Sustainable TU Delft

Vision, Ambition and Action Plan for a Climate University

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The motto of TU Delft is 'Impact for a better society'. The #betterTUgether hashtag furthers this pursuit: society can rely on our university to become better. Through science, engineering and design TU Delft vows to contribute to a better world, a civilisation that needs to become sustainable for mankind's own sake.

Informed by science, climate action is urgently needed and universities should pave the way for society to see, learn, and adopt. Therefore, TU Delft in 2019 declared to take climate action itself, and the founding of the Climate Action Programme is testimony to this serious intention.

Now we need to continue forward. This report is setting the scene for that.

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Preface

Humankind is facing a big crisis related to climate change, the availability of resources, and liveability on the planet. Taking inclusive climate action, establishing a circular economy, and again increasing biodiversity are the strategies paramount to secure sustainability of our society.

We are TU Delft, a university that delivers ingenious, creative, positive and proactive engineers, designers, planners and scientists. Therefore, to an important extent we can help to shape a brighter future. And we are doing this already. Sustainable development has been at the heart of our community, education, research, and operations for a very long time. And it will be even more in the coming decades.

Although we send out masters of science and doctors that have learnt to deal with societal challenges, and although in our research we intend to create impact for a better society, as university we need to do more. We consider this as our responsibility: to not just show the sustainable pathway, but to also pave it, so that other people, organisations, cities and countries can follow. We want to become the climate university of the world.

This is why I am happy and proud that TU Delft started, amongst others, a Climate Action Programme and appointed a Sustainability Coordinator responsible for the transition towards a fully sustainable organisation. In education and research, as community and in its operations on the campus and beyond.

This report – to be accompanied by a shorter executive summary – is the result of one-and-a-half year's work of the sustainability coordinator, together with more than a hundred other people – students, academic staff, supporting staff, management, external parties – who collaborated in teams on a wide range of sustainability themes. It presents the vision and ambitions for our sustainable university and an action plan to get there.

Informed by this report we will start and continue to implement sustainability measures on the campus, focussing on our ambitious targets in 2030. May it be a source of inspiration and guide for the better future our society needs.

Drs. Marien van der Meer
TU Delft Vice-President for Operations

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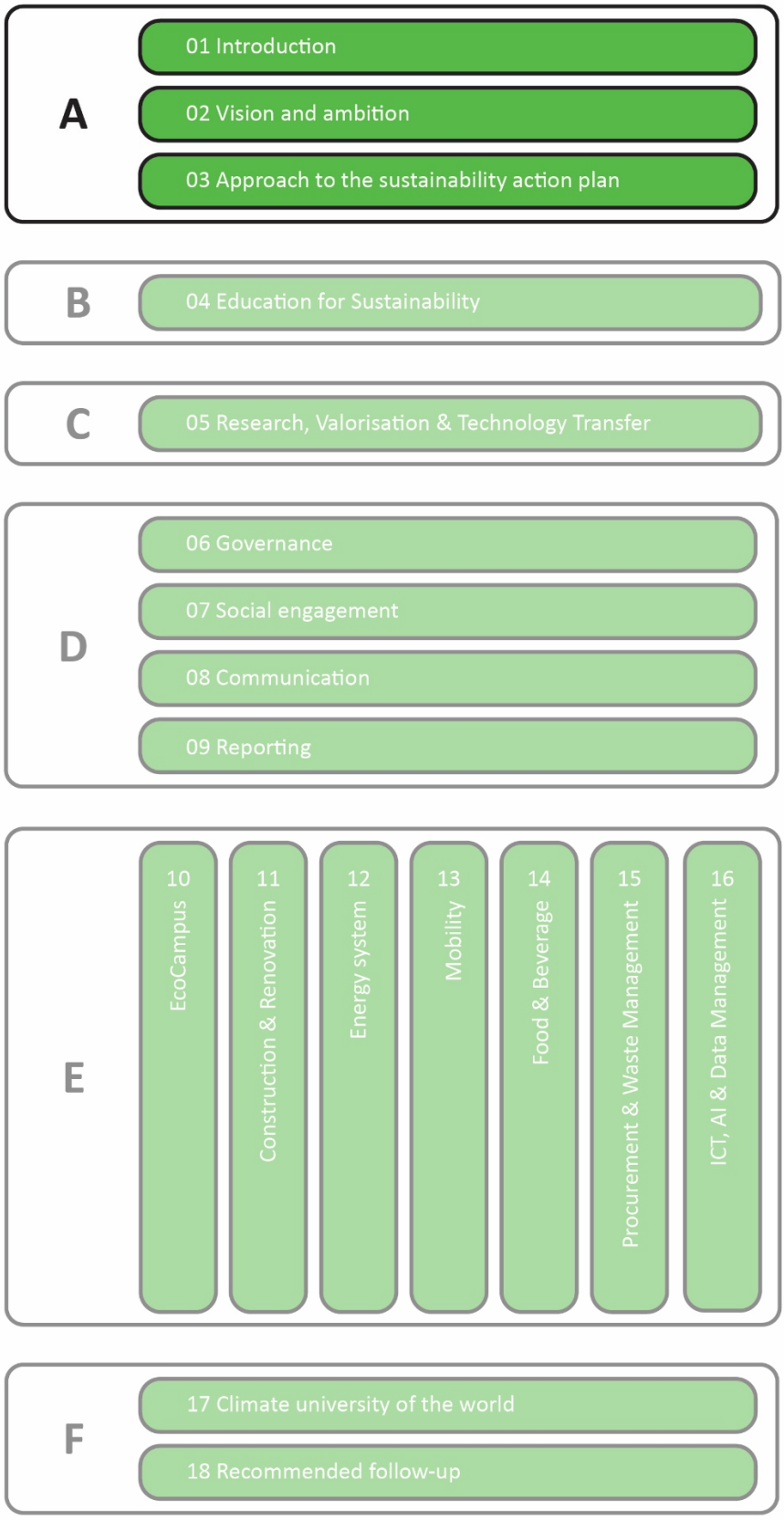
PART A

VISION AND AMBITION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01 Introduction

01.01 Background

TU Delft has always had sustainable development at the core of its activities. There is a lot of education and research related to aspects of sustainability and innovation for a better world, energy being the dominant theme. Since 2014, The Green Village has gradually grown to a successful field lab and demonstration site for innovation and sustainability. Also in its real estate portfolio, TU Delft has been gradually improving its environmental performance, with the realisation of Pulse, TU Delft's first energy-neutral building, as milestone, followed by ECHO, which has become energy producing and to a great extent circular in its material use. Nonetheless, as a whole, the TU Delft Campus cannot be called sustainable yet.

CO_2 Roadmap
In its Strategic Framework 2018-2024, TU Delft states that it intends to be carbon neutral and circular by 2030 [TU Delft 2018]. For TU Delft, the year 2019 was a turning-point for sustainability. That year's anniversary theme was Climate Action. Following discussions in various media, TU Delft published a position paper on climate action[1], and its Campus & Real Estate division (CRE) asked Andy van den Dobbelsteen to do a carbon analysis of buildings and the energy system of the campus. In the research Andy conducted with his colleague Tess Blom, he however considered more than originally asked for, including travel, food, waste, water and green for a more complete picture of the university's greenhouse gas emissions. This resulted in the CO_2 Roadmap for TU Delft [Blom & Dobbelsteen 2019], which drew a clear picture of the enormous challenge to get to net zero carbon by 2030.

Sustainability coordinator
In that same period, Gerrit Kahlman had already been appointed as sustainability coordinator and he worked closely with the students of GreenTU and with GreenTeams operating at the various faculty buildings. In autumn 2020, Gerrit retired and Andy van den Dobbelsteen was asked to take over his coordinator's role, reporting directly to the Executive Board of TU Delft. This commenced on the 1st of January 2021. Alongside, Deirdre van Gameren was appointed as young researcher to support Andy.

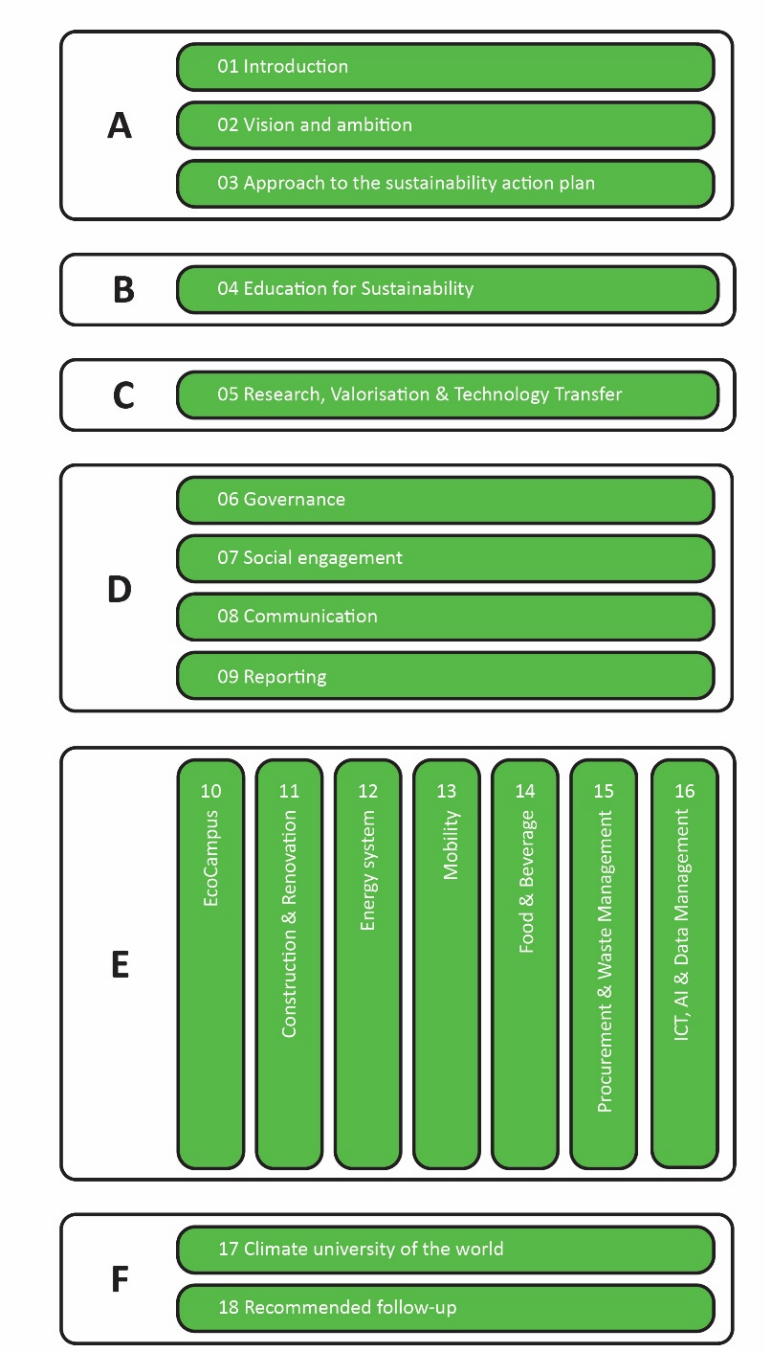
Action plan
This report, made during the COVID-19 pandemic, is the first result of the work that Andy and Deirdre did in the year 2021. Around a core team representing all faculties, supporting divisions and students, teams were formed that focussed on specific themes of the sustainable transition of TU Delft. It became a formidable enterprise, dealing with everything that is done on and from the campus. In this report, a vision and definition of ambitions for sustainability are described and, most importantly, recommendations are

[1] https://www.tudelft.nl/en/tu-delft-climate-institute/tu-delft-position-on-climate-action

given for specific organisational measures, projects and actions, which all should become part of the TU Delft Campus as a living lab for a sustainable and liveable built environment.

