinks carton) and residual waste can be disposed. In the restaurants you will also find a green bin for food waste [23].

[5] Vegetable, Food and Garden waste

one. At the entrance of every lecture hall there is a bin, and on the second floor (study places) there are more than enough coffee bins. Also, next to every vending machine for coffee you will find such a bin.

Figure 2.2: The two types of coffee cup recycling bins in EEMCS.

As you can see, on the smaller bin there is a very small text, which is quite hidden, which says 'Recycle'. Although it may be clear to people that the cups are recycled, it is a missed opportunity to educate them more on how they are recycled. We see a great opportunity here to make for example a large poster above the bin, which states how the coffee cups will be recycled - this way, the public is made more aware of the importance of throwing the coffee cups in the designated bins.

As mentioned, paper is collected separately at the faculty. Throughout the faculty, near printers, there are paper bins in which you can throw away your paper waste. If you take a closer look at all of the bins, is becomes apparent they are not consistently marked as paper bins - the bins throughout the building are not the same. Figure 2.3 shows two types of paper bins found, one on the ground floor and the right bins are from the second floor (a study area). A very positive feature is that every printer has a bin in the vicinity, but because of the inconsistency of how these paper bins look, it can be very confusing for people if these bins are meant for paper waste. Also, it does not portray the separate collection of paper waste clearly. Thus, there is definitely room for improvement regarding the paper waste disposal possibilities.

Figure 2.3: The two types of paper bins in EEMCS.

Recommendation 2.4: It would be beneficial to improve the promotion as well as the distribution of the recycling bins for the coffee cups. It must be clear that when you throw your coffee cup in these bins, your cup will be recycled. It has been found that helping people think about how recyclables become new products inspires consumers to recycle more [18], so it is suggested to replace the labels on the bins with a clearer explanation of the recycling process. People will be more willing to consciously recycle their waste when they

know what will happen to it. Lastly, the distribution of the bins can use improvement - more coffee bins in the cafeteria are needed.

Recommendation 2.5: It would be beneficial if the paper bins, which are in the vicinity of the printers, look more consistent. The bins for recycling paper should look uniform throughout the faculty, so that people know exactly where to throw away their paper waste.

2.2. Catering

Within the faculty of EEMCS, we have the following forms of catering:

- CirFood, the cafeteria on the first floor
- Coffee Star in the central hall
- Vending machines all over the faculty (coffee, soda, snacks)

If you look at the carbon footprint of the TU Delft, a large part of our footprint is generated by food (28,8% of the CO_2 footprint of the TU Delft in 2018) [16]. Therefore, it is worthwile to look at how we can reduce the carbon footprint of our food. All different kinds of food are served at CirFood, Coffeestar only offers cakes, bars and chocolate (of Tony's Chocolonely - a fairtrade chocolate brand). Currently, CirFood is the caterer of all the cafeteria's on campus. This means, they work with one contract for the whole campus, and thus not a separate regulation for every faculty. CirFood offers some vegetarian options. However, most of their menu consists of meals and snacks containing meat. Figure 2.5 shows the answers of the sustainability survey on vegan/vegetarian options at EEMCS . GreenTU is working with CirFood to look into ways to make the food more sustainable - one of their goals is to shift the 60% meat 40% vegetarian distribution to 40% meat and 60% vegetarian. CirFood is quite willing to sit around the table with GreenTU and together exploring how they can make their offer more sustainable. Figure 2.4 shows how the survey participants feel about the importance of sustainable food choices at the Faculty. Because the discussions with CirFood are held for the whole campus, it is on the TU Delft central scheme and thus the responsibility of GreenTU. As a GreenTeam of EEMCS, there is not a lot to say in this process as GreenTeams deal with decentralised matters[6].

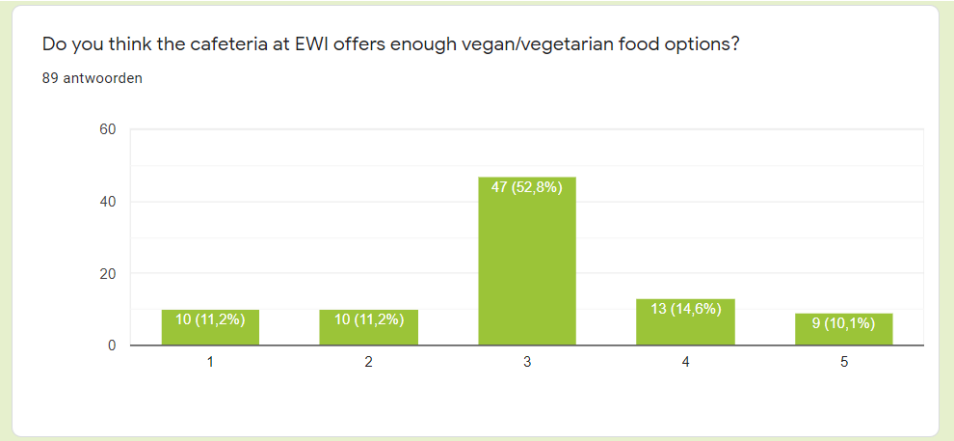


Figure 2.4: Sustainability survey answers on the availability of vegan/vegetarian food options at EEMCS

A lot of students and staff members use the vending machines to buy snacks or drinks. Whether it is a machine dispensing snacks, coffee or soda, they are all popular. The supplier for the vending machines is Maas. This company also is going through negotiations with GreenTU, as they have a contract to supply the whole campus with vending machines. Again, the GreenTeam of EEMCS does not have a lot of influence on what happens in that field. Luckily, GreenTU is doing their best to make sure all snacks and drinks in the vending machines are as sustainable as possible (sustainable packaging, small carbon footprint etc.). This is

[6]Private conversation with Sarah van Amerongen, operations coordinator of GreenTU.

Figure 2.5: Sustainability survey answers on the importance of having sustainable food choices at EEMCS

in line with the opinion of the survey participants - 75.6% wants to have plastic-free packaging options, 48.9% would like to see locally sourced products and 32,2% would prefer products without palm oil. On the ground floor of EEMCS there are three vending machines - one coffee machine, one soda machine and one snack machine. This same distribution is also the case on the first floor.

2.3. Events

2.3.1. Open Days

One of the biggest events held at EEMCS a couple of times a year, is the 'Open Day' - this is a one or two day event where pupils from secondary schools come to visit the faculty to gain more information on their possible future study course. A staggering 1300 people on average come to the faculty during these days . But how does the faculty score on sustainability during these events?

Let's start with the 'promotional material': posters, banners, flyers etc. The posters and banners are re-used until the information on them is no longer relevant, or the material is simply said too old and worn out. These posters and banners are said to last at least four years, which means that these materials are reused quite successfully [7]. Every student is given a brochure with information on a course of study. Say, of the 1300 visitors, there are 800 secondary school visitors, and they all take three brochures (for the three different Bsc. courses), that would mean 2400 brochures.

The faculty offers free tea and coffee to the visitors, which means a lot of coffee cups and tea bags are used. The coffee and hot water is provided in large percolators, and the tea bags are displayed in bowls - they are all separately packaged, however this is necessary due to reasons of hygiene.

One of the aspects of the open days which is wasteful are the so called 'werkcolleges', or 'instructions'. During these instructions, every person in the lecture hall gets a pen and a sheet of paper (parents included) to do exercises on. However, a lot of people do not use the paper and pens, and end up throwing them away. Mind you, if the lecture hall is full, about 400 students and parents fit in there! This means, if the open day has 3 rounds (of 3 studies) and lasts 2 days, 9600 sheets of paper and 9600 pens are needed. A lot of these are thrown away. This is an aspect of the open days which could use another approach in order to be less wasteful.

Recommendation 2.6: It is strongly suggested to look at the possibilities for printing the brochures on recycled paper. This does not only reduce the impact on the environment, but it also shows all of the -possible- future students that EEMCS finds sustainability important.

[7] Private conversation with Owen van Hooff, student assistant at Communications and helps to organize the Open Days.

Recommendation 2.7: Because so many of the visitors use the coffee cups to drink coffee and tea all day, it would be a good idea to place more coffee cup recycling bins on the ground floor (where all of the visitors are) and clearly mark them.

Recommendation 2.8: What would help during the instructions, is for the department of Communications, the organizing party of the Open Days, to take a look at the waste they produce during the instructions. Because so many people do not use their sheet of paper, it is suggested to ask the visitors who would like to actively participate in the exercises, and to only provide them with paper. Also, Communications could ask the visitors to bring their own notepad and pen to the open day, they could mention this in their information e-mail.

2.3.2. EEMCS Recruitment Days

Another large event at EEMCS which takes place once a year are the EEMCS Recruitment Days. During this week long event organised by the Electrotechnische Vereeniging [8], 450 students and over 45 companies gather to conduct interviews.

Most of the promotional materials of the Recruitment Days are not sustainable - think of more than 50 posters, 1250 flyers and 1500 bookmarks. These are single use materials, which need to be bought every year. There are some promotional materials which are reused, such as two large banners and two standing banners. During the event, lunch is provided for the companies every day. Since this academic year (201/2020), sustainability has become more of a criteria for the organisation of the event - everything is bought in bulk, which means less packaging, all the plates and cutlery used is glass/ceramic, and the food is 50/50 vegetarian/meat. There is also a drink after every day of interviews. Only glass is used here, which is great because glass is easily reused.

Looking at the total picture, the most wasteful aspect of the Recruitment Days are the promotional materials - all the flyers, bookmarks and more which are single use, but bought in bulk [9].

Recommendation 2.9: If the organising committee of the Recruitment Days wishes to continue using flyers and bookmarks as a promotional material, it could be a good suggestion for it to be printed on recycled paper to reduce the impact on the environment.

2.3.3. Freshmen Weekends

Probably the two biggest events organised by the faculty are the freshmen weekends of the two study associations, the ETV and Christiaan Huygens[10]. Although they do not take place entirely at the faculty, they are connected to EEMCS and worthwhile looking at. Because the two freshmen weekends are very different, we will evaluate them separately.

ETV: The freshmen weekend is attended by over 80 future Electrical Engineering students, together with the organising team of about twenty to thirty people. The event lasts four days, of which one day and one night is spent at the faculty. The remaining days are spent at a camping site outside of Delft. All of the future students are expected to bring their own bike, mattress/sleeping bag, water bottle, plate and cutlery. This is required to minimize the plastic bottles/cutlery the ETV has to buy. There is one crate of reusable plates/cutlery for any student who forgot their supplies. Additionally, all of the freshmen students are given a glass jug for them to use the entire weekend. Because of these mugs, the use of plastic cups is almost not necessary at all.

The main mode of transportation of all of the students is by bike, for the entire weekend. There are two mini-vans used during the weekend, to transport food/bags of the students/camping gear. Breakfast and lunch during the weekend is the same every day - bread and toppings. The breakfast and lunch are both going to be completely vegetarian from this year forward. The dinner at the camping site varies throughout the days. One evening there is a large barbecue. Up until this year, this barbecue was mainly meat and bread. However, the ETV plans to make the barbecue 50/50 meat/vegetarian in the future. On the third night, it is

[8] Or ETV, the study association of Electrical Engineering.
[9] Source is Shea Haggerty, one of the organizing committee members of the Recruitment Days.
[10] Or CH, the study association of Computer Science Engineering and Mathematics.

tradition to serve take-away Chinese food. All of this food, for about 100 people, is delivered in single use containers and bags. This year, the organizing committee of the ETV is set to search for a take-away option where the food is served in aluminium/reusable containers, to reduce waste [11].

CH: The freshmen weekend of CH is attended by about 250 freshmen students, and next to this 50 mentors, and 35 organising committee members. The main way of transportation is by bus, because the weekend takes place in Eindhoven. All of the freshmen are brought there by bus, but once they are there they mainly walk everywhere. The freshmen are not expected to bring cutlery/water bottles, these are provided. The food is quite similar of that of the ETV: every morning and afternoon bread and toppings (vegetarian and non-vegetarian options), and in the evenings wraps with meat and a barbecue. CH are not considering making their freshmen weekends more sustainable at the moment, other than buying hard cups in bulk in order to avoid using plastic single use cups for their parties in the evening [12].

Recommendation 2.10: CH could possibly look into the opportunities of providing a vegetarian lunch/breakfast.

2.4. Water, electricity and heating/cooling

2.4.1. Water

EEMCS is a large faculty, where a lot of water is used daily. A source of water usage which could be controlled easily, is the amount of water which is used while washing hands. There are two types of water taps present in EEMCS: time controlled taps with a movement sensor, and taps with a manual lever. The taps which respond to movement switch on almost immediately after you hold your hands under the tap, but continue to run for 2.5 seconds after you remove your hands from the tap. What if we could reduce this time with a second, so 1.5 seconds? We assume the fact that an average tap dispenses 100 ml of water in one second, and that on average 3000 people wash their hands at EEMCS per day. This would mean it saves us 300 litres of water per day! In a year, this would accumulate to more than 100,000 litres of water.

This covers the taps with a sensor, but there are still a good number of manual taps in the Faculty. Because manual taps do not switch of automatically, you are at risk of people forgetting to turn the tap of immediately, and thus wasting water. Installing motion sensor faucets will reduce this kind of waste by stopping the water flow every time the hands are removed. It is believed that installing motion sensor faucets can save as much as 30% to 50% [12].

It is also useful to consider whether or not you can fill your bottle at the taps of EEMCS. In all of the taps on the ground floor and first floor this is possible. However, when you look at the toilets in the lower part op EEMCS, it is not possible to fill your bottle. Not being able to fill your bottle near your work place can discourage people to bring a reusable bottle to the Faculty, and thus buying drinks in a nearby vending machine.

Recommendation 2.11: It would hugely inhibit the water usage if the taps with motion sensors could reduce the time of dispensing water by one second.

Recommendation 2.12: As stated above, replacing the manual taps by sensored taps could reduce a lot of water waste at EEMCS. It would be a good idea to look into replacing the manual taps.

Recommendation 2.13: On all of the floors at the lower part of EEMCS, there could be looked at the possibility to place water fountains to fill your water bottle (water dispensers such as Join the Pipe), as this is not possible at most taps in the toilets.

[11] Source is Shea Haggerty, she is chair of the ETV and helps to organize the freshmen weekend.
[12] Source is Marleen Hielkema, she is chair of CH and helps to organize the freshmen weekend.

2.4.2. Electricity

Recently, a lot of the older lighting in EEMCS has been replaced by LED lighting. This is a huge improvement, however not all of the building had LED lighting yet. Recently the whole lower part of EEMCS has been provided with LED lighting, and the goal is to have 95% of the lighting in the faculty being LED [13].

One way to reduce the electricity used by lighting is motion sensors in rooms and toilets. A movement sensor prohibits the unnecessary use of electricity for lighting by switching the lights off when there is no one in the room. For example, the toilets on the ground floor have lighting with motion sensors, but not the toilets on the first floor. The usage of these motion sensor lights is not consistent throughout EEMCS, so it could be a great energy saving implementation to have all lighting installed with motion sensors.

On the roof of the lower part of EEMCS and on the roof of the EPS-Hall are a lot of solar panels - 762 to be precise. This number was obtained by precisely counting all of the solar panels by looking at pictures from Google Satellite images (see figure 2.6). As is indicated by the red rectangle, there is a lot of unused space on the roof of the faculty.

Figure 2.6: The solar panels on the roof of EEMCS. The red rectangle shows the unused space on the roof (*Source: Google Satellite Images*).

In order to educate people about the use of solar panels, the faculty displays a slide on the net presenters, as in Figure 2.7. This displays the amount of solar panels at the TU Delft, and how much kW is being generated by the panels. It is a great start, but it does not display Faculty specific information, which people may find more interesting. This would also actively showcase that there are solar panels on EEMCS roofs, which is very positive.

Recommendation 2.14: It would have positive impact on the electricity usage to install lighting with motion sensors in all rooms where it is not installed yet, in order to save energy. 61.1% of survey participats would like to see automatic motion sensor lighting in the Faculty.

Recommendation 2.15: To make use of the free space on the roof of EEMCS, a good idea would be to create a solar farm for students to conduct experiments regarding solar energy, or giving them space to test out their own solar-related projects.

[13] Private conversation with Erik de Vos, FM EEMCS.

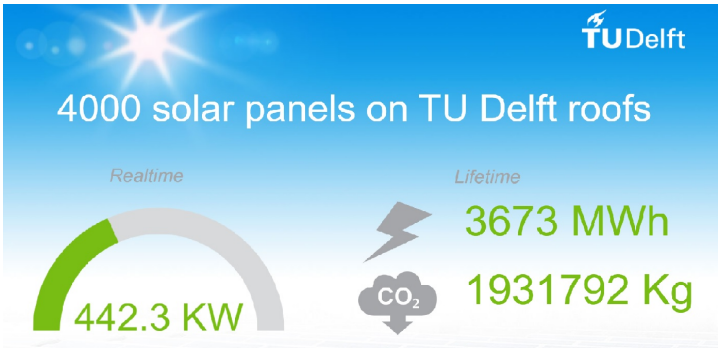


Figure 2.7: The image on the net presenters as is now displayed in EEMCS [8].

Recommendation 2.16: It is believed altering the image displayed on the net presenters to something more faculty specific would be a great addition to the current net presenter image. This information is for example how many solar panels are on the roof of EEMCS, how much they generate and what percentage of the total usage of EEMCS this covers. An example of this can be seen in Figure 2.8.

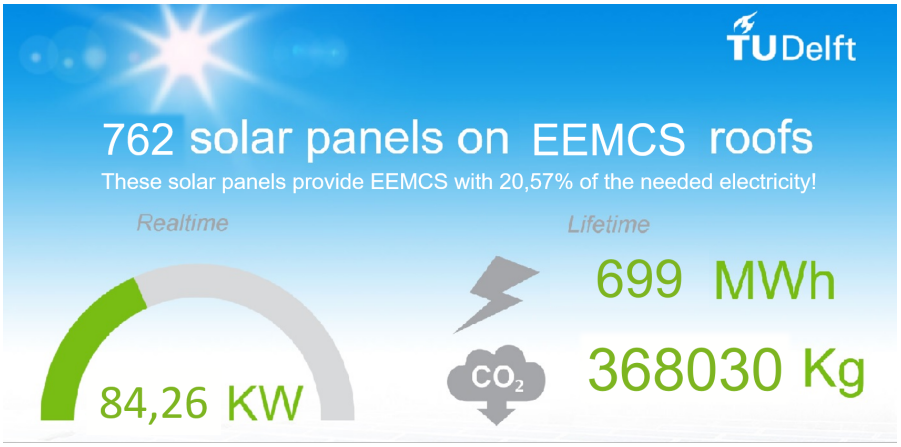


Figure 2.8: The altered net presenter image with more EEMCS specific and other relevant information (the numbers are an estimate, they are not the real values).

2.4.3. Heating and cooling

The TU Delft was, back in the day, one of the first large organisations in the Netherlands which stored underground seasonal thermal energy. In 1998 four underground wells were drilled under EEMCS for heating/-cooling the building. Seasonal thermal energy storage (WKO - commonly used Dutch abbreviation) was used more and more throughout the whole of the TU Delft, because it is a proven sustainable implementation. In the winter of 2017, the WKO of EEMCS delivered 1,3 GWh of warmth - this is a 20% reduction of CO_2 and gas for the whole of EEMCS. A lot of the coldness which comes from the WKO's is used to cool the EEMCS clean rooms [17]. At the moment, every WKO is attached to at most two buildings, but there are future possibilities to connect the WKO to more buildings. This way, if one building receives too much heat, the excess heat can be transported to another building. However, this is not implemented yet [10].

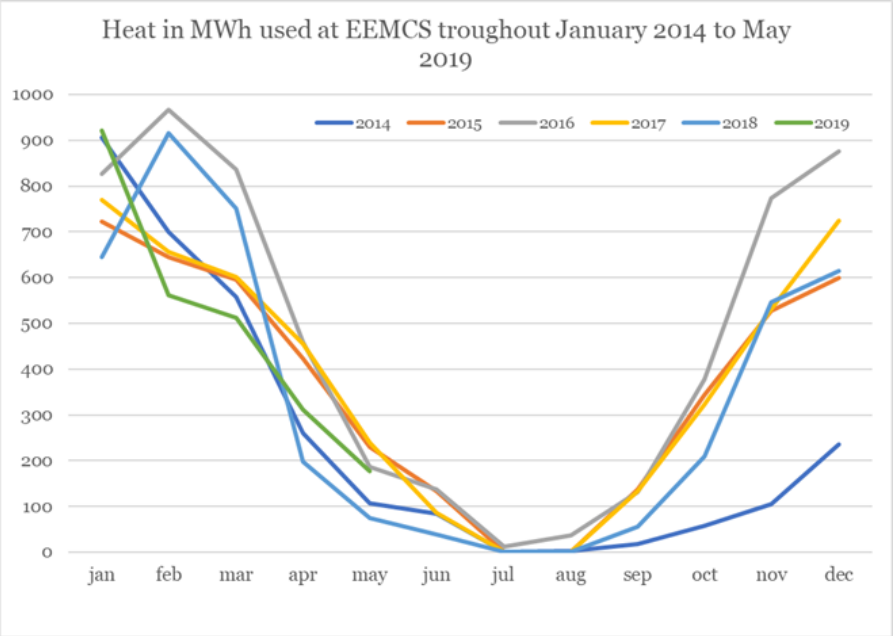


Figure 2.9: Data of the heat in MWh used in EEMCS from January 2014 until May 2019 [5]

One aspect of the building itself which drastically influences the temperature, is the fact that a lot of windows in EEMCS are single-glass. This means in the summer that it can get unpleasantly hot, meaning more energy must be used to cool down the rooms. In the winter a lot of warmth is lost through the many single glass windows. 72.2% of the survey participants would like to see EEMCS better insulated. As you can see in Figure 2.9, the heat used at EEMCS skyrockets in the colder months. These numbers could be inhibited by replacing the single glass with double glass panes. If you look at the pro's of a double pane window with a coating for preventing heat loss, the U-value[14] of the window is more than twice as small. The lower the U-value, the better insulated a structure is [19]. A double pane and coated window also saves you 23 m^3 of gas per year per square meter of window [6]. Keep in mind that EEMCS has a lot of windows - this would mean a huge saving on gas yearly.

Recommendation 2.17: As the faculty of EEMCS has four wells at its disposal, it would be a good idea to investigate how we can optimise the system by connecting the wells to other buildings in the vicinity.

Recommendation 2.18: Replacing the single pane windows with double pane windows would be a great improvement for the isolation of the building, thus saving a lot of energy which is used for heating/cooling the building.

[14] The U-value is also known as thermal transmittance, and is the rate of transfer of heat through a structure (W/m^2K).

2.5. Interior of EEMCS

The interior of a building has a great impact on how people feel. One of the goals is to look at implementations regarding the interior of EEMCS which motivates people to make more sustainable choices. Right now, the central hall of EEMCS does not give a sense of a sustainable environment. In the EEMCS sustainability survey, 61,8% of the participants answered that the atmosphere at EEMCS is nothing special, regarding the question: "Does the atmosphere at EEMCS inspire you to be more sustainable?". 36% answered 'a little', and just 2.2% answered yes. When we look at Pulse, for example, it does have an ambiance of being a sustainable building (green walls, a lot of glass and wood used in the construction, use of green colours).

Figure 2.10: Example of a green wall used in a building. *Source: Archello.com*

Recommendation 2.19: It would make a huge positive impact if all of the large, outdated pictures of people in the central hall would be replaced with living green walls (as in Figure 2.10. This does not only make the space feel more environmentally friendly, but living green walls are natural air-filters, creating a cleaner work environment that will lead to better overall employee health and production. Living green walls metabolize harmful toxins while releasing oxygen into the workplace air, much like office plants but on a much larger scale. Not only is there a huge health benefit related to the green walls, but they are also widely used for noise reduction [11] - in a space such as the central hall this could be very beneficial. To support this idea, 61.1% of the survey participants want to see more plants in EEMCS.

EEMCS should not only 'feel' more sustainable, but solutions must be implemented to make the space actually more environmentally friendly. Right now, the elevators are placed very dominantly in the central hall. There is not much to do about that, but it is very unclear where the stairs are to go to the upper levels of EEMCS. The only stair which is easily spotted is the one leading up to the cafeteria, however, if you wish to walk up to the second floor, the stairs are quite hidden. This is also the case for the stairs which lead to the other floors of the lower part of EEMCS.

Recommendation 2.20: The stairs which are not in direct view could be clearly indicated by using signs, thus helping people notice them and hopefully being more inclined to take the stairs.

2.6. Exterior of EEMCS

EEMCS's exterior mainly exist of places to park bikes or (electric) cars. It would be beneficial for staff and students to commute to the faculty by bike, or public transportation. A lot of the survey participants commute to EEMCS in a sustainable way, a staggering 90% uses their bike or the bus. There is a bus stop right in front of the faculty, and more than enough places to park bikes. For people who prefer stalling their bike under a shelter, there is a bike shelter near the back entrance of EEMCS. Furthermore, there are enough bins (including cigarette bins) around EEMCS.

One possibility which presents itself regarding the exterior of EEMCS, is the large open space between the ‘laagbouw’ and the glass hallway leading there. This space contains an artwork, but has a lot on unused space around it.

Recommendation 2.21: It could be a good idea to investigate the possibilities to place trees or plants on the large open space behind EEMCS. Planting more greenery (like at the front of EEMCS) is not only beneficial for the environment, but if you were to place benches or a seating area, people will be more inclined to spend their lunch break outside.

3

Communications

In our opinion, an effective communication system will accomplish the following:

1. Inform the public of the sustainability policies being carried by TU Delft.
2. Inform the students on how they can get involved in sustainability, both for their official studies (ie. internships or selecting subjects) and extra-curricular work (ie. post-grad work, university research groups, sustainability offices).
3. Highlight research within the field of sustainability by EEMCS research groups.
4. Inspire students, staff and visitors to be more sustainable in their daily lives.

Sustainable initiatives should not remain hidden to the public. A remarkable project that no one knows about is bound to eventually be forgotten and disappear, but those that are prominently featured in the public eye gain interest and importance. Making sustainability a recognizable part of EEMCS, a part of the Faculty's identity, will mean sustainability awareness and projects will become a usual and natural characteristic of the Faculty instead of a novelty idea.