01.02 Reading guideline

With this vision, ambition and action plan we want to show the current state of TU Delft and provide insight into which steps are needed to achieve the sustainability goals posed. The outline can be found below.



TU Delft

02 Vision and Ambition

02.01 Definitions

Since many terms are being used under the umbrella term of sustainability, this section gives definitions by means of which TU Delft's vision and ambition is directed.

Ambition levels

Sustainable
This term is derived from 'sustainable development' [Brundtland et al. 1987]: a development that meets the needs of the present without compromising the needs of future generations. According to Brundtland et al. 'sustainable' is about equity across the world and a balance between economy and ecology.
As defined by Elkington [1997], sustainability has three main dimensions: social sustainability (people), ecological sustainability (planet) and economic sustainability (profit, altered to prosperity later). For full sustainable development, all three need to be addressed.
Kristinsson [Kristinsson & Dobbelsteen 2012] defined 'sustainable' as: everything future generations want to inherit, use and maintain. This definition clearly makes sustainability focussed on what each generation leaves for the next.

Greenhouse gases (GHGs)
Greenhouse gases (GHGs) are the chemical gaseous compounds that in the outer layers of the atmosphere prevent infrared heat waves to escape to outer space, a phenomenon called the greenhouse effect, which is natural to Earth but aggravated due to human influences, thereby causing global warming. Dominant greenhouse gases are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and water vapour (H_2O).
In order to unify the impact on climate change, based on their global warming potential, these emissions are commonly converted to CO_2 equivalent emissions, i.e. relative to the amount of CO_2 that would have the same impact.

Global warming potential (GWP)
The global warming potential (GWP) is an indication of the potential greenhouse effect (heat trapping) of a gas relative to an equivalent mass of carbon dioxide, 100 years after its release into the atmosphere (GWP_{100}). GWP_{100} of CO_2 = 1, GWP_{100} of CH_4 = 34, GWP_{100} of N_2O = 298 [IPCC, 2013]. So, methane is 34 times more harmful than carbon dioxide.

Climate neutral
Climate neutral means that an organisation, a project or action has net zero GHG emissions over the period of a year [Graamans & Dobbelsteen 2018]. Net zero does not mean 'no emissions', but that over a year's time, emissions are reduced to a minimum and remaining ones compensated.

Carbon neutral
Literally, carbon neutral means that an organisation, a project or action has net zero carbon emissions over the period of a year, which can refer to CO_2 and CH_4. When speaking of carbon neutral or CO_2 neutral, in this report, we mean climate neutral, referring to all GHG emissions, or in other words 'CO_2-equivalent neutral'.
Carbon neutral is not the same as energy neutral, because for energy neutral (according to Dutch law) renewable energy needs to have been produced in the vicinity of the project or action considered; with carbon neutral, renewable energy can come from afar and carbon emissions can be compensated for [Graamans & Dobbelsteen 2018].

Energy neutral
Energy neutral means that an organisation, a project or action produces as much (renewable) energy over the period of a year as it uses [Graamans & Dobbelsteen 2018]. An energy neutral building, for instance, is a building that produces, via sustainable sources, the same amount of energy it requires over the period of a year.
Overproduction of renewable energy can compensate for remaining fossil fuel consumption. So, in an energy-neutral system, one is still allowed to use fossil fuels as long as these are compensated for by extra renewable energy. An example thereof is the Danish Island of Samsø, which is energy neutral although it still uses fossil fuels for cars, ferries and some old boilers. The overproduction of wind power compensates for this quantity of fossil energy. Samsø is now in the process of becoming entirely fossil free.

Fossil free
A fossil-free organisation, project or action eliminates the use of fossil fuels. In this case, no use of fossil resources (mineral oil, natural gas, coal) is allowed anywhere in the system considered. In a fossil-free system, all elements run on renewable energy resources. A fossil-free system can be called circular for the use of energy but not yet for other flows, such as water, materials and food (nutrients) [Broersma et al. 2018].

Circular
Circular refers to all resources: energy, water, materials, and nutrients. A circular economy ([Ellen MacArthur Foundation 2013], strongly linked to Cradle to Cradle [McDonough & Braungart 2002]) has two possible cycles it can refer to: the technical cycle, focussed on high-quality technical products that can be reused, recycled or reprocessed infinitely, and the natural cycle, which is based on replenishment of renewable sources and which entails safe, non-toxic wastes to nature. Reusing or reprocessing renewable sources is even better, obviously.
From the moment a system is circular, all resources are reused and recycled or replaced by renewables; one could call this a self-sufficient, autarkic system. From that moment onwards, one would say that a sustainable system has been established, but a circular system does not amend for damages and lingering impacts from the past. Therefore, a system needs to be regenerative.

Regenerative

Understanding that at present the earth is already overstretched, unbalanced and damaged by human developments, a truly sustainable situation would arise when a system also repairs old damages, restores natural reserves and rebuilds capacity that got lost in the past. This is called a regenerative system. A regenerative system therefore does more than a circular one, in that it regenerates damages and shortages that have evolved over time, before a system became circular. Therefore, becoming regenerative means that a system not just takes care of its own self-sufficient functioning yet also makes amends for the damage created in centuries before [Broersma et al. 2018]. Therefore, it is the ultimate system for a truly sustainable world.

Carbon compensation

Every system will be imperfect in the sense that carbon emissions are difficult to avoid entirely. Compensation of carbon emissions than is an option to enable becoming carbon neutral. Carbon compensation can entail, for instance, purchasing carbon certificates from the EU Emission Trading System (ETS), planting of trees[2], (re)forestation[3], or investments in sustainability projects that reduce carbon emissions.

Carbon trading

The ETS enables polluting industries to buy European Union Allowances (EUAs) or 'carbon rights' from industries that are cleaner and that emit less. The ETS uses a market price for each tonne of CO_2 emitted[4] (figure 02.01). So, buying carbon certificates off the market does not reduce the overall emission of CO_2 but it makes polluters pay more than clean industries. Or make them reduce their carbon emissions, which is the ultimate goal.

Figure 02.01: Recent development of the EU ETS carbon price, reaching € 80/ton of CO_2 equivalents [Source: Ember Climate 2021]

Organisations such as Carbon Killer (www.carbonkiller.org) buy CO_2 emission permits off the market for clients and subsequently eliminate these carbon rights (see figure 02.02). That way, on paper at least, the overall emissions in Europe are reduced: polluters have fewer

[2] 1 adult tree can sequester approximately 70 kg of CO_2 in the period of a year [Sharma et al. 2021]
[3] 1 hectare of North-West European forest can sequester 11.5 tonnes of CO_2 [Pulselli et al. 2019]
[4] At the moment of writing one tonne of CO_2 costs around €40 on the market

options to buy EUAs, which forces them to reduce their carbon emissions. So, this purchasing and destroying of carbon rights in fact shifts the responsibility of carbon emission reduction to other parties.

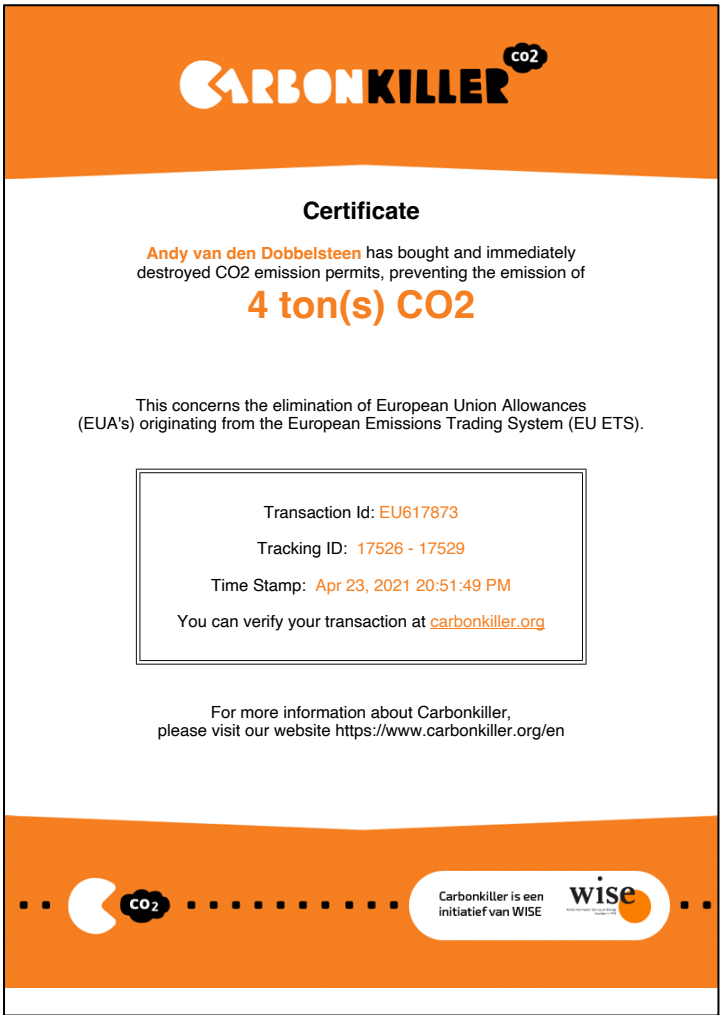


Figure 02.02: Carbon Killer certificate, declaring that the permits for 4 tonnes (4000 kg) of CO_2 have been bought and destroyed. At the time of purchase this cost € 158, which is much more than what you pay for carbon compensation with airline companies.

Tree planting

Instead of buying and destroying ETS rights, investing in plantation of trees is also an option to compensate for carbon emissions. Organisations such as Trees for All[5] offer this service to organisations. At present, the price paid for a tonne of CO_2 is lower than the actual ETS level, and the question is whether that amount of money will secure the planting of enough trees (average uptake: 50 tons of CO_2 per adult tree) to actually compensate the total emission. The advantages of planting trees over carbon trading however are manifold:

[5] www.treesforall.nl

contributing to biodiversity, improvement of soil and microclimate, and supporting local communities.