3.1. External communications

External communications refers to that information that is available to any public, inside and outside from the faculty.

3.1.1. TU Delft and EEMCS faculty website

The TU Delft website [1] acts as the main external communication hub of the university. The site is available both in Dutch and English. The site features a selection of relevant information that is periodically updated, including announcements, project highlights, and relevant contact data. In addition to this, there are five menus within which important informaiton about the university is categorized: Education (including the sections "Programmes", "Information and experience", "practical matters" and "Admission and application"), Research (including the sections "Research news", "Faculty and disciplines", "Thematic cooperation", "Grants & Grantees", "Research facilities", "Open Science" and "Research assessments"), Technology Transfer (including the sections "Tech Investment", "Entrepeneurship", "Home of Innovation" and "Development and Innovation"), Current (including the sections "Latest news", "Agenda", "University magazines", "Student projects", "Press officers", "Universiteit van Nederland", and "178th Dies Natalis"); and About TU Delft (including the sections "Working at TU Delft", "Finnd employees", "Contact and accessibility", "Strategy", "Facts and Figures", "Organization", "Faculties", "Alumni", "University Fund", "Crowfunding", "Visit TU Delft", and "Our campus"). As it can be seen, there is no direct mention to the sustainability of the university in any of these menus. This is remarkable, considering that an online site dedicated to the sustainability efforts in the

[1] https://www.tudelft.nl/en/

university already exists [2], but it cannot be directly reached form the main TU Delft website. It has to be purposely searched in the web browser.

The EEMCS faculty also has its own online website [3]. It is built with the same template as the TU Delft main site, and just like it it displays a changing selection of news and information, and has six different access menus to present other relevant information. These menus are Home, Study (with the sections "Bachelor programmes", "Master programmes", "Minors", "Online education", "PHD @ TU Delft", "Exchange", "Events", "Dreamteams", "Programme assessments", and "EEMCS Bloggers"); Research (with the sections "Computational Science", ·Data Science", "Energy Transition", "Health & Wellbeing", "Next Generation Sensing & Computing", "Quantum Computing", "Safety and Security", "Publications" and "Facilities"); Cooperation (with the sections "Collaborations", "Delft Data Science", and "Powerweb"); Current (with the sections "Latest news", "awards & Funding", "Calendar", "Nodes", and "Humans of EEMCS"); and The Faculty ("with the secitons "Dean", "Profile, facts and figures", "Professors", "Departments", "Diversity & Inclusion", "Alumni", "Contact", "Student associations", "Studierverzameling", and "Find your dream job at EEMCS").

Just as with the main TU Delft website, the EEMCS website has no mention to the sustainability efforts of the faculty, and any interested virtual visitor would have to purposefully search that information - which would lead them to the main TU Delft sustainability website, instead of finding information readily tailored for the EEMCS users.

Recommendation 3.1: include a sustainability tab in the main EEMCS website. Currently, the efforts of the Faculty towards sustainability are "hidden" on the online world, but the EEMCS GreenTeam believes that they should be displayed and celebrated in the main faculty site, such that any online visitor can easily find about them. Iit would be very recommendable to have a tab dedicated to sustainability in the EEMCS website. This could be included in the "The Faculty" menu, and have an overview of sustainability on a faculty level as well as a link to the main sustainability website and a highlight of relevant university-wide sustainability issues. Inside this tab, different topics related to sustainability can be highlighted with the goal of displaying to an external reader the variety of efforts being done by the Faculty on that area. The following sections are suggested:

- Education: a selection of courses that explicitly deal with sustainability, as well as online educational resources such as MOOCS interesting for the areas of study of the faculty.
- Research: highlight research groups and topics done in the faculty that are specifically about sustainability.
- Sustainability at EEMCS: highlight the different sustainability operational practices available at EEMCS, such as the recycling bins.
- Student involvement: showcase all the student groups that deal with sustainability within the faculty (such as the EEMCS GreenTeam) and in the university (such as the Delft Energy Club).

3.1.2. Social media

The EEMCS faculty has a Facebook [4] and an Instagram [5] page. These sites feature important announcements and highlights of various activities and operations of the faculty, but sustainability is not prominent on either.

GreenTU's social media presence counts with an Instagram [6], a Facebook [7] page, and a LinkedIn profile [8] (albeit the former is more focused towards professional contacts, while the formers are oriented towards interacting with a broad online audience in an engaging and more casual way). They mostly share university-wide sustainability information. As of 2020, each faculty GreenTeam is also expected to have their own social

[2] https://www.tudelft.nl/sustainability/
[3] https://www.tudelft.nl/en/eemcs/
[4] https://www.facebook.com/TUDelft.EEMCS/
[5] https://www.instagram.com/eemcs_tud/
[6] https://www.instagram.com/greentu.delft/
[7] https://www.facebook.com/GreenTUDelft/?__tn__=%2Cd%2CP-R&eid=ARAqWJkbcA30h_pdtvcc6tEk6U5Il7igZ_F3BdgNxpiEqGOm6vHL-bCPUmT-xt9ZPXTpTH9UOCsKcfh0
[8] https://www.linkedin.com/company/tu-delft-green-office/

media pages. The EEMCS GreenTeam launched its Instagram [9] and Facebook [10] page on the 12th of April, 2020. They were found to be the most fitting social media sites to reach out to the public, but it is important to keep in mind that the social media platforms might have to be changed in the future (depending on which platforms the target audience uses the most in the future).

Recommendation 3.2: maintain an active social media presence. For a body like the GreenTeam, which is relatively small compared to other faculty organizations, having a good social media presence is very important to reach out to students, university users, and external parties in general. Both the Instagram and Facebook pages should be maintained and updated regularly, at least once a week. Currently, the posts are published with a frame designed to make them unique and recognisable. While the frame can be changed, the post grid should have a consistent and recognisable aesthetic, and always include the "EEMCS GreenTeam" rubric. Cross-publications with other social media pages from the university is highly recommended (such as shoutouts or collaborations with GreenTU, EEMCS...).

The content should be tailored to deliver current and interesting information regarding sustainability. This includes posting information about timely events, commenting on university news, highlighting interesting research, and promoting the Faculty's sustainability efforts in general. Additionally, the social media content could be made more engaging by featuring posts that are not strictly related to the Faculty or the university, but will still be appealing and encouraging for the audience (such as tips on how to live more sustainabily, or highlight of worldwide news related to sustainability topics).

3.1.3. News articles (for instance, TU Delta magazine)

TU Delta is a magazine covers university-wide news, and it is available to an open audience inside and outside the university through its online site. As such, they only publish significant news that are interesting for a broad audience. Mrs. Sharina Ligtelijn, the GreenTU GreenTeams coordinator, has previously collaborated with TU Delta and has confirmed that the magazine was interested in posting further content about the GreenTeams, which would be a very positive PR campaign.

Recommendation 3.3: periodically publish articles on different sites. It is recommended that future EEMCS GreenTeams have an active communications officer who takes care of contacting external publications (such as Delta TU) in order to provide interesting content that will engage readers and make them aware of the GreenTeam efforts. Other online serial publications could also be started, such as a GreenTeam blog or collaborating in the Vlogs posted by the EEMCS faculty on YouTube.

3.1.4. Workshops and events that include the participation of external parties

It is common for the Faculty to host different events in collaboration with external parties. It is important that visitors and collaborators are aware that sustainability is taken seriously at the faculty and that everyone is encouraged to adopt small pro-sustainability motions.

Recommendation 3.4: engage external visitors in sustainability practices. The faculty should aim at facilitating a sustainable experience for external visitors. This includes actively communicating with them to inform of recommended sustainable practices, and providing enough facilities so that they can practice said practices in a natural manner. Guests should be noted of the sustainability practices done at the faculty and encouraged to follow them, so as to honor the commitment of the EEMCS faculty towards reducing its environmental impact. Examples of this are being paper-less whenever possible, being mindful about turning off lights and electronics, carrying reusable bottles, recycling, favoring transport via public transportation or bike over private vehicles... If guests have to bring extra material to hand out at the faculty, they should be contacted in advance and be let know that the faculty favours items that are easily recyclable, made out of sustainable materials (so for example, try to avoid plastic), etc...

Recommendation 3.5: reach out to collaborators involved in sustainability.For events and collaborations dealing with sustainability in particular, the GreenTeam could reach out to the involved collaborators and get

[9] `https://www.instagram.com/greenteameemcs/`
[10] `https://www.facebook.com/GreenTeam-EEMCS-102319584783518/`

involved with them in some way. Examples of this interaction could be having a representative attend their event or organizing a meeting with them. The objective is to let sustainable-oriented companies know that the faculty appreciates their field of work and is interested in keeping a partnership with them.

3.1.5. Partnerships and sponsorships

TU Delft has numerous partnerships and sponsorships with a wide variety of companies. In relation to their sustainability operations, these companies can roughly be divided in three categories: actively sustainable (their operations are based around sustainability), neutral (not related to sustainability, but not harmful for the environment either), and opposing (their operations are contrary to sustainability in any of the three aspects defined in the introduction section of this document). The GreenTeam is aware that some of these partners might develop operations contrary to the sustainability vision of the GreenTeam. How we will relate to them is a delicate topic which needs much further discussion before we decide on a position with respect to this.

Recommendation 3.6: publish a partners and sponsors list. With the purpose of being transparent with the public, it would be recommended that the EEMCS faculty releases a yearly actualized list of partners and sponsors and their relation to the faculty.

Recommendation 3.7: build a network of interesting partners and companies. It is also very recommendable to start a hub to connect all partners and sponsors that work within the field of sustainability - this could be done through the GreenTeam. It would act as a meeting place for companies with similar goals and targets, in order to strengthen their ties to the faculty and get them in touch with each other.

3.1.6. Recruitment events (for future students)

Anne Aarts, Communications and Information Officer EEMCS, was contacted by email to learn about what information about sustainability is given to prospective students: “In our promotion we do not necessarily point out sustainability as one of the main targets of EEMCS, but we try to give examples of how a student can contribute to sustainability or societal growth when they choose a certain BSc. Programme. We do that for each programme.” The GreenTeam finds very exciting that sustainability is already being addressed during recruiting events. It is also important that potential students are aware that sustainability is a habitual part of EEMCS and of TU Delft. They should be well aware of other initiatives, such as DreamTeams, the GreenTeams and GreenTU, the GreenVillage, sustainability MOOCS, etc...

Recommendation 3.8: include sustainability in the recruitment information. For open days, instruct recruiters to tell visitors about the sustainability initiatives on a faculty and university-wide level. Lots of them are very interesting for prospective students, such as DreamTeams and the GreenVillage. Make sustainability a sign of identity of the faculty, both from something they can expect on their day-to-day lives and as an interesting field of study and research. If the event allows for it, a representative group from the GreenTeam and/or GreenTU could also be present to provide first-hand information to visitors and propspective students.

3.1.7. Miscellaneous

This section covers information that was considered to be of interest but did not fit any of the previously shown categories. A great way to communicate sustainability in a practical way is to practice what we preach. That way, any person who comes to the EWI faculty will realize that the Faculty takes sustainability seriously and acts on it. This could be done by highlighting the operational activities being done in the faculty - a great example of this is how the announcement screens display the energy being generated from the rooftop solar panels. These panels are “hidden” in the roofs of the faculty, so would it not be for those screens, maybe people would not know they are there. Similar practices could be done for other operations.

Recommendation 3.9: adopt a sustainable aesthetic [11]. A very interesting way in which the faculty could improve sustainability communications would be to “look” more green. The goal is that the public will associate the EWI faculty with sustainability and being “green”. Examples of this could be to stop using plastic (particularly single-use plastic) on events such as recruitment days - the faculty could only hand out paper

[11] Please note that this is not a suggestion for the Faculty to greenwash its image, but rather a visual complement to accompany the sustainability efforts being done by the EEMCS Faculty.

bags (instead of plastic bags), don't give freebies (like pens and keychains) that have non-recyclable plastics, make sure that no single-use plastic is being used, etc... and for events on which lots of single-use plastic is being handed out (such as events with companies that hand out free stuff for the participants), a plastic-only recycling point should be prominently featured.

Recommendation 3.10: re-decorate the faculty. Another way of adopting a more sustainable look would be to revamp the decoration of the faculty. Ideas for this could be having a vertical garden like the one in PULSE would look modern and sustainable - in addition to actually being an ecological and practical piece of decoration. It could be put in the walls which currently have large pictures of people with technological gadgets. Having more interior plants in general would also be a good idea. Recycling points should be signaled prominently.

3.2. Internal communications

Internal communications refer to that which is directed only towards affiliated users of the faculty: students and staff. Effective change will only happen if the entire EEMCS family is aware of the importance of taking sustainability seriously and the power of many people doing small everyday gestures to reduce their environmental impact.

3.2.1. Communication among faculties

Regarding inter-GreenTeam communications, as of 2020, all GreenTeams are connected mainly via Whatsapp and Google Drive. Each team has its own Whatsapp group, connecting members of the GreenTeam as well as at least one representative from the GreenTU, the GreenTeams coordinator. There is also a large Whatsapp group in which all members from all the GreenTeams as well as the GreenTU are present. Periodic meetings are held in which all GreenTeams get together and discuss relevant issues. The work of each GreenTeam is stored in a public folder that other teams have access to, so that everyone is free to participate in the work of other faculties and improve on their own with new ideas. Periodic meetings are held in which all GreenTeam members are presents - wither as a whole group or represented through a speaker for their team. The purpose of these meetings is to put in common advancements and ideas carried in each individual faculty. It is important to note that this work methodology has only been active for the first generation of GreenTeams and the platforms used by each GreenTeam might change in the future.