02.02 Scopes

Emissions can be divided into three categories: scope 1, scope 2 and scope 3.

- Scope 1 emissions, i.e. direct emissions, are emissions emitted by installations owned or controlled by the organisation. For example, emissions from gas use (by gas boilers) and emissions from the university's vehicle fleet.
- Scope 2, i.e. indirect emissions, are emissions that are released during the generation of electricity, heat and cooling, and steam, in installations that are not owned by the organisation, but used by it. For example, these are emissions that are released during the generation of electricity in power plants.
- Scope 3 emissions, i.e. other indirect emissions, are emissions from activities of the organisation of which the source of emissions is not owned or controlled by it. This scope is divided into upstream and downstream emissions. Upstream emissions are emissions that are released during the production of purchased goods, whilst downstream emissions are released when the organisation offers work, project, service or supplies [Tax, 2021].

Table 02.01 shows in which scope the aspects discussed in this report fall for TU Delft.

Table 02.01: The three emission scopes and examples for the TU Delft Campus

Scope 1	Scope 2	Scope 3
▪ Geothermal heat plant ▪ Low-temperature heat network ▪ PV on campus ▪ Gas use on campus	▪ Electricity delivered by Eneco	▪ Commuter travel ▪ Business travel ▪ Student travel ▪ Catering ▪ Procurement ▪ Waste management ▪ Water management

Beyond the defined scopes

Not everything we take into account is classified in a certain scope by standard. Sustainable construction and building renovation can be placed in scope 1 and 3. The building must be designed in such a way that a sustainable form of energy can be used, which is scope 1. However, the reuse of materials and the application of new sustainable materials fall under scope 3. Also, implementing green and other carbon-absorbing materials is something we propose in this document. This cannot be subdivided among scopes, but it is something that can reduce the total emissions.

The same applies to (sustainable) behaviour. Everyone who works on and from the campus influences the footprint of the TU Delft with their daily actions. The Social Engagement chapter looks into the possibility to nudge people into a more sustainable direction.

Financial ties
Finally, something beyond scope 3 might be financial or other ties to entities that possibly invest in environmentally damaging activities, such as commercial parties that fund research projects, insurance companies and pension funds. TU Delft is affiliated with ABP, a pension fund that invests money from TU Delft employees. In the recent past, the pension fund partly invested in controversial targets, which indirectly negatively contributed to the university's environmental footprint. In the year 2021, a plea signed by 500 employees of TU Delft, a letter by TU Delft's executive board, and a meeting with the board of ABP contributed to the pension fund's decision to no longer invest in fossil fuels. This was an important first step in the direction of a fully sustainable pension fund.

02.03 The current carbon performance

Carbon accounted
From the study of Blom & Dobbelsteen [2019], it turned out that in 2018 the annual carbon emission of TU Delft is around 50,000 tons of CO_2-eq, slightly less than in 2017. When in line with the CO_2-prestatieladder method, which is compliant with the international Greenhouse Gas Protocol (GHG Protocol) [Ranganathan et al. 2004], Cassandra Tax wrote the formal carbon accounting report of 2018 [Tax 2020a], the figures of 2018 were similar to those of Blom & Dobbelsteen.
Figure 02.03 shows the carbon footprint of 2019 [Tax 2020b], translated into the forest area required to sequester these emissions annually, with (in Dutch) the sources of these emissions. This forest area comprises around 1.5 times the territory of the city of Delft.

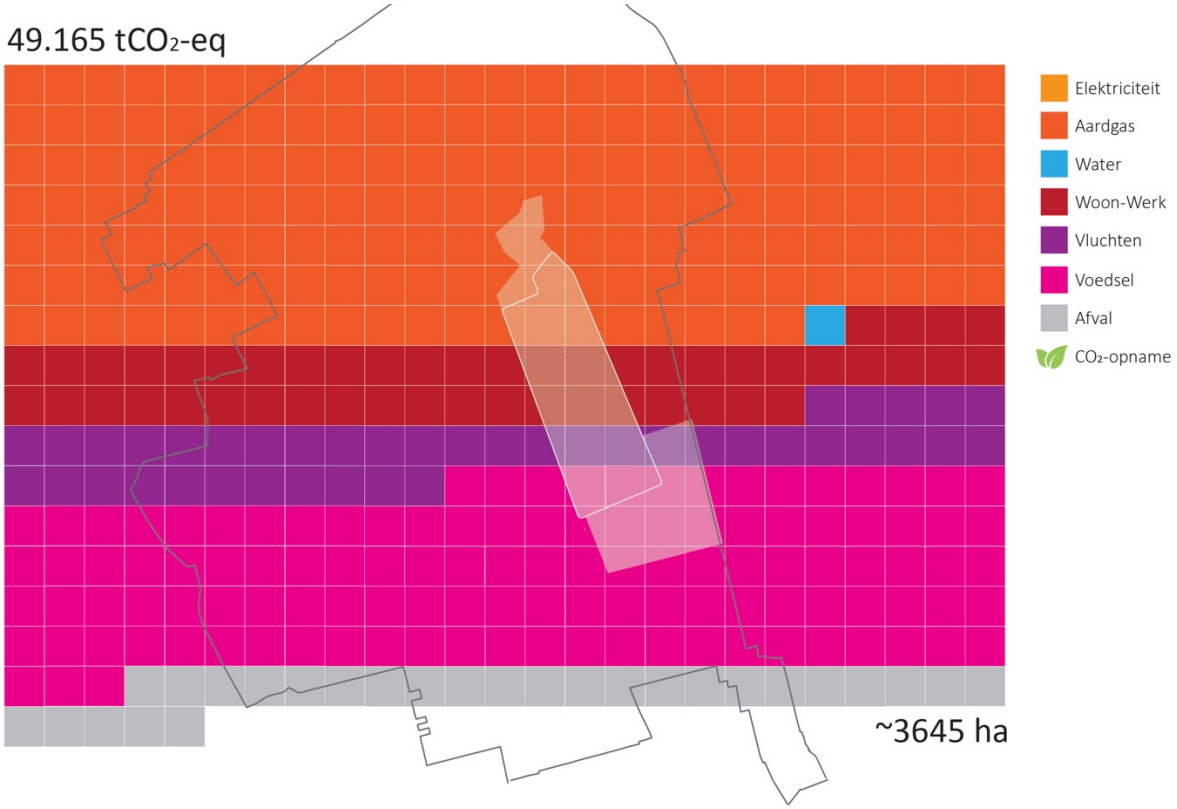


Figure 02.03: Carbon footprint of TU Delft in the year 2019, expressed as forest area that is needed to sequester all CO_2-equivalent emissions, with the borders of the city of Delft (grey lines) and domain of TU Delft (white patch) visible underneath [based on Tax, 2021a]

The corona year

For TU Delft, in 2020, a year almost completely defined by the corona crisis, emissions went down considerably, although not for energy use in buildings, disturbingly enough. Moreover, we should take into account that due to employees and students working from home, an increase in energy consumption may be expected for that year. We assumed 10%. Furthermore, less food was consumed, less water used and less waste produced on campus, but during working hours these were now happening at home, so it is fair to include these as TU Delft related emissions. For these factors we made estimations that are slightly lower than what would have occurred on the campus. The main actual reduction in carbon emissions happened due to reduced commuter, student and business travel.

Use of resources

In 2021, Herth & Blok wrote a paper in which the carbon calculations of 2018 had been executed according to another method, particularly focussing on the use of resources and services. In their study, apart from a new dominant source of carbon emissions, i.e. procurement, some figures were significantly different (i.e. energy and food). See table 02.02.

Figure 02.04 illustrates table 02.02 visually. Clearly visible is the blue category that previously was hard to assess, i.e. the use of resources.

Table 02.02: Comparison of the footprint of TU Delft from 2017-2020, according to different methods

year	2017	2018	2018	2018	2019	2020
source	Blom & Dobbelsteen 2019	Blom & Dobbelsteen 2019	Herth & Blok 2021	Tax 2020	Tax 2020	Tax 2021
energy	**23285**	**21740**	**25359**	**20993**	**20703**	**22102**
electricity	9330	8379	3695	0	0	0
natural gas	13955	13361	17522	20993	20273	19739
own operations				0	430	363
energy to third parties on campus			4142			
energy home office (estimated +10%)						2000
mobility	**13055**	**11630**	**13854**	**8308**	**8106**	**2503**
commuter travel	6104	4963	4066	3010	3118	1230
fuels on campus				0	40	27
business travel				5298	4948	1246
transportation & travel			4319			
flights	6951	6667	5469			
food	**13123**	**13797**	**5429**	**13816**	**14225**	**13652**
food on campus	13123	13797	5429	13816	14225	3652
food at home (estimated +10000)						10000
resources	**805**	**1006**	**59462**	**4297**	**3315**	**3286**
resources purchased				50	54	33
real estate & construction			19375			
equipment			14279			
ICT			8354			
facility services			8283			
research expenses & consumables			5036			
paper products			1395			
distribution				1	1	275
water consumption on campus	115	98	98			
waste	690	908	274	4246	3260	1978
resources at home (estimated +1000)						1000
other			2368			
services	**0**	**0**	**5252**	**2952**	**2816**	**802**
services				2952	2816	802
administration, consulting & auditing			4476			
finance & tax			776			
carbon uptake	**-216**	**-216**	**0**	**0**	**0**	**0**
green on campus	-216	-216				
green elsewhere						
total	**50052**	**47957**	**104104**	**47414**	**46349**	**41543**
employees (fte)					5607	6042
students					25407	26960
total	**28650**	**30124**	**30124**	**30124**	**31014**	**33002**
CO2/fte	**1,747**	**1,592**	**3,456**	**1,574**	**1,494**	**1,259**
		-8,9%			-5,1%	-20,0%