Recommendation 3.11: maintain an active GreenTeams communication. GreenTeams should be actively connected in order to synergize their isolated work. It would be recommendable that a form of collective private communication is maintained (such as a group in Whatsapp or other instant message applications) and a regular schedule is set for all-GreenTeams meetings (for example every two months). It would also be very recommendable to encourage activities that strengthen the personal bonds among different GreenTeam members, such as actively participating in events at different faculties (for example, all the GreenTeams were invited to the vegetarian week in the Architecture faculty) and having the opportunity to socialize among them (for example, encourage socialization at the large GreenTeam meetings by having some aftertime to chat, or do a yearly workshop for all GreenTeam members).

3.2.2. With the students

For students, the university is more than just a place to study - it is also an environment that will also shape student's perspective on their future outlook and on the possibilities, opportunities and needs for developing certain technologies. Hence, the EEMCS believes that the Faculty should make students acquainted with the idea of sustainable technology as a habitual and serious matter. As the GreenTeam, our role should be to give students all possible ease to find out about research and development on sustainability fields and give them the tools to embrace a more sustainable life themselves.

Digital media (Brightspace and Webmail)

Brightspace allows students to access the course catalog. Any student can find courses on sustainability by simply searching in the catalog. Brightspace would be an extremely powerful tool to reach the students, because everyone has a Brightspace site that can be easily updated. A downside is that students have to search and enroll in the courses (although some pages, such as "organization" type pages, only require a one-time enrollment). Plus, students would have to be aware that the course exists in the first place - so if anything was

to be added to Brightspace, we would have to do some “PR” to get people to know it exists.

In regards to the WebMail, each faculty GreenTeam has an official TU Delft email address. But users of the faculty should know that this email is meant to be active and accessible for everyone. The mail should be prominently featured in every announcement or communication from our GreenTeam. In addition to being the official address to gather information and contact other people, it could be used to take suggestions and comments from people, ask questions, etc...

Recommendation 3.12: build a Brightspace page for the EEMCS GreenTeam. This page could act as a hub through which students can find out information about sustainability matters and sustainability-related activities they can get involved with. The site could have the following sections:

- Education: one tab highlighting all courses dedicated to sustainability, or useful for it, for masters and bachelors.
- Research: publish research opportunities (for thesis, for example) on the field of sustainability. It could also include research done on other faculties that EEMCS students can also do.
- Internships: internships at sustainable companies. In coordination with the internship department.
- Extra curricular activities: highlight university and faculty organizations that are involved with sustainability. This could include student associations such as the Delft Energy Club, position openings in sustainable student organizations such as GreenTU, lunch lectures...
- Events: either sustainability-specific events, or sustainable parts/participants of “generic” events. For instance, if an event with multiple companies is taking place, those that work in sustainable projects will be highlighted.

The GreenTeam should also carry a PR campaign to let Faculty users know about its existence and means of communication. In that line, it is important that all communicates from the GreenTeam clearly feature the means of contact and encourages the public to reach out.

Direct communication: Whatsapp

It is commonplace for students to have a Whatsapp group for their programs. This is a very powerful communication method, because it allows to reach students directly and in the most personal way. Whatsapp allows for instant and constant communication, and through a platform that allows to easily open and complete actions such as taking surveys or gathering contacts. It could thus be used to inform students about information backed by the GreenTeam, such as sustainability-related events. However, very large Whatsapp groups usually don't have a main contact point, meaning that it is usually up to us to find someone within a given Whatsapp group willing to pass the information. Also, this channel should be used sparsely, since too much communication from outside parties can quickly turn into spam.

Recommendation 3.13: Each study program could have a student “spokesperson” in charge of delivering news from the faculty to the student's Whatsapp group. We can then use this contact list of Whatsapp spokesperson to quickly and easily deliver direct information to students. Especially recommendable for things like events, particularly those that require inscription. This motion could be carried in coordination with the communications department of the Faculty, in order to make sure it is efficiently used (as other courses might also want to make use of this functionality) and the privacy of the students is preserved.

Physical media

The faculty has two main poster boards, as well as a few more scattered around the faculty - another visible one is in the cafeteria. The main ones are organised in different sections, depending on the subject of the posters being hanged. Posters hanged in the two main bards have to be approved and stamped by the Faculty student organizations beforehand. Posters provide an easy and immediate way of communications, but they have a major downside in that they are constantly in rotation, meaning that it can be hard to find out again the information an interested person was looking for after the poster is taken down.

Another physical mediaboard in the faculty are the digital screens distributed along the building (including those in the coffee machines). They could be very effective for communicating ongoing sustainability operations. They currently highlight the energy generated by the rooftop solar panels, so they could also display short bits of information about other operational activities.

The main use of screens is actually to inform about upcoming events. The issue when it comes to sustainability events is that they might get lost among all other announcements shown in the boards. The announcement on these screens is usually shown for only a few seconds, and depending on the design of the poster it can be hard to read the details of the event.

Recommendation 3.14: set up a virtual pster board. In order to facilitiate the finding of information from posters, it would be recommendable to have a "virtual" poster board that makes use of a tag system to quickly categorize and locate posters. Posters could be scanned and uploaded to this virtual poster board. Sustainability offers would then be easy and accessible to find from anywhere.

Recommendation 3.15: include a quick visual identifier on screen announcements. Regarding the screens, in order to facilitate the quick identification of sustainability-related announcements, there could be a visual indicator shown on every sustainability-related event - like a “stamp” on the bottom right corner, that would allow people to quickly identify it as a sustainability event before they read the details.

Recommendation 3.16: include more sustainability announcements on the screens. For example, highlight operational sustainability practices in order to make Faculty users aware of them. Since these would be recurrent announcements that will not change a lot over the course of the year, the screens at the coffee machines would be preferred for displaying them continuously, instead of “taking up” space from the main screens that showcase important events. They should also be displayed on the main screens, but sparsely and for short amounts of time.

Recommendation 3.17: have a dedicated poster board. Having a dedicated part on the poster boards for sustainability would be a good idea so that students can quickly find out about events and information.

Class content

This overlaps with the “education” portfolio. This section presents recommendations on how to improve the way students interact with communication regarding sustainability in their academic activities, with the objective of making sustainability a familiar and close topic for the students.

Recommendation 3.18: it would be very recommendable that teachers switch to using exclusively sustainable examples or set-ups for class examples and exercises. It would also be recommended that, if possible, projects are shifted so that they are contextualized towards sustainable technology uses. It is important to note that this is not meant in any way to be restrictive for the academic personnel, and it is only proposed to be used as background context for class activities. For example, if a particular exercise requires the analysis of a certain component, have that component be part of a sustainable technology (if possible!).

Events only for students (ie. bedrijvendagen, career workshops, hackathons...)

Different events catered for students take place throughout the academic year. Some of these events take place on a large scale, involving all TU Delft faculties and gathering many different companies and sponsors that participate in them. If the event is not about sustainability in itself, it can be hard for students to know what part of it is about sustainability or which of the participating companies work on the topic.

Recommendation 3.19: highlight interesting companies. for multi-company events, the GreenTeam could make a selection of those that work in sustainability topics and publish it so that students can quickly find out about them. For posters and visual media of the event, a small “stamp” could be featured next to the names of those companies.

3.2.3. Among the staff

If the EEMCS faculty wants to make significant changes in pro of sustainability, it is very important that the staff understands the need to make changes and knows what action they can personally take [12]. The GreenTeam considers that having this synergy with all the staff is very important in order to make the proposed changes for sustainability permanent measures that will be appreciated by all the Faculty users.

Educational staff

When talking about educational staff, we are considering exclusively the staff in charge of imparting knowledge onto students. In the case of a person who teaches a class and also has a separate administrative or managerial role, only their teaching side is considered for this case. Their role as an administrator would be covered under "non-educational staff".

The primary purpose of teachers is to educate the students. On a practical level, this education has to be contextualized - some topics are treated more in depth than others, examples and hypothetical situations have to be invented for class exercises and practical assignments, etc... As mentioned in the "Education" section, it is highly recommendable that all these contextualization are given using sustainable technologies whenever possible.

There are many teachers who are involved in research groups and projects, both within and outside of the university. Those who are involved in sustainability topics should advertise their work to the students so as to inform them and encourage them to get involved. Although all the professors at the university are extremely highly educated, perhaps some might be less aware about topics related to sustainability or the environment, and the GreenTeam believes it is a positive measure to also make them participant of positive sustainability advancements.

Recommendation 3.20: engage the academic staff. the GreenTeam could work alongside professors to design suitable class and assignment examples that are framed within the use of sustainable technologies. In order to promote dynamic and engaging sustainability education among teaching staff, it would be recommended that the professors themselves are the responsible to push it forwards. Maybe a campus-wide sustainability day for professors could be scheduled, including a think tank where they can exchange ideas. Besides all of this, professors at the faculty should also be informed of good sustainability practices within the faculty and in their personal lives.

Recommendation 3.21: encourage communication among teaching staff of different faculties. Inter-faculty communication among academic staff is also an aspect that should be considered. A recommendation to improve it could be to have a staff-only online site that would allow academic staff to post relevant information about sustainability projects and advancements, so that professors can interact with each other in developing new ideas.

Non-educational staff

The GreenTeam believes that, if we truly want our faculty to embrace sustainability, we have to ensure that every part of our Faculty family is involved. Non-educational staff should also be educated and informed about sustainability topics, particularly when it comes to those relevant to the operation of the faculty. As of now, there is no formal training program for non-educational staff on topics related to sustainability.

Recommendation 3.22: educate non-teaching staff. At the beginning of each year, we recommend that all non-educational staff is given an training session on general environmental problems, how individuals can help with them, and how the faculty in particular is taking measures to be more sustainable, in particular regarding to the department of the faculty they work in. The idea is that they will be aware of the relevance and nature of environmental problems, and of the importance of embracing changes for sustainability. Additionally, the faculty GreenTeam can put together a newsletter for the staff, covering the most important problems and breakthroughs related to sustainability, maybe to be sent twice a year.

[12] It is important to note that it is not the intention of the GreenTeam to suggest that individual actions are meant to overwrite the responsibility of the EEMCS faculty as an institution in taking action for sustainability. The objective of this suggestion is to create an environment in which sustainability is a habitual part of the daily workings of the Faculty and enables all its users to participate in it to the extent they desire.

Recommendation 3.23: define recommended sustainability practices. The GreenTeam could also make a “good practices” manual, explaining how people can be more sustainable in their day-to-day lives.

3.2.4. With student organizations

As per the academic year 2019-2020, all student organizations from TU Deft faculties are in direct contact with GreenTU via the outreach coordinator Lauren Besselaar. Mrs. Besselaar was contacted regarding this issue - the following information has been gathered based on her response: GreenTU has contact with every study association in the university, as well as all the student-led sustainability initiatives such as Students4Sustainability and the Energy Club. GreenTU also provides case-by-case jobs for for instance DROP or the OWee. The communication with student organizations takes place by email, Whatsapp (to a lesser extent and for more personal and direct communication), and the bi-monthly SCC (Students Sustainability Council) meetings. Each student organization has provide a list of representatives interested in sustainability issues. There are currently no sustainability requirements imposed on student organizqations, but GreenTU is currently working with them on creating a Sustainability Label what will allow organizations to see what they can change to be more sustainable.

Regarding EEMCS study associations in particular, Mrs. Besselaar said there is currently a well-established and active communication with ETV for sustainability topics, but has had no tangible success in doing the same with the Christiaan Huygens association.

Recommendation 3.24: engage with student associations. Regarding the communication between the EEMCS GreenTeam and the EEMCS study associations, it would be recommendable that firstly the GreenTeam gets in touch with GreenTU to discuss the specifics of how both institutions should handle communication with the same organizations, in order to make sure they do not step over the tasks of the other or create confusion for the student organizations. Once this is cleared up, the relationship between the GreenTeam and the student organizations can be more clearly defined. It would perhaps be a good idea if the GreenTeam assisted both GreenTU and student organizations in enacting the Sustainability Label initiative.

4

Research

This section presents an overview of the sustainability involvement of the research carried at the EEMCS Faculty.

4.1. EEMCS Research facilities

The EEMCS houses a number of research facilities:

- DUCAT: an anechoic chamber with an antenna for measurements.
- Else Kooi laboratory: a laboratory for manufacturing micro-electromechanical components.
- Electrical Sustainable Power Lab: this laboratory hosts utilities to advance research on a wide catalog of fields related to sustainable energy, paying special attention to the integration of technology. The research focus includes:
  - Materials development
  - Development of space charge measurement for commercial and non-commercial purposes
  - Power electronics energy storage
  - Development of cables for DC transmission
  - System integration of new technologies and components such as solar PV, wind conversion technologies and electric vehicles
  - Effect of transients in the power system on components and materials quality
  - Stability, Protection, and Control of hybrid AC/DC power system
  - High-voltage testing, modelling and validation
  - Ancillary services markets
  - Digital infrastructure
  - Labs and tools

  The Electrical Sustainable Power Lab counts with two special facilities:

  - High-Voltage Laboratory: this laboratory counts with three AC transformers for 500 kV which can be arranged in cascade to make up to 1500 kV, and a 20 stage lightning impulse generator up to 4 MV and 200 kJ - plus a 600 kV DC source. This allows for full-scale testing of High-Voltage devices. In addition to this, the lab counts with monitoring equipment such as dielectric spectroscopy, devices for capacitance and tangent delta measurements, high-tech oscilloscopes, SF6 handling equipment, vacuum ovens, high voltage amplifiers and special devices for partial discharge measurement.