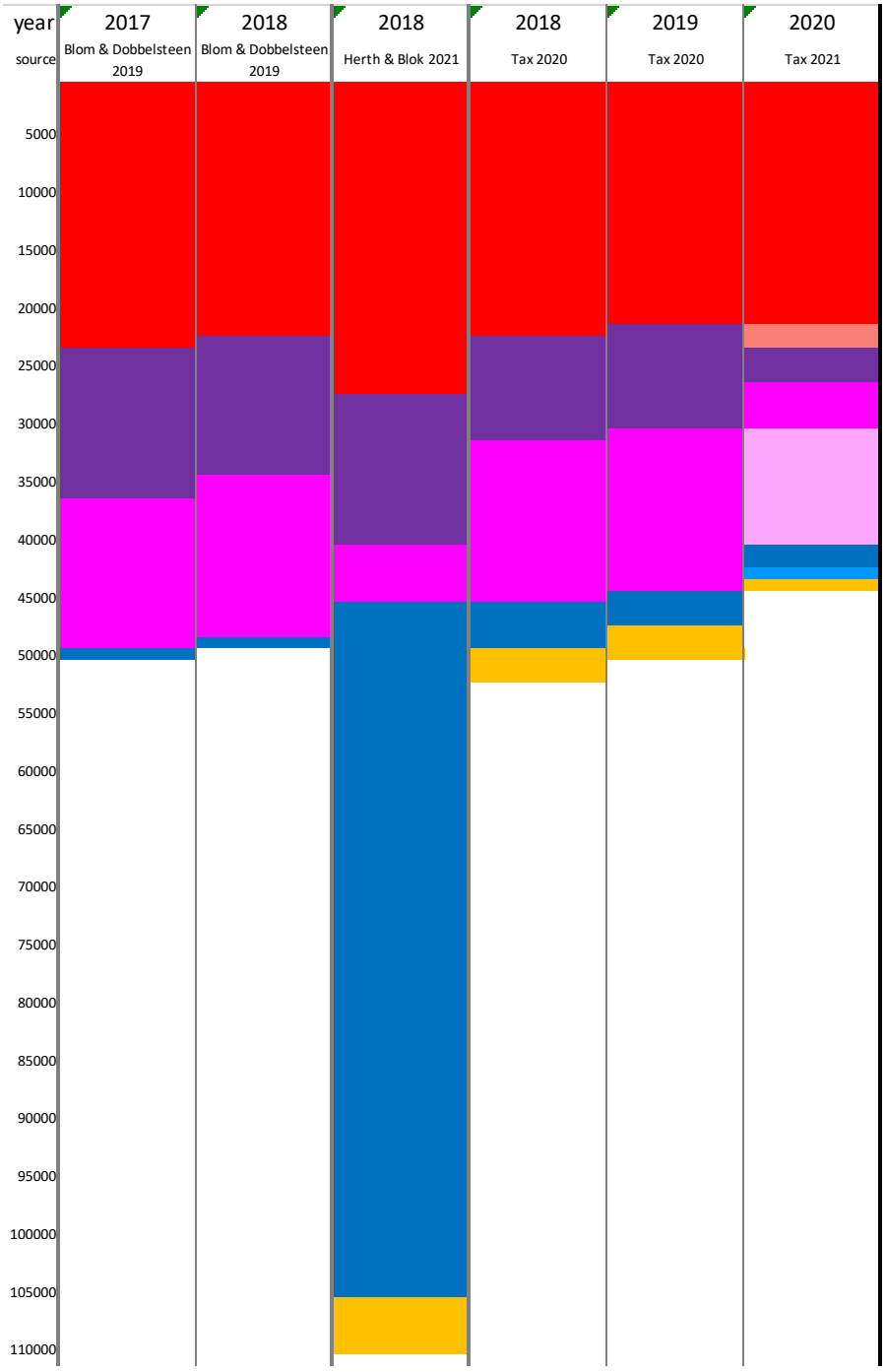
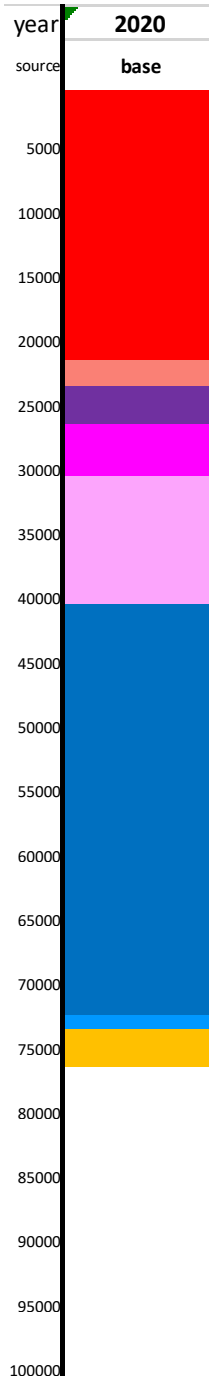


Figure 02.04: Carbon accounting of the years 2017-2020, according to various sources

The reference

Since we have to work with a reference, from which we can work towards the future, for 2020 a combination needed to be made of the sources mentioned. We propose to take the GHG protocol-based method by Tax, and add the use of resources by Herth & Blok (figure 02.05). In this table we estimated the relative use of resources in the corona year.



energy	**22102**
electricity	0
natural gas	19739
own operations	363
energy to third parties on campus	
energy home office (estimated +10%)	2000
mobility	**2503**
commuter travel	1230
fuels on campus	27
business travel	1246
transportation & travel	
flights	
food	**13652**
food on campus	3652
food at home (estimated +10000)	10000
resources	**32528**
resources purchased	
real estate & construction	9700
equipment	7100
ICT	4200
facility services	4100
research expenses & consumables	2500
paper products	700
distribution	
water consumption on campus	50
waste	1978
resources at home (estimated +1000)	1000
other	1200
services	**2600**
services	
administration, consulting & auditing	2200
finance & tax	400
carbon uptake	**-300**
green on campus	-300
green elsewhere	0
total	**70485**
employees (fte)	6042
students	26960
total	**33002**
CO2/fte	**2,136**

Figure 02.05: Carbon accounting data for the reference year 2020

02.04 Vision of a sustainable TU Delft

Ambitions

The ultimate goal of TU Delft would have to be to become regenerative, but there is an order by means of which that can be established. The first objectives of a sustainable campus, to be achieved by 2030 are the following Cs:

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

These objectives will be explained for the TU Delft campus below. They are the explication of the principle 'practice what you teach and preach'.

Why 2030 already?

In line with the Paris Agreements, the Dutch government has set the goal of being climate neutral as a country by 2050. TU Delft aspires to achieve this target twenty years earlier. There are several reasons for this.

Firstly, TU Delft considers its responsibility to pave the way forward, ahead of others who can follow. As a frontrunner university that is focussed on innovation and sustainability in science, engineering, design, planning and governance, TU Delft should demonstrate how a complicated assignment as becoming sustainable can be achieved, so that other universities, organisations and cities can learn from it.

Secondly, TU Delft recognises that the biggest challenge perhaps is not the ultimate end situation, but also the way to get there, the transition process. That transition path is still full of barriers, while scaling up requires acceleration. TU Delft wants to lead the way in not only reducing its carbon footprint in an absolute sense, but also in helping to remove bottlenecks and barriers that still stand in the way of making society more sustainable.

Unique opportunities

TU Delft is in a unique position for this. It has all the ingredients to be at the forefront of the technology transition. Research by scientists and innovative ideas are scaled up by motivated students in start-up companies. Field labs in The Green Village facilitate early testing of (system) innovations in a protected environment.

In addition, the campus can serve as an innovative ecosystem, a place where the sociological transition can be shaped. Both transitions are essential and the combination will ensure 'impact for a better society'. That way, our students are trained not only to develop their skills in technology, but also to learn how this technology can be adapted to its context.

Sustainability goals for the TU Delft Campus

Carbon-neutral campus
Everything done on and from the campus, as part of activities of TU Delft, need to be carbon neutral by 2030. This means that in the period of a year no more CO_2 or other greenhouse gases are net emitted as a result of the direct and indirect activities and facilities (scopes 1, 2 and 3)[6]. By 2030, all energy for electricity and heat comes from renewable sources. This also applies to the user-related energy required for research (primary processes).

Circular campus
By 2030 too, TU Delft intends to have a circular campus. This means that activities on and from the campus form part of the circular economy. Insofar as new materials, products or services are required, these are contracted or procured on the basis of sustainable, circular processes. The lifespan of available raw materials is maximised without harmful emissions to the environment. As described in the Roadmap Circulaire Campus 2030 [Ellen 2020], it is a requirement for both procurement and construction projects that they follow circular guidelines. Circularity will be translated to KPIs, just as with carbon emission targets.

Climate-adaptive campus
Although we attempt to diminish the long-term effects as much as possible, recent measurements indicate the climate is already changing rapidly. This means that the built environment should cater for different circumstances than it has been developed for so far. Also, the TU Delft Campus should be climate adaptive, ready for different circumstances, as expected by the meteorological institutes. In particular, this means that the urban plan and buildings should be better prepared for hot summers, for more precipitation on average, but long periods of drought too, and for extreme weather conditions, storms in particular.

A campus contributing to quality of life
Quality of life can refer to the life of people, but also to that of plants and animals on the campus. Therefore, improving the ecological value of the campus and increasing biodiversity is a deliberate goal of the sustainability action plan. This ambition should coincide with improved climatic conditions on campus, contributing to the health of staff, students and visitors. The TU Delft Campus should offer a high-quality working and learning environment in which health and well-being are at the core and where sustainable circular initiatives are stimulated, tested and evaluated.

A fifth objective has not been mentioned yet. That one refers to making the campus a place where every user forms part of the experiment. This campus as a living lab will be discussed hereafter.

[6] CRE [2020] limited this goal to direct activities and facilities (scopes 1 and 2), but we expanded it to scope 3 as well.

02.05 The campus as a living lab

The desired future

An entirely sustainable university
TU Delft will be a university operating in a completely sustainable manner, both on and outside the campus. All activities will be carbon neutral and the campus will be circular, climate adaptive and contributing to the quality of life of its users and nature. TU Delft's performances will be continuously measured, adjusted when needed and justified by annual reporting. Thereby, TU Delft will be an exemplar for the rest of the world, regarded highly for its pioneer role in a world in transition to a sustainable state.

A thriving and bustling campus
The TU Delft Campus will be the pinnacle of a thriving, bustling community that studies, researches and works for a better world. The campus will be visibly boasting innovative and sustainable projects, pilots and activities, oftentimes exposed in living lab settings. Everyone making use of the campus will be part of the experiments taking place, learning from innovative technology and novel processes. The newest ideas, techniques and processes will be tested here, and since they are sometimes of an experimental nature, they may go wrong, only to be improved in an enhanced version.

TU Delft has a unique proposition to develop (research) projects that both contribute to the sustainable campus assignment as well as take away barriers that unlock the potential of sustainable innovations in society.

Opportunities at present

Making innovation visible
At TU Delft a lot of innovative work is done, also in the area of sustainability, including circularity, both in research and education. However, little of this is visible on the campus itself. The Green Village is perhaps the best-known and most exposed part of innovative constructions tested on the campus, and the D:Dream Hall is where one can find the ground-breaking student projects of Dreamteams, but outside of these, TU Delft's campus could be any university's campus. Also regarding buildings on campus, little can be sensed of the sometimes effervescent, energetic processes taking place behind the walls.

Making sustainability visible
Few people will notice Pulse is an energy-neutral building. Not that the energy system always needs to be distinguishable but demonstrating innovation and sustainability can be seen as part of the educative aspect of the TU Delft Campus. The approach to the next educational building, Echo, was already a step ahead, and the Kluyver area development is going to be the new flagship project for sustainability. So, sustainability is an ever more important aspect of the construction and renovation of buildings on the campus, and this may be made visible and demonstrated as part of the campus living lab setting. The greatest

challenge now lies in the sustainable renovation and transformation of existing buildings, i.e. the ones that will be preserved, and to make these a part of the living lab as well.

Approach to living labs

Although the primary process always must be ensured, tests and demonstration of technology – but also (non-physical) research and experiments to improve societal embracement, regulation or alternative business propositions of sustainable innovations – can use the campus as living lab and join the (visualised) community of a sustainable living lab portfolio. The free zones on the campus are great places for (temporary) living labs. In addition, special zones can be attributed to longer-term living labs. Living labs can potentially offer a completely new dimension to the campus, attracting new partners and offering a significant contribution to the mission of TU (i.e. impact for a better society).

Short-term strategy

We start with small evidence projects, such as the micro-grid configuration (photovoltaics, battery, intelligent EV charging) at the Rotterdamseweg parking garage, the high-temperature (HT) aquifer thermal energy storage (ATES) in combination with a geothermal test facility next to the cogeneration plant of TU Delft, a DC system installed in buildings, and the aquathermal energy pilot of Firma van Buiten. Also, the Brains for buildings project will become part of the living lab strategy. Another project already ongoing is climate-adaptive civil innovation (the 'Waterstraat' at The Green Village). More structural in nature is the digital twin that needs to be developed for the campus' energy system. Scaling up the 24-7 lab on the campus is another living lab extension.

On a more financial term, a pilot has started about incorporating TCO (total cost of ownership) into the EEMCS tower renovation project and new Physics building in the Kluyver area. In order to incorporate key figures for circularity in the TCO calculation, further research is necessary and this will be initiated together by Campus & Real Estate (CRE), researchers, and external parties (e.g. Cirkelstad, ASR). Moreover, a structured and justified way to work more closely with innovative start-ups should be liaised with the procurement department of Finance and with the Innovation & Impact Centre (I&IC).

Developing and testing a community software application is another living lab initiative focussed on communicating progress and testing incentives (for instance, a local green bitcoin currency that you can earn and spend locally on campus). This same community tool could be used to introduce and improve the personal carbon budget, which will described further on.
The boundary conditions should be developed, such as setting up a living lab methodology and the integration thereof with construction and renovation projects, the energy system, climate-adaption themes, etc.

Medium-term strategy

The living lab approach needs to be further implemented in the core processes of CRE, I&IC and procurement of Finance. It would be good to establish an innovation funnel, including

different TRL levels: prototyping, testing at The Green Village or in a local lab environment, testing and demonstrating on campus, scaling up to the municipality. The living lab methodology and innovation funnel need to be communicated at TU Delft internally and subsequently, with I&IC, also to external partners who would be interested.

Resources strategy
In the years 2021-2023, the sustainability work will be executed within and in parallel with the Strategic Framework of TU Delft.
New contracts and procurement strategies (design, finance, build, maintain, operate) can be explored. Internal TU Delft talent and skill pools (experts, change managers, funding experts, etc.) can be developed; Human Resources (HR) can be involved to actively match students and staff to projects with the ambition to develop for and contribute to the sustainable transition. Standard contracts ('raamcontracten') can be established with trusted firms that support the sustainable transition (such as Copper8, Alba Concepts, Metabolic, PHI Factory etc.).

In the years thereafter (2023-2025) there can be a transition in the contract approach, focussed on result-oriented contractors with sustainable goals as performance criteria.

02.06 TU Delft's sustainability ambitions

TU Delft will be:

- **Carbon neutral, by 2030**
  referring to all TU Delft related activities done on and from the campus
- **Circular, by 2030**
  related to all resource and waste flows going through the campus
- **Climate-adaptive, by 2030**
  dealing with heat, drought, excessive rainfall, floods and extreme weather
- **Contributing to quality of life, increasingly so**
  aiming at biodiversity, safety, health, comfort, inclusiveness and happiness
- **Exposing its excellence and sustainable character on campus**
  accommodating and demonstrating living labs and innovative projects

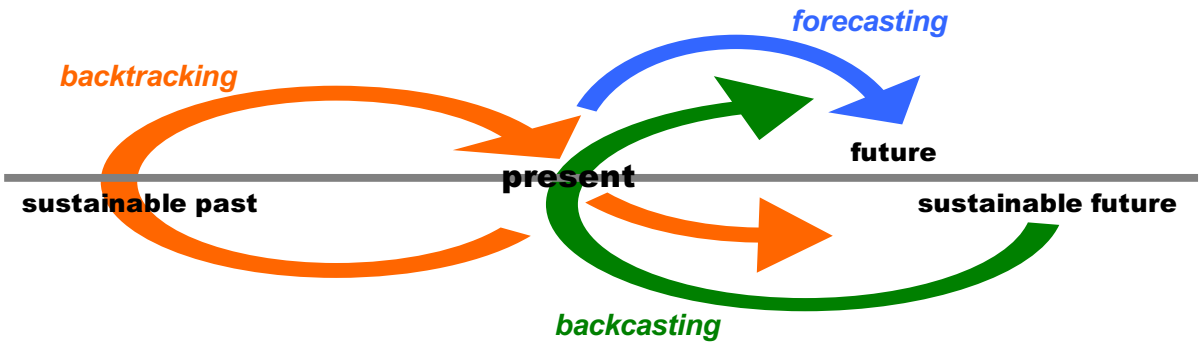
03 Approach to the Sustainability Action Plan

03.01 Theoretical basis

Backcasting

In the early 1990s, it was already expected that the global population would grow by a factor 2 in the 50 years thereafter and that if nothing changed (if the efficiency of the technology remained the same), the eco-capacity of the earth would be exceeded by a factor of 10-50 by 2040, also because developing and emerging economies would have to catch up with prosperous countries [Speth 1989; Ehrlich & Ehrlich 1990].
New technologies are needed for the fulfilment of societal needs. Backcasting is used to map out these required technologies. This means that the desired future situation is envisioned first and then it is examined which steps are needed to achieve this [Vergragt & Jansen 1993]. For TU Delft it means that we envision first how the campus should be around 2040 or 2050, before we define steps to get there.

Figure 03.01 illustrates three principles of working towards a sustainable future: the usual forecasting of expectations from now, based on present-day's system and technologies; second is backtracking, which entails learning from past sustainable systems; finally, backcasting is taking the desired future situation as the start and defines from that state the required developments and technologies. Backcasting is a more effective means to arrive at the desired state in the future than forecasting or backtracking, although both others can be helpful.



Figuur 03.01: Graphical representation of the principles of backtracking (learning from a sustainable past), forecasting (forward projecting of expectations) and backcasting (basing interventions on a desired sustainable future [Dobbelsteen et al. 2006]

The City-zen methodology

As with the CO_2 roadmap study of Blom & Dobbelsteen [2019], the methodology from the City-zen EU project [Dobbelsteen et al. 2019] is a good one to apply to the TU Delft Campus, as it in fact is a small city in itself. The City-zen methodology gives structure to the development of plans in the direction of a sustainable built environment and it results in an energy roadmap for a certain area. This roadmap is based on an energy analysis (demand

and potentials) and targets defined prior. It encompasses different energy interventions and measures, at different technical and strategic scale levels and times.

Steps

Figure 03.02 schematically presents the different steps of the City-zen methodology [Broersma et al. 2018]:

1. Energy analysis: the zero measurement (current situation, energy demand, system etc.)
2. Current plans and planned developments
3. Societal and stakeholder analysis
4. Scenarios for the near future (external variables influencing the future circumstances)
5. Sustainable vision
6. Roadmap with energy strategies and actions

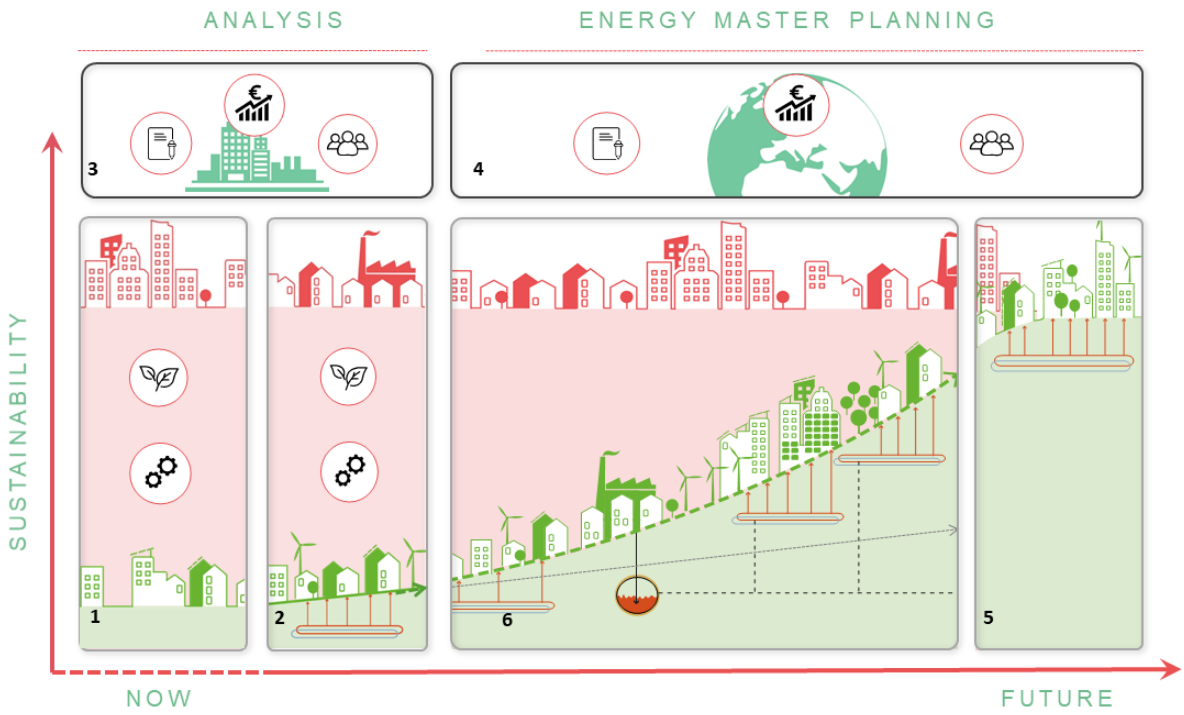


Figure 03.02: Graphical explanation of the City-zen methodology:
how does a city get from an unsustainable, starting situation (1) and already planned developments (2) via stakeholder analysis (3) and scenario studies (4) to a desired sustainable future situation (5). The roadmap in between (6) is the defining element [Broersma et al. 2018]

The roadmap between now and then can be determined in two directions: forward and backward. As explained, we propose to work according to the principle of backcasting, and to work from the desired future state.