    According to their website, the High-Voltage lab includes research on the following topics:

- ◇ Materials research: solid insulation, liquid insulation, nanoparticles, space charge.
- ◇ Monitoring and diagnostics: partial discharge sensors, tangent delta, acoustic methods, UHF and HF partial discharges, sensors for smart grids, partial discharge signal processing, partial discharge clustering.
- ◇ Asset management: remaining lifetime analysis, smart agents for smart grids

– Electrical Energy Conversion Laboratory: formerly known as the VEEM-hall laboratory, and currently located on the second floor of the low-rise building of the EEMCS-faculty; this laboratory deals with research related to power electronics and energy conversion. It is also used for educational purposes for courses such as "Power Electronics" and "Electric Machines". All the below mentioned facilities are open and supervised from 8.30 till 17.00h, however, work at voltages below 50V can be performed at any time the university is open in the Flex laboratory. This lab, which consists of four tables, is available for all DCES staff and students. The following research topics are highlighted in Electrical Energy Conversion Laboratory website:

- ◇ Power Electronics
- ◇ Electric Machines and Drives
- ◇ Hardware in the loop simulation (HIL)
- ◇ Smart grids, at DC as well as AC, or even combined ...
- ◇ Storage of (electrical) energy
- ◇ Wireless power transfer

The Electrical Energy Laboratory counts with the following subdivisions:

- ◇ Power Electronics and Grid Laboratory: this department investigates Power Electronic circuits and devices used for switching power converters in general, such as DC-DC, AC-DC, and DC-AC converters and their applications.
- ◇ Electric Machines Laboratory: this department validates computer models of rotating electric machines, such as new generation wind turbines, electric transport, etc.
- ◇ Technology room: this department houses extra technological equipment to be used in power electronics research, such as climate chambers or heat-plates for broad conditioned testing, SMD and vapour phase soldering equipment, impedance characterisation tools, a wide range DC and AC Power Supplies, a wide range of active and passive loads, thermal imaging, and a Li-ion battery storage and measurement facility.

The there are plans to upgrade the ESP lab with the following utilities:

– Smart Grids simulation and testing tools for testing the behaviour of sustainable energy sources and components, and simulating large-scale networks with different components connected.

– A DC laboratory focused on High-Voltage DC components for wind energy integration and Mid-Voltage DC for micro-grids with renewable energy and energy storage components. This will be used for developing components for Smart Cities and electric transport.

– A PV lab for testing and optimizing small-scale PV systems.

– Testing utilities for measuring energy conversion in PV devices, power electronic and converters, such as high-end oscilloscopes and smart sensors.

– Equipment for dielectric spectroscopy, space charge measurements, partial discharge analysis and fast transient measurements to promote synergy between materials research and system design.

– Material characterization techniques for solar energy conversion.

Recommendation 4.1: optimize the functioning of the research facilities. It is recommended that an overview of the operational sustainability of each facility is done, with the objective of reducing the environmental impact of each and ensure that the good sustainability practices proposed by the GreenTeam are observed. This should be done in coordination of the responsibles of each research facility.

4.1.1. EEMCS Research departments

There are five research departments at the EEMCS:

- Delft Institute of Applied Mathematics
- Electrical Sustainable Engineering
- Else Kooi Laboratory
- Intelligent Systems
- Microelectronics
- Quantum and Computer Engineering
- Software Rechnology

4.2. Research at EEMCS

This section presents an overview of the research topics and departments at the EEMCS Faculty.

4.2.1. EEMCS Research topics

Depending on the application of research carried by the different research departments of the EEMCS faculty, the publications can be divided into five themes:

- Computational Science: this theme is related to the TU Delft Institute for Computational Science and Engineering. This department focuses on the development of complex computer models and simulations for applications on a wide range of fields. This includes dynamic physics, mechanics and structures, solid structures, and socioeconomics and life. The institute is also developing a compact supercomputer under the name "The Little Green Box".
- Data Science: this theme largely deals with big data research and its applications. Big data can be implemented in a vast range of applications. The department cites smart cities, health, security, online education, and sports among them.
- Energy Transition: this theme has the goal of researching solutions for advancing from the current energy system, based on fossil fuels, into one powered by sustainable and renewable sources. The work of this department is twofold: on one hand, they produce research on new technological developments needed to advance the energy transition. On another, they study how to integrate new and existing technologies in order to make this transition feasible and attractive. Areas of study include wind, photovoltaic and biomass power sources, as well as other experimental forms of sustainable energy generation; grid control, management and security; design of AC and DC micro-grids; market analysis, and integration within the current existing infrastructure.

  Research within this theme is closely related to the Delft Energy Initiative (DRI), a university-wide group that aims to bring together different fields of engineering to help realize the energy transition towards a more sustainable system. The DRI focuses on the following topics:

  - Wind Energy Institute (DUWIND): DUWIND focuses on research related to wind energy generation, considering all aspects involved in the process - from material performance to aerodynamics, wind farm performance, meteorological studies, market performance, and power generation.
  - Urban Energy Institute: this institute focuses on designing sustainable urban infrastructure. The research is organized in six different themes:
    - Towards zero-energy buildings beyond
    - Fast transition existing building stock
    - Thermal urban energy systems
    - Solar Urban
    - Smart Monitoring, Management Control

    - ◇ Transforming the Cities
  - PowerWeb: the PowerWeb initiative aims to transform the current energy transport infrastructure by implementing SmartGrids. It develops research on the topics of hardware (physical systems), software (management systems), and peopleware (societal and economic factors). It has several projects closely related to the education in the EEMCS faculty:
    - ◇ COBRAcable: An expandable point-to-point (PtP) VSC-HVDC link
    - ◇ TSO2020: "Transmission and Storage Options" along TEN-E and TEN T corridors for 2020.
    - ◇ ADREM: Adaptive clustering for Decentralized Resilient Energy Management
    - ◇ MVI: Designing Responsible Innovative Heating Systems
    - ◇ CESEPS: Co-evolution of Smart Energy Products and Services
    - ◇ ERIGrid project: Technology support for development and roll-out of smart grid solutions in Europe
    - ◇ PROMOTION: PROgress on Meshed HVDC Offshore Transmission Networks
    - ◇ P2P-TALES: Enabling peer-to-peer energy trading by leveraging prosumer analytics
    - ◇ Smart grid infrastructure: MIGRATE
    - ◇ Assessment and Enhancement of Power System Stability in Power Electronics Dominated Transmission Systems
    - ◇ ATES Smart Grids+
    - ◇ MVI: Capturing the societal value of smart grids
    - ◇ Reliability Evaluation of Power Systems with Integrated Large-Scale Offshore Wind Energy
  - e-Refinery: according to their website, *[...] e-Refinery initiative focus their research on the electrochemical conversion of sustainable electricity into fuels and chemical building blocks, from the molecular scale to large-scale system integration.*

- Health and Well-being: this theme focuses on developing biomedical electronic devices and computational systems designed to improve health monitoring and treatment
- Next generation Sensing and Communication: this theme focuses on data acquisition and device connection, particularly for wireless devices. The description on their website explicitly states that *...The theme is expected to make strong technological contributions to the TU Delft Space and Climate institutes.*
- Quantum Computing: this theme focuses on research aimed at developing quantum computers and their applications.
- Safety and Security: this theme focuses on improving security by protecting the physical sensing mechanisms and developing cybernetic security measures to protect the data. Among their interests, they explicitly cite microgirds security, within the context of energy transition.

4.2.2. Institutional repository

All research carried by TU Delft is stored in the TU Delft research repository [1]. This online repository contains all the published research pieces from all faculties of the university, some of them dating back to the early XX century. It is divided into two main categories: the research repository, which includes works carried by research personnel; and the education repository, which includes student research such as MsC and BsC thesis, and other student publications. The repository is managed by the TU Delft library.

The site makes use of a tag system to classify the documents by faculty, year of publication and subject. The information presented in this section makes use of this tag system for analysing the repository archives. However, **it is very important to note that not all documents in the repository are adequately tagged**. As per the time of writing this report, more than 22000 publications do not have an affiliated faculty tag. This issue was brought up to the library information service, to which they explained *publications did not always mention a faculty, we did not always register faculty names, faculties were known by different names not matching your queries, sometimes only department names or names of research groups were included, over time faculties*

[1] https://repository.tudelft.nl/

have been dissolved, faculties merged with other faculties, faculties were renamed or faculties moved underlying organizational units to other faculties, and so on....

The information presented down below made use of this tag system to classify the different publications on the repository, as else there is no way to know which ones were produced by the EEMCS faculty. However, it means that this data might not fully represent the actual research history of the faculty, since those documents that did not have tags were not accounted for.

Published articles and PhD research
The total number of research publications per faculty is shown in Figure 4.1.

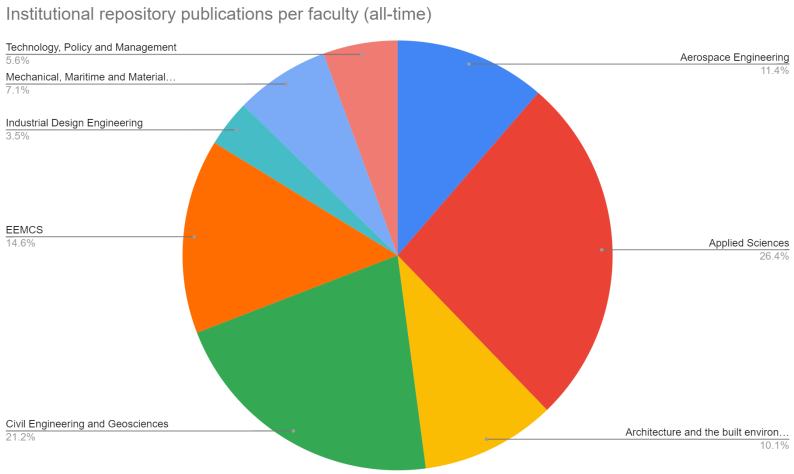


Figure 4.1: Per-faculty division of research publications, all-time.

It is also useful to consider a closest time period, in which all faculties were established and actively producing research, and this research was being carefully recorded. Figure 4.2 shows the research per faculty between the years 2000-2021. The total research output is of 19286 publications, of which the EEMCS produced 3267 pieces. This represents 16.9% of the total publications produced by the university, making the EEMCS faculty the third most active behind Civil Engineering and Geosciences (4478 publications, 23.2% of the total) and Applied Sciences (3658 publications, 19.0% of the total) and

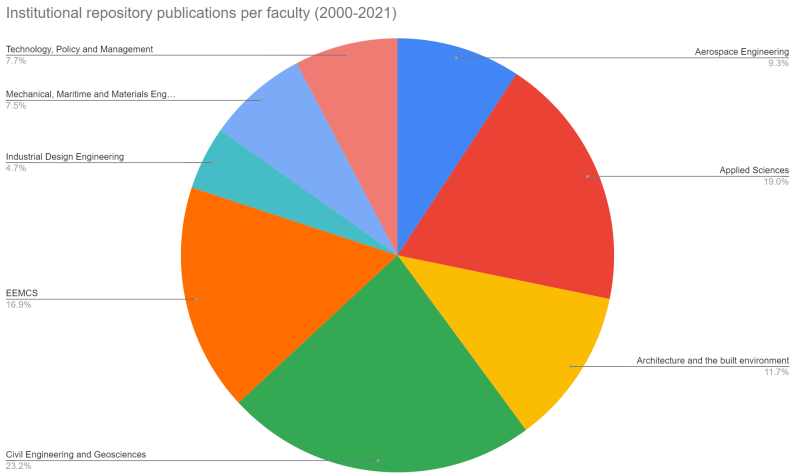


Figure 4.2: Per-faculty division of research publications, between the years 2000-2021.

Looking at the research produced by the EEMCS faculty, it can be classified as follows:

- By class: doctoral thesis make up the largest body of research from the repository with 1,254 entries (37,1 %), followed by journal articles (1340 entries, 32.7%).

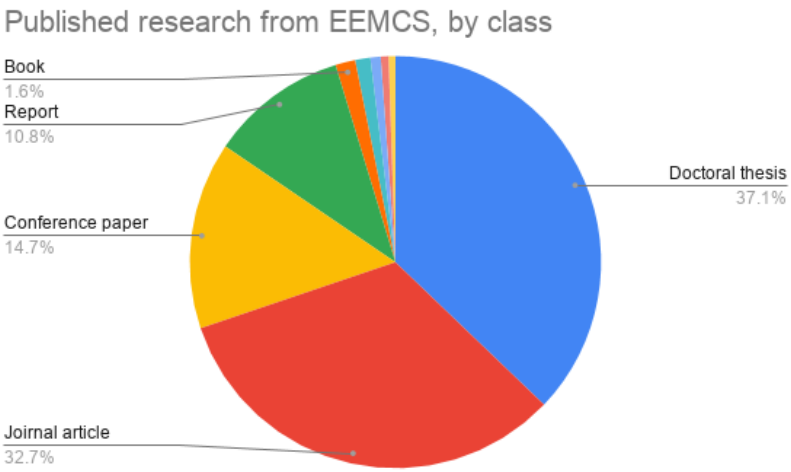


Figure 4.3: EEMCS published research, by publication class

- By subject: the subject of the research produced by the EEMCS faculty, according to the tags used in the Institutional Repository, is given in Table 4.1
- By year: the academic year 2006-2007 was the most productive for the EEMCS faculty, with 374 published pieces. That number has steadily declined and experienced a substantial drop in the year 2016-2017, with 218 publications less than with respect to the 2015-2016 year.

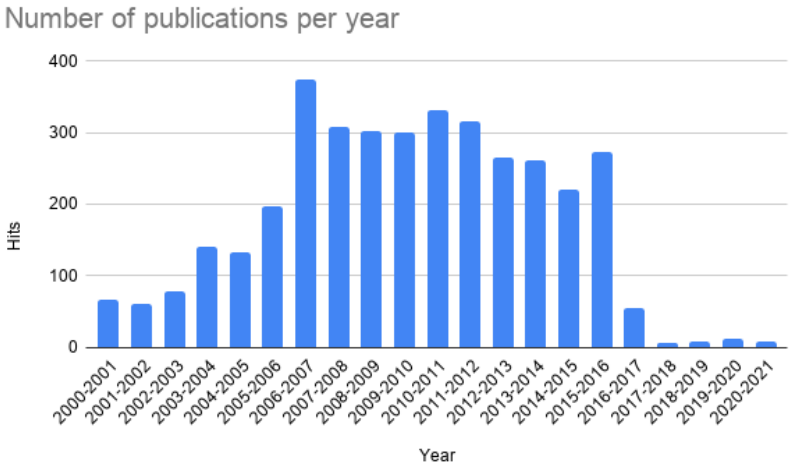


Figure 4.4: EEMCS published research, by publication year

As it can be seen, most of the research produced by EEMCS is neither for nor against sustainability topics, focusing on topics with no relation to environmental sustainability. It can be seen that practically all the research focuses on advancing the knowledge and applications of either "neutral" technologies that can be used as tools for applications on different industries, or on areas that have a tangible impact on human well-being, such as health and cyber security.

Table 4.1: Research published by EEMCS, per subject

Subject	**Number of publications**
Silicon	31
Elemental semiconductors	23
Solar cells	19
Intreerede	18
Deflation	18
Simulation	17
Scheduling	14
Machine learning	13
Optimization	13
Power electronics	13
Micro-Electro Mechanical Systems	12
Data assimilation	12
Dynamic analysis	12
Modeling	12
Complementary Metal Oxide Semiconductor	11
Micromachining	11
Preconditioning	11
Bioinformatics	10
Iterative methods	10
Reliability	10
Robustness	10
Semiconductor thin	10
Films	10
Visualization	10
Pattern recognition	9
Performance	9
Planning	9
Preconditioners	9
Program	9
Comprehension	9
Reconfigurable computing	9
Orthogonal frequency-division multiplexing	8
Adaptive optics	8
Amorphous semicondictors	8
Coordination	8
Image processing	8
Multigrid	8
Power amplifier	8
Social networks	8
Stability	8
Detectors	3
Silicon	3
Acute Myeloid Leukemia	2
avalanche photodiodes (APDs)	2
photodetectors	2
photon counting	2
4D flow	1
AML subtypes classification	1
ChIP-Seq	1
DNA-methylation	1
DNA-methylation profiles	1
DNS	1
DNSSEC	1
Domain Name System	1
NGS analysis	1
Purkinje cells	1
WPMCM	1
Wingless-Int (WNT)	1

Subject	Number of publications
Wingless-Int (WNT)	1
Analysis	1
Analysis of variance	1
Animal performance	1
Anxiety	1
Arrays	1
Authentication	1
Behavior	1
Bioinformatics	1
Boron	1
Boundary value problems	1
Cardiovascular magnetic resonance	1
Carrier frequency offset	1
Centrality	1
Charging	1
Chemical vapor deposition	1
Chromatin	1
Chromosome 16	1
Chromosome mapping	1
Chromosomes	1
Cognitive radio	1
Cognitive radio networks	1

4.2.3. MSc and BSc thesis and research

TU Delft also counts with an educational repository which stores the research produced by bachelor and master students, largely in the form of graduation theses.

- By class: out of the 2,710 documents registered for the EEMCS Faculty, the majority are master theses (72.5%), with a small presence of bachelor theses (27.4%) and a couple of student reports.

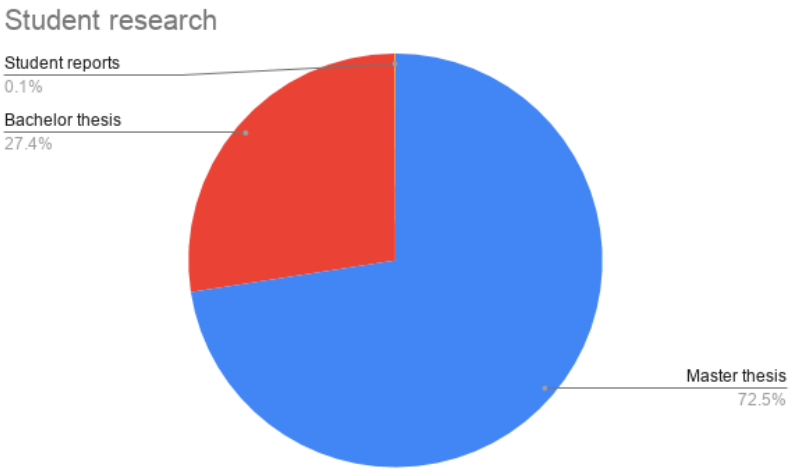


Figure 4.5: EEMCS student research, by class

- By subject: the subject of the student research produced by the EEMCS faculty, according to the tags used in the Institutional Repository, is given in Table 4.2. The term "sustainable" yielded 164 results.
- By year: the student research only began to be recorded in the year 2005, and no results were found for years posterior to 2018. No explanation was found for the sudden lack of student publications; a

Table 4.2: Add caption

Subject	Number of publications
FPGA	41
CUDA	20
GPU	18
Optimization	18
Scheduling	17
Visualization	17
Sensor	15
Android	14
Machine learning	14
Wireless	14
DEMO	13
VLIW	13
Low power	13
Radar	13
CMOS	12
Distributed	12
HVDC	11
MRI	11
UWB	11
Android	11
Smart grid	11
3D	10
ADC	10
DNA	10
Control	10
Mobile	10
Software engineering	10
Monte Carlo	9
RFID	9
SAR	9
TDC	9
Communication	9
Compiler	9
Image processing	9
Microcontroller	9
Model	9
Network	9
Peer-to-peer	9
Real-time	9
Security	9

hypothesis for this could be that the tag system was not used correctly to manage the research in the repository. The number of publications per year can be seen in Figure 4.6.

of student publications per year.png

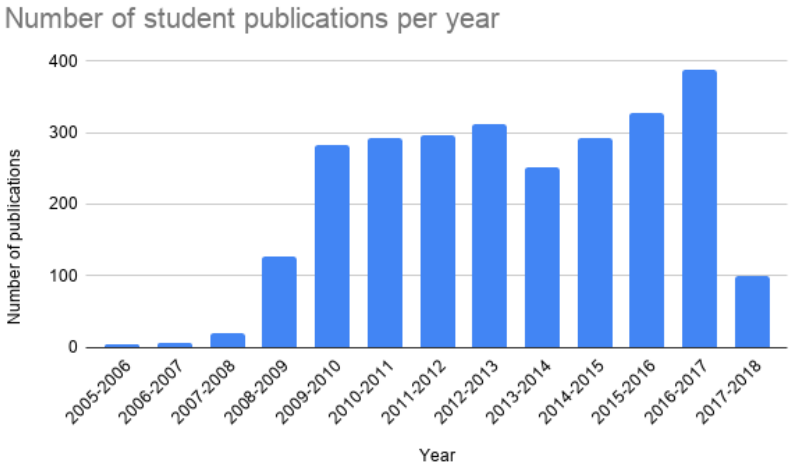


Figure 4.6: EEMCS student research, by publication year

Procedure for uploading research to PURE and the institutional repository
TU Delft has an Open Access policy that requires all published research carried by the university is uploaded and stored in the institutional repository. The publications are first registered in PURE and through Pure they are archived in the TUD research repository. There are three commonplace methods through which a publication is uploaded PURE: the research is gathered by the library from online sources, the researcher sends the publication to the library and they handle the upload, or the research author is in charge of the uploading and tagging of its own publications.

Instructions on how to upload and register research in PURE are provided by the library [2]. The instructions in this website present a rundown of the steps needed to transfer a publication to PURE and how to navigate the different fields that must be filled in order to provide all the information necessary to archive the research.

Each faculty also has a PURE responsible (in the case of EEMCS this person is Mr. Jasper van Dijck).

Recommendations: the EEMCS GreenTeam greatly values how the Faculty's main focus is on improving the well-being of society. Although only a fraction of the research is directed specifically towards environmental sustainability, it can be said that there is a strong focus towards improving the social sustainability. The EEMCS GreenTeam believes that this should be cherished and valued, and they encourage the research directors to stay within this path of promoting research to improve the living conditions of mankind.

As the GreenTeam, it is not easy to propose recommendations to the faculty in terms of research, as this is carefully planned in long-term plannings. The following ideas have been suggested as a way to improve the sustainability of the research at EEMCS without interfering on the research plans drafted by the faculty:

Recommendation 4.2: ensure that the research activities within the faculty are carried with as little environmental impact as possible: researchers in the faculty, particularly those performing experimental research, could be given a basic training on how to reduce the environmental impact of their field of interest. This could include training on material recycling, sustainable material sourcing, components upcycling...

Recommendation 4.3: make researchers submit a compulsory environmental impact assessment form for their research topic, including possible impacts from the application of their research and the impact of

[2] https://www.tudelft.nl/en/library/current-topics/libraryfor-researchers/library-for-researchers/publishing-outreach/register-publications/instructions-support/

performing the research itself.

Recommendation 4.4: honor the commitment to improving human well-being. The faculty could make a non-binding pledge to only promoting research that will be beneficial for mankind as a whole: this is not meant to be a ban of any kind on any research, but rather clearly defining the faculty's position on the ethics of the research produced by it. Setting clear boundaries around what is considered ethical, sustainable or beneficial research is a very complex and subjective task; but the GreenTeam would consider beneficial that the faculty publicly takes a stance on this matter. Another issue is that the EEMCS faculty cannot control how the fruits of the research might be applied by external parties who use them; however, this recommendation is meant to only refer to the extent that the faculty is involved in producing that research. This would for example ban research that is carried explicitly to be applied towards warfare uses, or restrict experimental research processes that would be against ecological sustainability. Research experiments that could raise questions regarding is social or ecological sustainability could be asked to submit an alternative research set-up with less concerns on those grounds.

Recommendation 4.5: create a new uploading guide. It would be highly recommendable to improve the use of the tag system in the institutional repository, in order to make research more accessible and provide better control over the documents uploaded by the faculty. In order to do so, it would be recommendable to create a new version of the PURE uploading instructions that emphasize the importance of using the appropriate tags for each article (for example, every article should at least include the year of publication, the responsible faculty, and one representative keyword)

4.3. Internships

There is currently no database for the internship topics done by students. The records for the internship reports are not accessible to third parties. Hence, any further information on the topic would have to be gathered by directly asking the students. After reaching out to the internship office, the GreenTeam was informed that about 50% of the internships are done by Sustainable Energy Technology MSc students, which must do an internship with a sustainability-oriented company.

The EEMCS internship office has a Brightspace site that publishes available internship opportunities for students. Internships can also be found by reaching out to academic staff or researchers, or to other student organizations. Those that deal with sustainability issues (such as Students 4 Sustainability or the Delft Energy Club) offer exclusively opportunities that are focuse on sustainability topics.

Recommendation 4.5: have a dedicated tab for all available internships on sustainability topics. This can be done either by coordinating the internship office with sustainability-related student organizations, or by centralizing them in the suggested Brightspace GreenTeam site suggested in Section 3.2.2.

5

Summary of Recommendations

Throughout the report, a number of recommendations can be found together with their description, reasoning and argumentation. This chapter lists these recommendations and expands briefly on the logistics of its implementation. This analysis is done separately for the recommendations presented on each portfolio treated in the report: education, operational, communication and research.

The first part of the analysis is a breakdown of three logistic aspects: the expected feasibility of the recommendation, expected time to implementation and expected budget to implement.

Feasibility refers to the overall estimated difficulty to implement the recommendation, considering the amount of effort it will take, the amount of people/parties involved and overall workload. Here, a green indicator means a high feasibility, while a red indicator means low feasibility (hard to achieve). The time to implementation refers to the duration of the work needed to implement the proposed recommendation. A green indicator refers to a lower time to implementation, while a red indicator refers to a longer time. The cost is simply the estimated cost of implementing a recommendation - a green indicator means low costs, while red means a large budget is needed. All the given values are not connected to exact values but serve to give an indication and quick overview of the different recommendations.