Adaptive pathways

The future is uncertain, always to a great extent. There are variables that TU Delft or any academic institute cannot forecast, define or even influence. Examples of these include the development of the campus population, national and international policies regarding water

management, energy systems and mobility, economy, politics, etc. Keeping an open mind to different scenarios and thinking in spatially adaptive pathways [e.g. Lieftink 2021] may be a proper way to address this uncertainty in subsequent stages.

Proposal

This vision, ambition and action document has both backcasting and the City-zen method lying underneath the projects, pilots and actions elaborated for TU Delft. And we do not propose a blueprint approach, however keep an eye on different scenarios and act in adaptive ways accordingly.

03.02 General principle: reduce, reuse, produce

The mantra 'reduce, reuse, produce' – reduce the demand, reuse waste flows, produce from renewable sources only – is known as the New Stepped Strategy [Dobbelsteen 2008]. These steps are preceded by understanding the local circumstances. It has been used mainly for zero-energy design of buildings but can be applied to various types of flows of resources and their wastes. We need to avoid the necessity of resource use or waste production, reuse products, materials and residual flows, and use only renewable energy and circular new products.

Understanding the local circumstances first

Too many decisions in planning and design are taken without proper understanding of the characteristics of the specific location. Think of: climate, landscape, ecology, underground, existing built environment, culture, habits. Therefore, before imagining any solution, we should understand what we are designing for. Step 0. Apart from avoiding mistakes, this enables optimal use of local potentials, hence saving auxiliary resources, energy and money.

Avoid or reduce the demand

Next, we can approach everything first by the question: is this really necessary? Think of not travelling abroad when meetings can be done online, think of prohibiting prepacked salads when people can also scoop it into a bowl, think of avoiding artificial lighting when adjusting the louvers admits enough daylight to work by, think of turning down the heating when leaving the office, think of turning off the online meeting when having a break. Most of the measures related to 'reduce' cost nothing at all and save a lot of money, energy, material and waste.

If certain things are necessary, one can find simple solutions that reduce the demand for resources. Think of thermal insulation to reduce energy for heating and cooling, think of positioning heat-producing functions in cool spaces, think of A+++ fridges, think of water-saving taps, think of parametric design to reduce material use in constructions.

Reuse everything on campus

The second step is to reject the concept of waste and consider everything as resource or nutrient. Incineration (or landfill) of unprocessable waste is the walk of shame for any

organisation that intends to become sustainable, a destruction of exergy and valuable matter. The most important part of the Ecodevice model [Tjallingii 1996] (figure 03.03) arguably is the means that helps to reduce the input into a system and the output thereof, to establish 'not in' and 'not out': reuse and recycling. TU Delft is an urban mine in itself: all resources that have been put into the campus should be considered as its valuable assets, which need to be retrieved when no longer useful in their initial function.

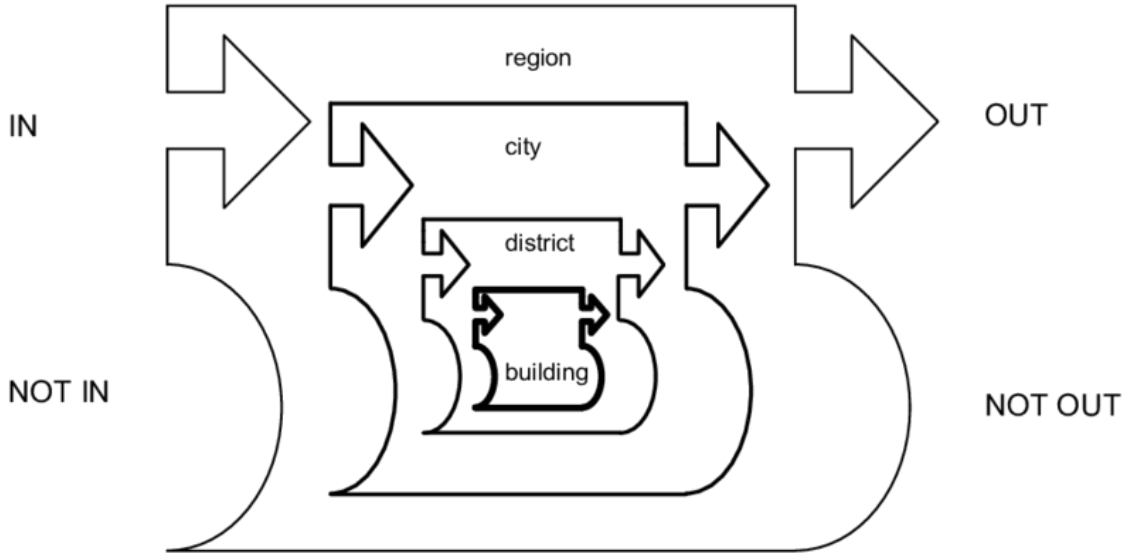


Figure 03.03: The Ecodevice model [Tjallingii 1996]

At present, around 40% of all waste collected is not reused or recycled but incinerated in the plant at Rozenburg (west of Rotterdam). We need to try to diminish this share and aim for zero waste. That entails a complete control over what TU Delft purchases and how it is processed afterwards. Regarding buildings on the campus: everything coming out of maintenance and demolition should be considered as urban mining, retrieving valuable ingredients and bringing back to nature that which is a harmless nutrient.

Produce from sustainable sources only

It does not necessarily have to be the last step – it can also be the first – but after having avoided and reduced the demand and after having reused products and waste flows, the remaining input needed of resources or activities should be coming from sustainable systems and renewable sources only. Think of solar energy, rainwater, biobased materials, demountable and reusable products, organic food, preferably from plants.
There is an escape route. If materials used for products are not coming from renewable resources, such as metals, most minerals and non-biobased plastics, we could take a step back to 'reuse' and ensure that the products in question are to be reused or recycled infinitely.

With these three steps as general principle, the use of resources on campus can be much better controlled, reduced, part of the circular economy and thereby sustained. In the

section following we will discuss the most effective interventions to be taken as part of the sustainability action plan.

03.03 Domains

This TU Delft vision, ambition and action plan is divided into 4 domains: 1. Education for Sustainability, 2. Research, Valorisation & Technology Transfer, 3. Community, 4. Operations. This document primarily focusses on the community and operations domains but also introduces the other two.

Education for Sustainability

The prime task of a university is knowledge transfer and teaching students. TU Delft offers eight types of programmes in the education domain: bachelor (BSc)[7], minor[8], master (MSc)[9], honours[10], exchange[11], doctoral (PhD)[12], post-academic[13], and online[14] programmes.
A part of the curriculum is fundamental and stable, basic knowledge required for certain disciplines. Another part is more dynamic. Considering the challenges society is facing, TU Delft has to adjust education offered on campus continuously to new themes. In its full broadness, sustainability is one of these areas that over the last few decades has gained more attention, but that in many places still lacks aspects, especially relatively novel topics such as circularity, climate adaptation and nature-based design. This action plan does not go into much detail for education but intends to set a few principles that help to make TU Delft a sustainable university, also in the education it offers. In addition to this action, there is a report forthcoming, written by GreenTU in collaboration with the TU Delft sustainability coordination, which in regards to education on sustainability will chart the voids and propose improvements.

Research, Valorisation & Technology Transfer

Academic research is also one of the prime tasks of the university. TU Delft states that it is their mission to make a significant contribution towards a sustainable society for the twenty-first century by conducting ground-breaking scientific and technological research (Roadmap 2020, p.12 [TU Delft 2012]).

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[7] There are 16 BSc programmes at TU Delft, spread over eight faculties.
[8] Students can do a minor during their BSc stage; it is a coherent programme of courses worth 15 or 30 EC.
[9] Students can follow a MSc programme after obtaining their BSc degree; at present, TU Delft offers 35 different MSc tracks.
[10] Students can follow an honours programme during the MSc or BSc stage; it was developed for students who perform above average.
[11] Students can partake in an exchange programme with one of the many universities TU Delft collaborates with worldwide.
[12] Someone with a MSc degree can do a PhD trajectory at TU Delft. This is a four-year research project.
[13] TU Delft offers post-academic programmes for professionals from the market.
[14] TU Delft offers online education in the form of massive open online courses (MOOCs) or online professional educational courses (ProfEds); these can be followed by everyone across the whole world.

Sustainability programmes
There are multiple research programmes at TU Delft that focus on sustainability. For instance, there are the Delft Research-based Initiatives (DRIs) such as Delft Energy Initiative and Delft Global Initiative, institutes such as the TU Delft Climate Institute, and – most recently – the Climate Action Programme. These will be introduced further in Chapter 5 (Research, Valorisation & Technology Transfer).

Valorisation
Valorisation is an important aspect related to research and a core activity of universities; for TU Delft it mainly relates to technology transfer. This refers to the transfer and application of knowledge for the benefit of society and the economy. Technology transfer is becoming increasingly important in national and international innovation policy, in which technical universities play a leading role. TU Delft sees it as its societal task to provide ground-breaking scientific, technical, design solutions that contribute to impact for a better society.

Community
Changing a community of 29,000 students (BSc, MSc and PhD) and 6,000 employees (academic, managing and supporting) cannot be done by 1 sustainability coordinator, not even with a dedicated support group. The sustainable transition is such a challenging endeavour that (almost) everyone on campus should partake in it. Therefore, governance and social engagement are an essential domain of the sustainability action plan. The entire community must understand the necessity of this process but also see it as something everyone can contribute to, and that it can be interesting and fun to do so. Therefore, we see this not only as a top-down initiative, sanctified by the executive board, but especially as a bottom-up movement of students and staff. And in the process, companies located on the TU Delft Campus and the City of Delft are also included.

Operations
Sending out engineers and young doctors to the world, who can help to make that world better, as well as conducting research that contributes to improving the environmental performance, are perhaps the best ways that TU Delft can demonstrate its climate and sustainability action. This can be amplified if the university gives the right example in its own operations. After all, how can we expect other organisations, companies and individuals to function, work and live sustainably, if we as university do not manage to establish that ourselves? Therefore, as assigned by the executive board of TU Delft, this report is predominantly focussed on getting our university's operations – on campus and outside of it – changed to fully sustainable.
Therefore, operations is the main focus of this action plan.

03.04 Organisational structure

The flower

At the beginning of this project, the organisation of the sustainability action plan was structured as a flower with petals, see figure 03.04. The grey petals represent the university's supporting divisions while the coloured petals are the faculties. GreenTU is the student organisation working on sustainability. The centre is formed by the sustainability coordinatorship of Andy van den Dobbelsteen and Deirdre van Gameren. They work directly for, report to and advise the Executive Board (CvB, College van Bestuur in Dutch), which eventually decide on proposed projects, pilots and actions. The CvB is represented by the stem. Otherwise, the existing structure of TU Delft is decisive, which is why the sustainability coordinator works closely with each supporting division and faculty.

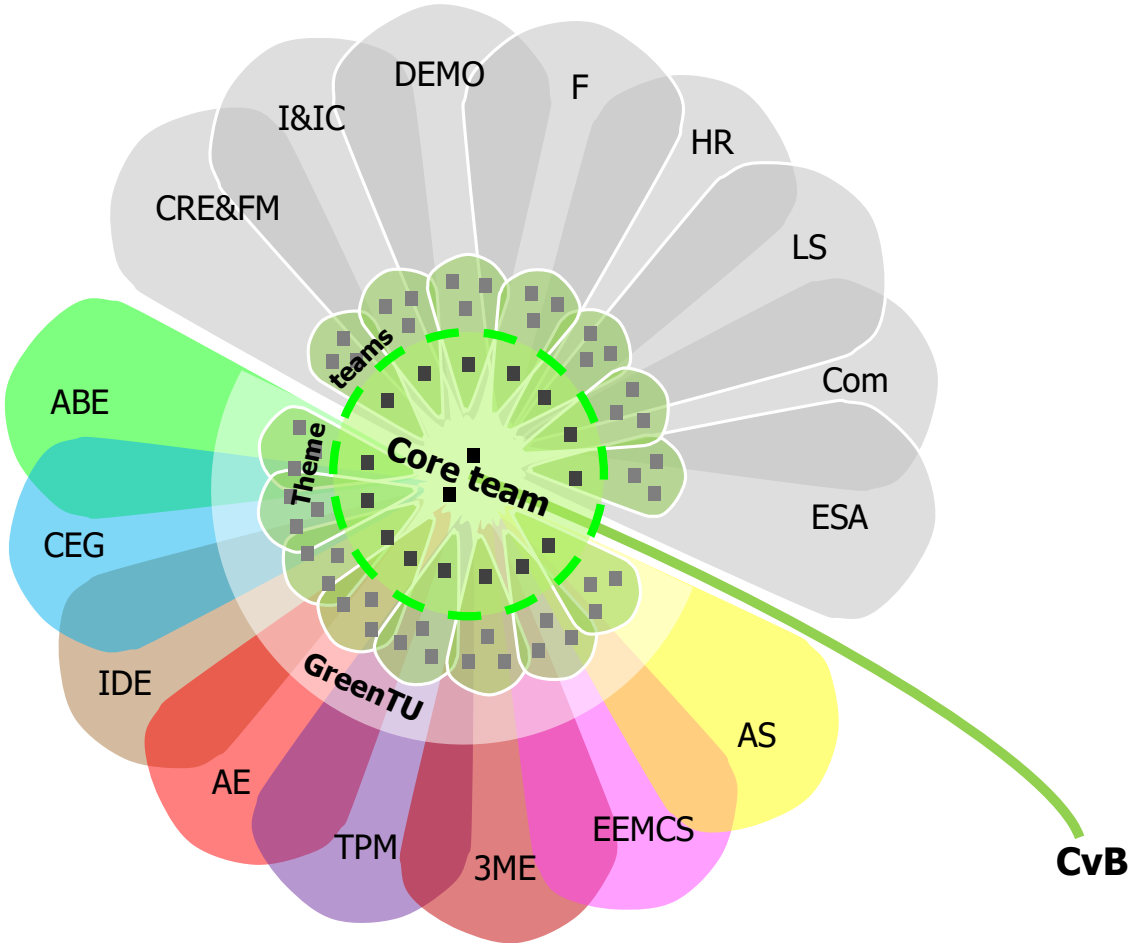


Figure 03.04: Organisational scheme of the sustainable TU Delft project

Representatives from the supporting divisions and faculties form the core team. These representatives, sometimes local sustainability coordinators, are the linking pin between the sustainability team and the faculty or service itself. They know the people and organisation from inside out and have their own GreenTeam of students within the faculty or a smaller

sustainability team within the service. Finally, the sustainability action plan is closely linked to the Climate Action Programme (CAP).

Faculties

The university's primary tasks – education, research and knowledge valorisation – are carried out by the faculties. There are eight faculties at TU Delft, which all have their scientific discipline and specialisms. In alphabetical order, these faculties are: Aerospace Engineering (AE), Applied Sciences (AS), Architecture and the Built Environment (ABE), Civil Engineering and Geosciences (CEG), Electrical Engineering, Mathematics and Computer Science (EEMCS), Industrial Design Engineering (IDE), Mechanical, Maritime and Materials Engineering (3mE), and Technology, Policy and Management (TPM). For the sustainability action plan, knowledge and expertise from all faculties is needed; therefore, academics are involved in the different theme teams.

Supporting divisions

TU Delft's divisions support and facilitate the primary processes in the organisation of the university. In addition, the services coordinate the administrative processes and coordinate central policy processes. The sustainability action plan collaborates with the following divisions, in alphabetical order: Campus Real Estate & Facility Management (CRE&FM), Communication (Com), Education & Student Affairs (ESA), Electronic & Mechanical Support Division (DEMO in Dutch), Finance (F), Human Resource Management (HRM), and Innovation & Impact Centre (I&IC, formerly known as Valorisation Centre).

GreenTU and the GreenTeams

The green half circle of figure 03.04 represents GreenTU, a student organisation that forms part of the Corporate Office of TU Delft. GreenTU, led by a team of six dedicated student board members, is devoted to stimulating sustainability in education, research, university operations and the university community.
Next to the board of GreenTU, there are GreenTeams in all faculties, which secure the embedding of sustainability in the local faculty building and education. These GreenTeams are sometimes supervised by the faculty's sustainability coordinator.

Core team

The core team of the sustainability action plan is formed by the representatives of the faculties and the supporting divisions. This group gets together regularly to talk about the overarching theme of sustainable transition and about the outcomes of the theme teams. Each of the representatives knows the structure and people from their own faculty or supporting division, so they know what to focus on and who to contact in order to take steps in the process. Some services and faculties have their own sustainability team coordinated by the representative, who is the local sustainability coordinator.

Theme teams

Twelve specialised and integrative theme teams have been formed to focus on a specific topic of sustainability: Education for Sustainability; Research, Valorisation & Technology

Transfer; EcoCampus; Construction & Renovation; Energy Systems; Mobility; Food & Beverage; Procurement & Waste Management; IT, AI & Data Management; Social Engagement; Communication; Reporting. Each team is comprised of employees of influential supporting divisions, academics from different faculties with expertise in the respective subject, and (not least) students from GreenTU or one of the faculty GreenTeams.
In the theme teams, measures, actions and projects are proposed, elaborated and initiated. This vision, ambition and action plan will include them.

03.05 The theme teams

The teams working on sustainability of TU Delft can be categorised by primary focus themes, community themes and specialised themes.

Primary focus teams

The primary focus teams are as follows:

- The **Education for Sustainability** team looks at the current implementation of sustainability in education within the faculties, cross faculty and cross university.
- The **Research**, **Valorisation & Technology Transfer** team is concerned with the implementation of sustainability in research, for the technology transfer towards society and to find funding for projects, pilots and actions on the campus, preferably set up as living labs that merge research, education and operations.

These themes will be discussed in the two chapters hereafter.

Community teams

The focus of the community teams is as follows:

- **Governance** is dealt with by the Core Team; this team focusses on structural changes to governance, i.e. the organisation, policies and management (decision-making) processes of TU Delft.
- The **Social Engagement** team prepares projects, events and actions to engage the entire community of TU Delft Campus.
- The **Communication** team focusses on the website, dashboard and internal and external communication of sustainability-related aspects.
- The **Reporting** team works on the carbon accounting reports, sustainability reports and assessment methods needed therefor.

These six teams are preceded by what can be seen as the core team's focus: structural change in the approach at TU Delft.

Specialised teams

The specialised theme teams for operations have the following focus:

- The **EcoCampus** team works on plans for a greener campus that has a better water management, aiming for increased biodiversity and improved climate adaptivity.

- The **Energy System** team focusses on a sustainable energy system with renewable power generation, thermal energy, sustainable fuels and energy storage.
- The **Construction & Renovation** team looks into the current building stock and the possibility to renovate these buildings on the one hand and into sustainable new construction on the other hand. Its focus is to reduce the carbon footprint of buildings on campus, old and new, and to incorporate circularity.
- The **Mobility** team works on a sustainable mobility policy and focusses on commuter, business and student travel. Furthermore, this team looks at employee and student services, as well as sustainable facilities at the campus, for example electric charging points, bike storage and safe infrastructure.
- The **Food & Beverage** team focusses on the catering at the campus, the environmental footprint of food and sustainable food policy.
- The **Procurement & Waste Management** team is dedicated to a system of circular resource management, through procurement through preferred and contracted suppliers and the avoidance of waste, or sustainable processing thereof.
- The **IT, AI & Data Management** team concentrates on reducing the negative carbon impact of IT and the positive potential of using IT and AI in energy efficiency in creating a smart campus.