Throughout this final chapter, readers should keep in mind that the classification of the presented recommendations has been decided based on the subjective experience of the EEMCS GreenTeam members. The logistic breakdown and ranking of each recommendation is thus an educated estimation based on the information gathered during the research done for this report, which was done based on a variety of official sources, including many interviews and conversations with staff members. Ultimately, all of the authors of this report are students with limited knowledge of the inner workings of the Faculty and the specific operational processes carried out in order to implement policies and changes.

Recommendations Education	Feasibility	Time	Cost
1.1: Add a Green IT elective course			
1.2: CSE1105: focus on topics related to sustainability for the to be developed software			
1.3: CSE2115: focus on topics related to sustainability for the to be developed software			
1.4: CSE2000: actively invite companies working on sustainability to submit proposals for software projects			
1.5: CSE3000: highlight topics related to sustainable research			
1.6: CSE1400: mention the environmental impact of the resources needed to build computers			
1.7: CSE1500: explain the energy cost of running the internet and large data-farms			
1.8: CSE1405: show the effects of more or less efficient communication protocols in term of electricity usage			
1.9: CSE2520: mention the importance of Big Data for tackling environmental issues			
1.10: CSE2525: mention the importance of data mining for tackling environmental issues			
1.11: EE2L11: stimulate students to build something which solves a small problem with regards to sustainability			
1.12: EE3L11: set up a number of project assignments related to sustainability			
1.13: EE1L11: include comments on the environmental and societal concerns regarding the used materials			
1.14: EE2L11: similar to the recommendation for EE1L11 + earlier comment			
1.15: EE2E11: relate the importance of energy efficiency to environmental impact			
1.16: EE2S21: mention in the introduction lecture how systems, control and feedback loops are important for environmental impact models and resource management			
1.17: EE3D11: mention the environmental impact of the resources needed to build computers/computer chips			
1.18: Add an elective course dedicated to teaching about the role of Mathematics in sustainability.			
1.19: AM1050-A Modelling A: explicitly incorporate the modelling of environmental issues and problems in sustainability as exercises			
1.20: AM1050-B Modelling B: similar to AM1050-A Modelling A			
1.21: AM2050-A Modelling 2A: similar to AM1050-A Modelling A			
1.22: AM2050-B Modelling 2B: similar to AM1050-A Modelling A			
1.23: AM3000 Bachelor Project: highlight topics related to sustainable research			
1.24: AM2520-H History of Mathematics: include a section regarding the role mathematical models have played in sustainability			
1.25: AM2520-P Philosophy of Mathematics: include a section about the ethical consequences of Mathematical modelling			
1.26: AM 2530 Systems Theory: mention the stability of global ecological- and climate systems			

Recommendations Operational	Feasibility	Time	Cost
2.1: Asking a fee for the cutlery in the cafeteria			
2.2: Exploring the possibility of selling reusable cutlery/water bottles at EEMCS			
2.3: Setting the printers to double sided black/white printing by default			
2.4: Creating awareness on how the coffee cups are recycled			
2.5: Improving the consistency in appearance of the paper bins			
2.6: Printing the promotional material for events on recycled paper			
2.7: Place extra coffee cup recycling bins during events			
2.8: Revise the possibility to reduce waste during the instructions on open days			
2.9: Printing the brochures for the Recruitment Days on recycled paper			
2.10: Exploring the possibilities of a more vegetarian freshmen weekend			
2.11: Reducing the water flow time of motion sensor taps			
2.12: Replacing manual taps with ones with motion sensors			
2.13: Exploring the possibility of installing water fountains			
2.14: Installing lighting with movement sensors			
2.15: Exploring the possibility of creating a solar farm/learning space on the roof			
2.16: Altering the image of PV information on the net-presenters			
2.17: Investigating how to fully optimise the WKO system at EEMCS			
2.18: Replacing the single pane windows by double pane windows			
2.19: Replacing the pictures in the central hall by greenwalls			
2.20: Indicating more clearly where the staircases are in EEMCS			
2.21: Exploring the possibility to plant more greenery near the statue behind EEMCS			

Recommendations Communication	Feasibility	Time	Cost
3.1: Include a sustainability tab in the main EEMCS website			
3.2: Maintain an active social media presence			
3.3: periodically publish articles on different sites			
3.4: Engage external visitors in sustainability practices			
3.5: Reach out to collaborators involved in sustainability			
3.6: Publish a partners & sponsors list			
3.7: Build a network of interesting partners and companies			
3.8: include sustainability in the recruitment information			
3.9: Adopt a sustainable aesthetic			
3.10: Re-decorate the faculty			
3.11: Maintain an active GreenTeams communication			
3.12: Build a Brightspace page for the EEMCS GreenTeam			
3.13: Have a student Whatsapp spokesperson			
3.14: Virtual poster board			
3.15: Include a visual identifier on screen announcements			
3.16: Include more sustainability announcements on the screens			
3.17: Have a dedicated poster board			
3.18: Use in-class sustainability examples			
3.19: Highlight interesting companies during events			
3.20: Engage the academic staff			
3.21: Encourage communication among teaching staff of different faculties			
3.22: Educate non-teaching staff			
3.23: Define recommended sustainability practices			
3.24: Engage with student associations			

Recommendations Research	Feasibility	Time	Cost
4.1: optimize the functioning of the research facilities			
4.2: Ensure that the research activities within the faculty are carried with as little environmental impact as possible:			
4.3: Honor the commitment to improving human well-being			
4.4: Create a new PURE uploading guide			
4.5: Have a dedicated tab for all available internships on sustainability topics.			

6

Recommendations for the next GreenTeam

This chapter contains recommendations for the next GreenTeam, as well as recommendations for the next GreenTU GreenTeam coordinator. Since this is the first GreenTeam of EEMCS, our experience can help the next GreenTeam coordinator of GreenTU in forming the GreenTeam, and to help sculpt a view of what to expect from the GreenTeam, given the defined workload/size of the team etc.

Workload
The EEMCS GreenTeam workload was defined as 2 to 3 hours per week. Experience has shown that although these hours are reasonable, it can get tight whenever the deadline of the report is coming up, or a lot of interviews are to be conducted. Naturally, the quality of the report is also dependent on how many hours per week the team members work on it. The report could have been more detailed if the workload was defined as 4/5 hours a week, however, the GreenTeam believes the results of this report are sufficient and complete and give a good impression of sustainability within EEMCS.

Size of the team
The EEMCS GreenTeam consists of three team members, covering the four different portfolio's and three positions in the team. The positions in the team are chair, secretary and contact person. Working on the report and dividing the tasks has shown that three people the three functions within the team work well.

However, three people covering four portfolio's is not ideal. Because one person has to work on two portfolio's, the focus will naturally be on one portfolio. Even if the two portfolio's receive the same amount of hours of work, it will be less hours than if you had a team of four people. Therefore it is recommended to look at the possibility of having four people in the next GreenTeam.

Staff involvement
While working on the report, the EEMCS GreenTeam had the most contact with Sharina Ligtelijn (GreenTeam coordinator of GreenTU) and Rene van der Swaaij, director of studies of SET[1]. The communication went very well, and they were both valuable contact points which helped in many different situations.

The recommendation for the next GreenTeam coordinator/ study coordinator would be to keep the contact easy and informal, as this is the most inviting for asking questions or asking for advice. It is also highly recommended to reach out to the Faculty Student Council sooner than later, as they can help with many matters within EEMCS - they know a lot of professors and staff members of the Faculty. It is also a good idea to come into contact with the two study associations, CH and the ETV. They organise a lot of events within the Faculty, are in close contact with the students and in general know a lot about the Faculty.

[1] Sustainable Energy Technology

Collaboration other teams
During the time as GreenTeam, there were a few occasions in which there was a chance to speak with other GreenTeams. Because of the outbreak of COVID-19, these meetings were held digitally and maybe less frequently than was originally planned. It would be very beneficial to have these meetings more frequently, as the teams can motivate each other or offer advice.

The recommendation for the next GreenTeam is to stay in close contact with the other GreenTeams. Try and stay up to date on their work/projects, as they can be a great source of tips and advice.

Collaboration GreenTU
The collaboration with GreenTU went mainly through Sharina - she was always available for questions, tips or advice when needed which was very positive. At some occasions, other members of GreenTU were contacted because of their knowledge on specific portfolio's. This communication was also pleasant, they were always enthusiastic to help.

For the next GreenTeam, the recommendation would be to plan an initial meeting, soon after dividing the portfolio's, with the person on the GreenTU board who has the same portfolio - this way, double work is avoided and boundaries between the work of GreenTU and the GreenTeam can be established quickly.

Message to next GreenTeam EEMCS
"Hi there! First of all, congratulations with your position in the GreenTeam of EEMCS. As you form the second GreenTeam of the Faculty, the inventory report has already been covered - we highly advise you to read this report thoroughly, as it contains a lot of insights, recommendations and information on all of the portfolio's. This report contains a lot of recommendations for improvement, and it is your choice whether or not you choose to follow them through. Do keep in mind that these recommendations were made after interviews with staff members, survey answers and a lot of research.

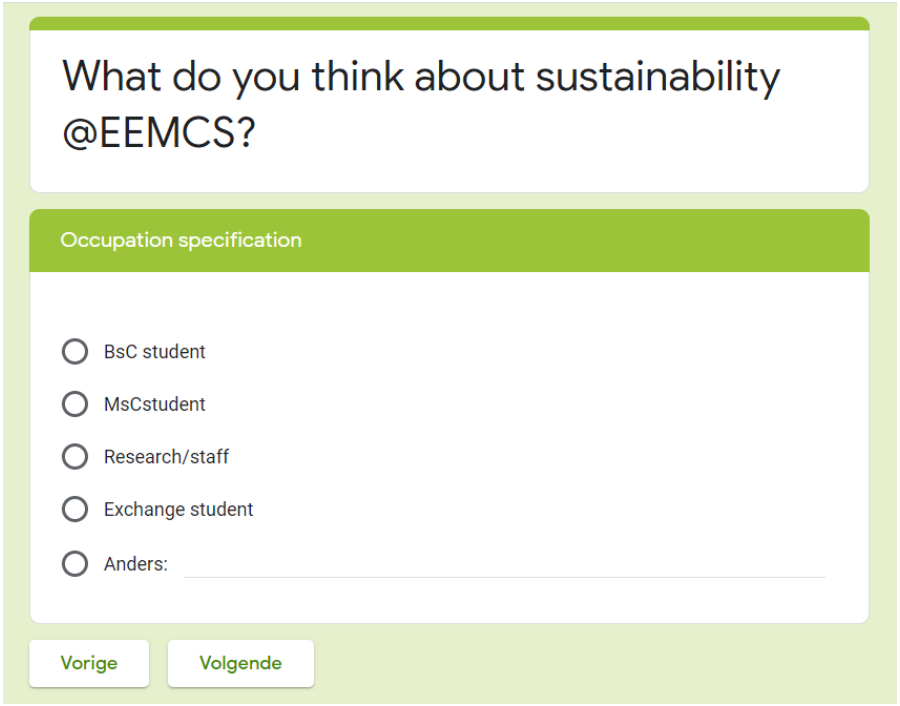
We had a great time together as a GreenTeam, not only because we were excited to work on sustainability within the Faculty, but because we got along really well with one and other. We highly recommend you to work on teambuilding, or just do something fun every once in a while. Also, do not forget that you can always contact us or the GreenTU Board if you have any questions or need help.

We wish you the best of luck, you are going to do great things!"

A

Appendix A

A.1. Survey

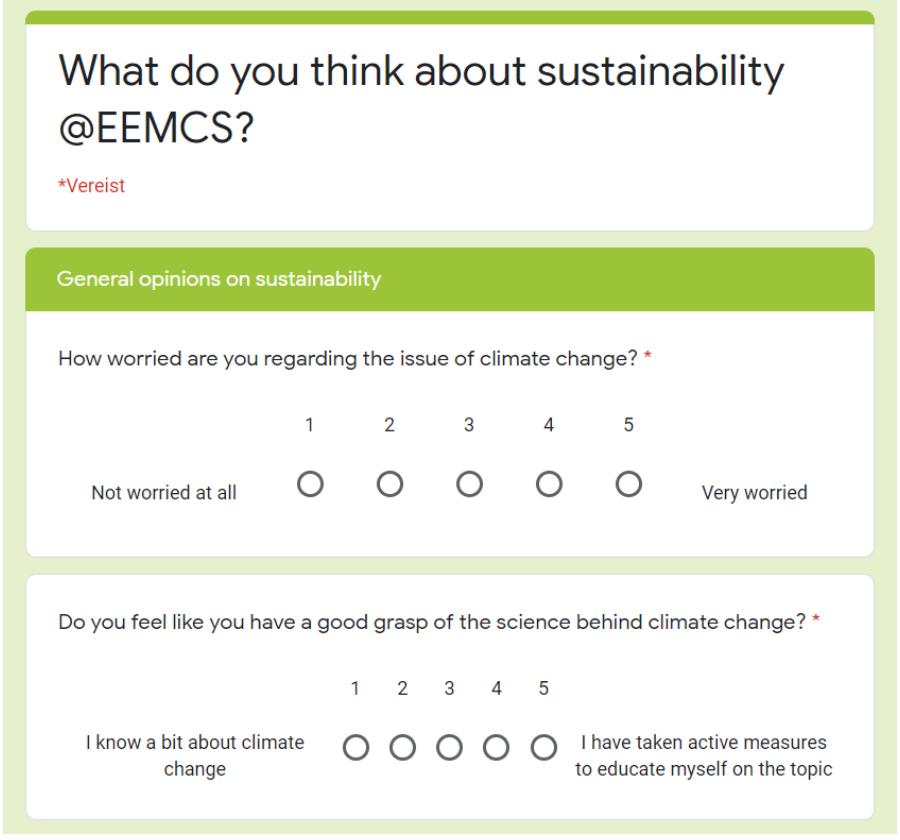


What do you think about sustainability @EEMCS?

Occupation specification

- ○ BsC student
- ○ MsCstudent
- ○ Research/staff
- ○ Exchange student
- ○ Anders: _____

Vorige Volgende



What do you think about sustainability @EEMCS?

*Vereist

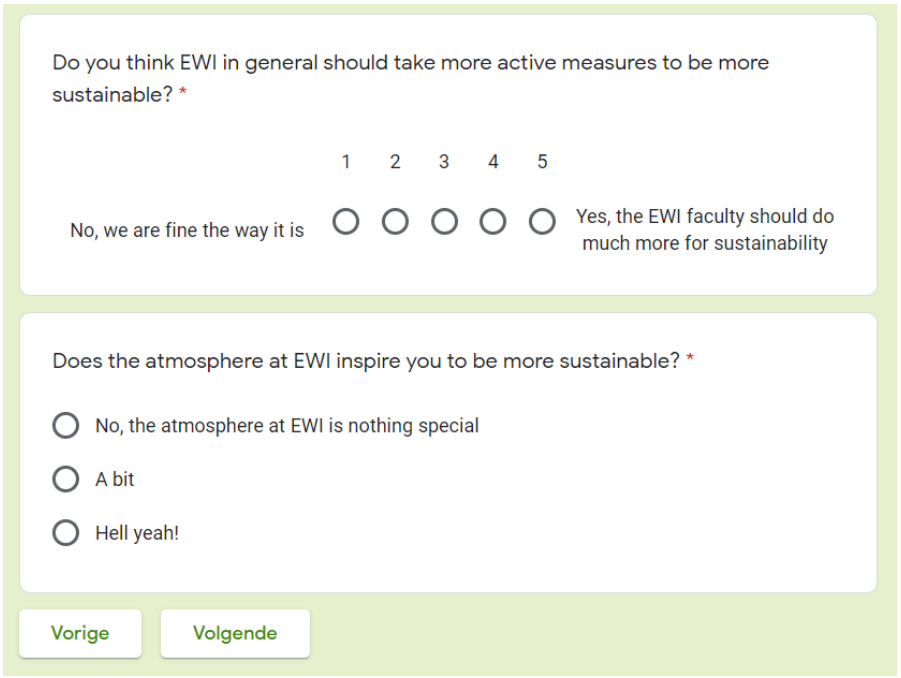
General opinions on sustainability

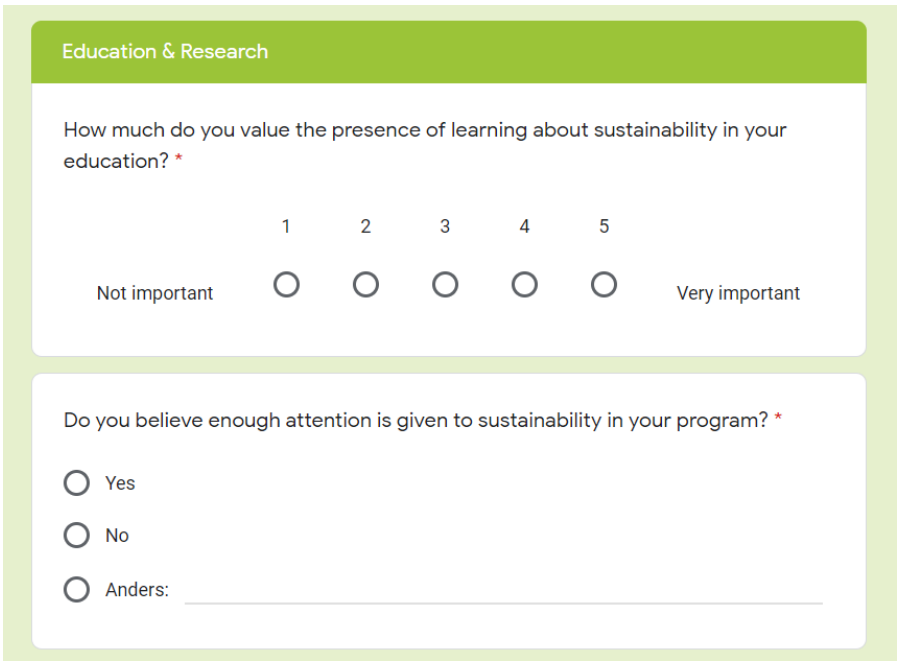
How worried are you regarding the issue of climate change? *

	1	2	3	4	5	
Not worried at all	○	○	○	○	○	Very worried

Do you feel like you have a good grasp of the science behind climate change? *

	1	2	3	4	5	
I know a bit about climate change	○	○	○	○	○	I have taken active measures to educate myself on the topic


Do you think EWI in general should take more active measures to be more sustainable? *
1 2 3 4 5
No, we are fine the way it is
Yes, the EWI faculty should do much more for sustainability
Does the atmosphere at EWI inspire you to be more sustainable? *
No, the atmosphere at EWI is nothing special
A bit
Hell yeah!
Vorige
Volgende


Education & Research
How much do you value the presence of learning about sustainability in your education? *
1 2 3 4 5
Not important
Very important
Do you believe enough attention is given to sustainability in your program? *
Yes
No
Anders:

Do you think there should be a specific course dedicated to showing the relevant parts of sustainability in your field of study? *

- ○ Yes
- ○ No
- ○ Maybe
- ○ Anders: _____

Would you be in favour of having sustainability be a bigger part of project courses in your degree? (for instance: as a marking criteria, or as challenges in sustainability being the topic of the project) *

- ○ Yes, in projects in general (including possibly my bachelor thesis/BEP)
- ○ Yes, in my bachelor thesis/BEP
- ○ No
- ○ Maybe
- ○ Anders: _____

Would you be in favour of sustainability being more integrated in existing courses in your degree (for instance: learning about the environmental impact of a certain part of engineering, or calculations being done with sustainably relevant examples) *

- ○ Yes
- ○ No
- ○ Maybe
- ○ Anders: _____

How else would you like to see sustainability integrated within your education? Please feel invited to add ideas in other. *

- ☐ More elective courses
- ☐ More options in Honours programs
- ☐ More Minors
- ☐ More lunch lectures
- ☐ More other non-mandotary events, such as as symposiums
- ☐ Anders: _____

To what extent do you value EWI researching sustainability in its respective academics fields? *

	1	2	3	4	5	
Not at all important	○	○	○	○	○	EWI should take a leading role

Do you have anything else to add with regards to sustainability and your education?

Jouw antwoord

Vorige Volgende

Communication

Have you ever tried to find courses/research topics/events on sustainability, but didn't know where to find information about it? *

- ○ I have never been involved with sustainability topics
- ○ I tried to get involved, but couldn't find any information
- ○ I tried to get involved and found all the information I needed about it

Which sustainability projects are you aware of exist at TU Delft? *

- ☐ Green Village
- ☐ Solar panels on faculties
- ☐ Carbon-neutral buildings on campus (pulse building)
- ☐ The university is powered by wind energy
- ☐ Faculty GreenTeam
- ☐ GreenTU
- ☐ None of the above
- ☐ Anders: _____

Which are your preferred platforms/ways to find out about events or other non-course work related information? *

- [ ] Brightspace
- [ ] Webmail
- [ ] Social media
- [ ] TU Delft websites
- [ ] Posters around the faculty
- [ ] Friends/word of mouth
- [ ] Anders: _____

Which social media do you usually use? *

- [ ] Instagram
- [ ] Facebook
- [ ] LinkedIn
- [ ] Snapchat/Tik Tok
- [ ] Not active on social media
- [ ] Anders: _____

Operational

Which of the following actions do you already undertake in your daily life at the faculty? *

- [ ] Sepereate food waste from non organic waste
- [ ] Seperate plastic and metals from other waste
- [ ] Recycle paper waste
- [ ] Print only when necessary, and double-sided when possible
- [ ] Turn off the computer regularly after use
- [ ] Switch off lights in the room (unless it is automatic)
- [ ] Use reusable coffee cups
- [ ] Turn down the radiator
- [ ] Travel to Faculty via bike / public transport / walking
- [ ] Anders: _____

Which factors could keep you from recycling at EWI? *

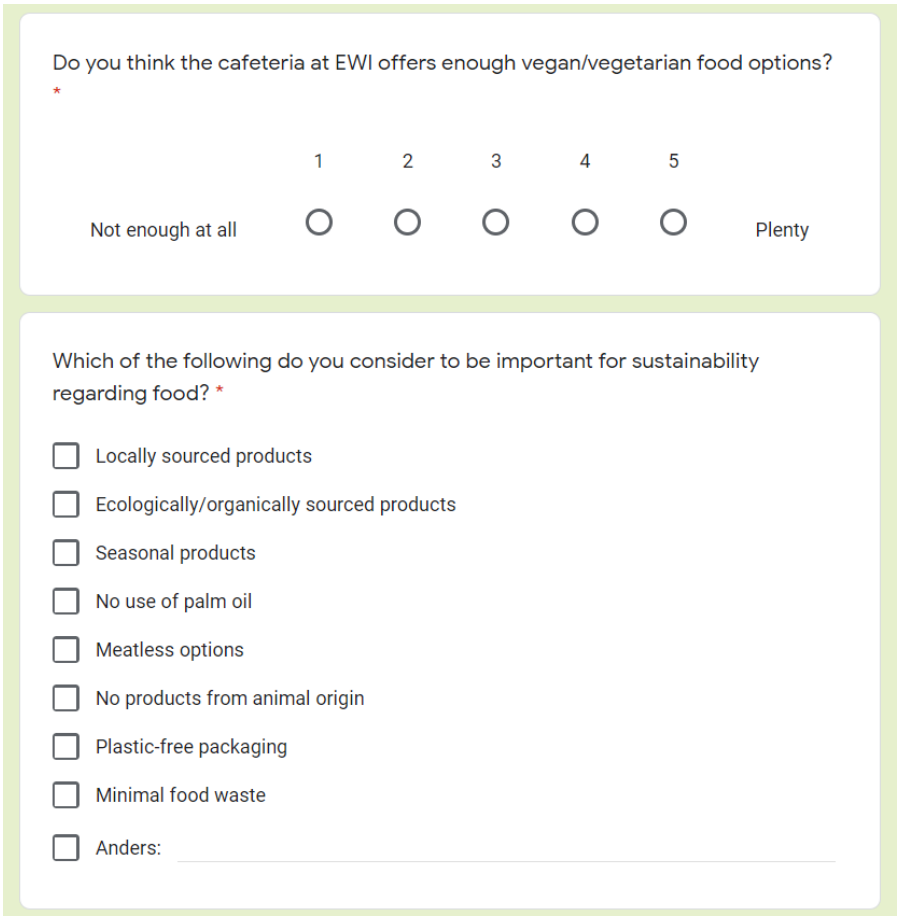
- [ ] Not enough recycle bins
- [ ] Unsure if products can be recycled / lack of instructions
- [ ] Don't know where to recycle
- [ ] Bins are usually full
- [ ] Too time consuming
- [ ] Didn't know TU Delft Recycles
- [ ] Don't care about recycling
- [ ] Anders: _____

Which of the following would you like to see implemented in EWI? *

- [ ] Have the default setting of the printers set to double-sided printing
- [ ] More spots to park your bicycle
- [ ] More loading poles for electric cars
- [ ] More recycling options
- [ ] Automatic light switches
- [ ] Better insulation of the faculty
- [ ] More plants in the interior of EWI
- [ ] Use less plastic in the faculty
- [ ] Reduce paper consumption
- [ ] Anders: _____

How important do you think it is to have sustainable food choices at EWI? (for example: locally sourced products; meatless options,...) *

	1	2	3	4	5	
Not important	○	○	○	○	○	Very important


Do you think the cafeteria at EWI offers enough vegan/vegetarian food options? *
1
2
3
4
5
Not enough at all
Plenty
Which of the following do you consider to be important for sustainability regarding food? *
Locally sourced products
Ecologically/organically sourced products
Seasonal products
No use of palm oil
Meatless options
No products from animal origin
Plastic-free packaging
Minimal food waste
Anders:

Thank you for filling in the survey!
Corona help
Due to the corona outbreak we are all a bit stuck in our houses, meaning we have a bit less contact with other students. We however want to have as much input as possible so if you are willing bounce back and forth some ideas about how sustainability is organized in your degree: email us at greenteam-eemcs@tudelft.nl and we can set up a call of some sort!
Vorige
Verzenden

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