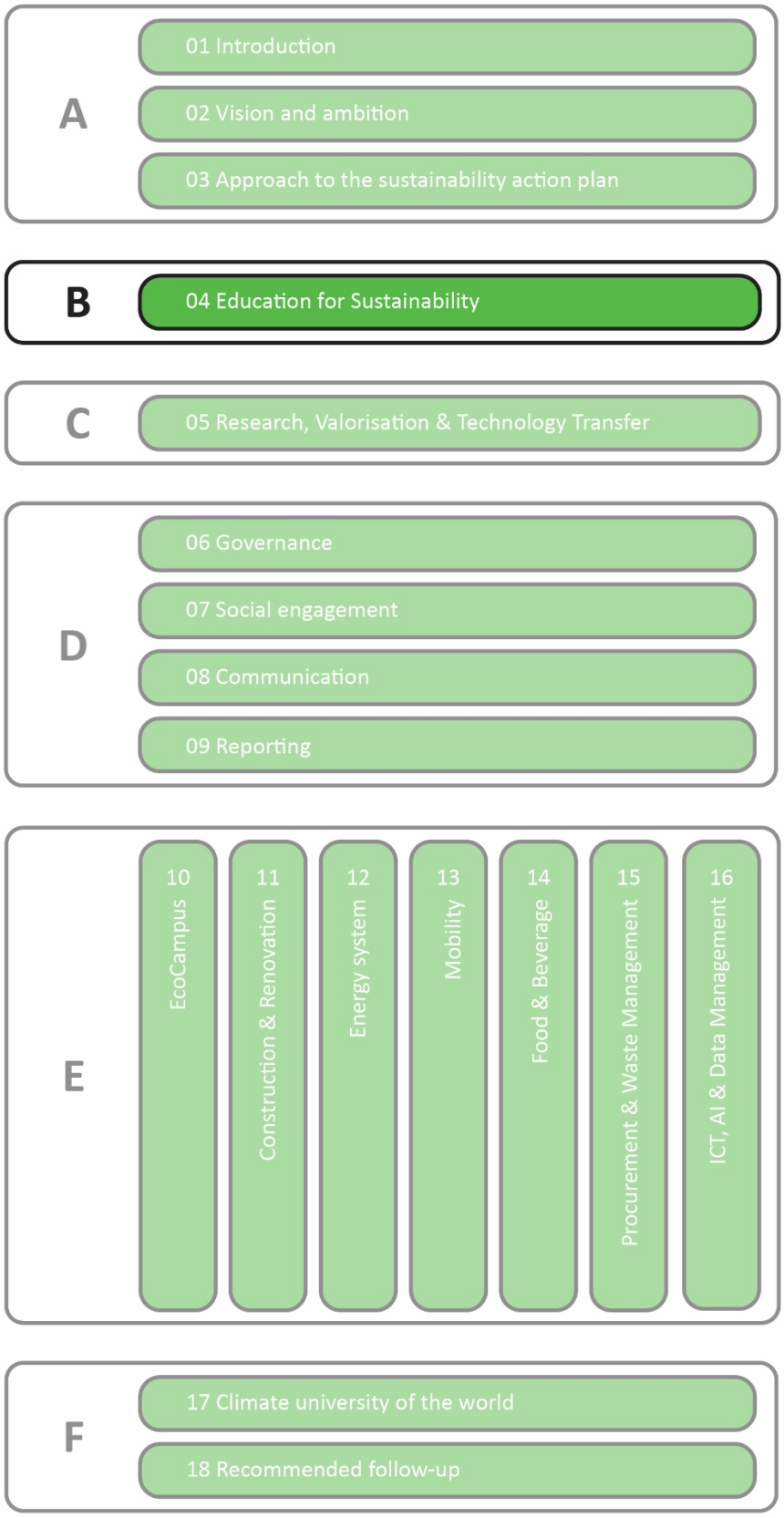
New responsibilities
The teams mentioned above will be made responsible for quality assurance in the area of their respective sustainability themes, based on regular monitoring of projects, pilots and living labs. A coordinator will be chosen per team. The new responsibilities will be implemented as soon as this vision, ambition and action plan has been formally approved by TU Delft's Executive Board.
As TU Delft sustainability coordinator, Andy van den Dobbelsteen will remain responsible for the overall quality assurance of the sustainability action plan.

In the part following, the primary focus themes will be discussed first, followed by the community themes, and finally, the specialised themes will follow.

TU Delft

PART B

EDUCATION FOR SUSTAINABILITY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04 Education for Sustainability

Team (in alphabetical order)

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- Jeremy Faludi – IDE assistant professor of Design for Sustainability
- Irene Fernandez Villegas - AE sustainability coordinator
- Deirdre van Gameren – TU Delft sustainability researcher
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- Linda Kamp – TPM sustainability coordinator
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- Jordi van Opzeeland – SD
- Rene van Swaaij – EEMCS Sustainable Energy Technology coordinator
- Rosa Weinzierl – GreenTU

Education for Sustainability
Main proposals

General aims and principles

- To deliver scientists, engineers and designers who can contribute to a better world
- To include sustainability in all forms of education offered by the TU Delft

To be investigated

- Implementing the Green Thread for minors
- Setting a minimum for sustainable BSc and MSc courses, PhDs, post-masters, MOOCs
- Financial support for students who travel sustainably

Projects, pilots and actions

- Sustainability-related projects from TU Delft as business case for JIP
- Honours programme as sustainability input to the studies of excellent students

This chapter describes the desired future situation and looks into the present state of education offered at the Delft University of Technology in relation to sustainability. Subsequently, specific actions, pilots, and projects are proposed to reach this desired goal. This chapter focusses on the following eight educational programme types: bachelor (BSc) programmes, minors, master (MSc) programmes, honours programme, doctorates (PhD), professional doctorates (PDEng), post-academic education, and online education.

04.01 Desired future situation

In the near future, TU Delft will have successfully implemented sustainability in the eight educational programme types. As a first step, a definition is drawn up for Sustainability Education, see section 04.03. Using this definition, gaps in terms of sustainability are identified in education and lecturers are helped to bridge these gaps by developing a teach the teacher module. In addition, a rubric will have been designed to grade bachelor and master programmes on sustainability.
All this will be achieved by following the “Roadmap for Sustainability Education”, see section 04.04, which was conceptualised by the Education for Sustainability team and elaborated and perfected by the person studying sustainability education. Through this roadmap, students will gain knowledge on the fundamentals of sustainability, receive relevant discipline-specific expertise on sustainability and are granted the opportunity to study and work on sustainability in an interdisciplinary environment.
As long as sustainable travel is more expensive than polluting mobility, there is financial support for students travelling sustainably. Students can delve into sustainability issues related to their studies during the honours programme.
TU Delft has become a brand for sustainable education in all disciplines, connected to exciting student competitions (the former Dreamteams) and research projects, and most interestingly, linked to what is happening on the campus. Students are part of the living labs on campus and most of them include sustainability in their graduation topic.

04.02 Education at present

As part of their second sustainability report, GreenTU investigated the current status of sustainability in education. In addition to an overall inventory, an in-depth study was performed of the faculties of Technology, Policy & Management (TPM), Electrical Engineering, Mathematics & Computer Sciences (EEMCS) and Civil Engineering & Geosciences (CEG). Results of this overall inventory are summarised in the following paragraph. More information can be found in Appendix B. Complete results are presented in the GreenTU sustainability report (2022).

Results of the analysis
Main findings from the 2021 inventory are:

- Few of TU Delft's 16 bachelor programmes directly incorporate sustainability, except the programme of Architecture, Urbanism and Building Sciences.
- Every faculty offers at least one minor that relates to sustainability, but only 10 out of 42 minors taught at TU Delft explicitly incorporate sustainability.
- Sustainability is mentioned in at least half of the 49 master tracks at TU Delft; however, only 5 out of 35 master programmes and 15 out of 49 master tracks clearly incorporate sustainability.
- The content of topics for honours students depends on the agreements between the students and their supervisor.
- Although sustainability can be and often is a topic of a PhD trajectory, candidates stated that too few courses of their Doctoral Education deal with sustainability or climate action.
- Sustainability is a topic in 2 of the 5 professional doctorates (PDeng).
- 3 of the 5 post-master programmes offered by TU Delft include sustainability.
- The TU Delft Global Engagement Framework 2018-2024 states that the university wants to develop an open and online portfolio focussed on contributing to the challenges described by the UN Sustainable Development Goals (SDG) [UN 2019, p.18] More can be done still concerning open courseware, MOOCs and ProfEds. The faculty of Architecture and the Built Environment stands out, as almost all of its MOOCs integrate sustainability or circularity. The faculty of Aerospace Engineering on the other hand offers not one MOOC or ProfEd that fully integrates sustainability.

The Green Thread
Overall, the findings outlined above show there is plenty of room for improvement to make sustainability a more integral and explicit part of all education offered by TU Delft. GreenTU therefore proposes to integrate sustainability horizontally throughout the various programmes. Adding a stand-alone course would need time to be implemented into the already dense curricula (at the loss of existing courses). Instead, the topic of sustainability could be integrated into project courses and the bachelor thesis, for instance. See also section 04.04.

04.03 Educating a new generation

It is essential that the educational programme at TU Delft, at all levels and in all disciplines, is compliant with the sustainability goals of the university. Perhaps more important than establishing a sustainable campus, TU Delft intends to deliver graduates, young doctors and post-graduates who can contribute to a sustainable world outside the campus. It is therefore paramount to offer sufficient courses that feed these new generations with essential knowledge, required to tackle the societal challenges humankind faces at present.

TU Delft defined Education for sustainability as follows:

> ***Education for sustainability*** *develops the knowledge, skills, ethical values, world views and sense of responsibility necessary for students to act in ways that contribute to a more sustainable world and more sustainable patterns of living. It enables individuals and communities to reflect on ways of interpreting and engaging with the world. Education for sustainability is future-oriented, focussing on protecting environments and creating a more ecologically and socially just world through informed action. Such actions require systems thinking with consideration of environmental, social, cultural and economic aspects, as well as their interdependence. Following this definition means that our graduates are able to critically evaluate the impact of engineering solutions on these systems, regarding sustainability in its entirety. A TU Delft graduate is therefore competent to implement their gained skills and knowledge into their engineering practices and subsequently contribute to climate action.*

With the world changing rapidly, having to adapt the education system accordingly seems inevitable. We acknowledge how challenging it is to change curricula, especially those that have been more or less the same for decades. It is believed though that a focus on sustainability should be implemented within all courses, alongside a few specialised courses that dig deep into (new) essential knowledge. The professors and lecturers of any given course play a key role in the adoption of sustainability as a fundamental aspect of their teachings. Yet we can only appeal to the responsibilities that go along with this role when professors and lecturers are aware and properly informed. Keeping this and the limited time and resources in mind, below we mention a few proposals on how to integrate sustainability in the curricula.

04.04 Specific projects, pilots and actions

Society has immense challenges regarding various issues, amongst which climate change, availability of resources and other aspects of sustainability. To tackle these issues, not enough skilled people and resources are available. In some cases, existing BSc and MSc programmes can address certain issues (e.g. sea level rise at the faculty of Civil Engineering & Geosciences). In some cases, however, new cross faculty programmes will be needed to educate engineers who can take up challenges such as energy transition, climate adaptation, circular construction and nature-inclusive development.

Roadmap for Sustainability Education

In order to ensure that sustainability is implemented in all educational layers, the Roadmap for Sustainability Education must be elaborated and perfected. The roadmap itself focusses on three layers: Fundamentals of Sustainability, Discipline-Specific Sustainability and Interdisciplinary Sustainability Knowledge.

Fundamentals of Sustainability
The first layer makes sure that students understand the general concept of sustainability and gain knowledge on how to deal with broad topics such as sustainability and climate action. There are several ways to achieve this, among which the Blue Engineering programme of TU Berlin (which is currently run by Martine Rutten at the faculty of Civil Engineering & Geosciences) and the Engineering for One Planet (EOP) framework, set up by five academic institutions in the US. Both approaches are proposed as adequate guidelines to develop courses or course material with a focus on systems thinking and other relevant skills that can be introduced into the curricula.

Discipline-Specific Sustainability
The second layer ensures that specific sustainability topics and themes are covered per bachelor and master programme, so that all students understand the relationship between their study/work field and sustainability or climate action.

Interdisciplinary Sustainability Knowledge
The final layer deals with providing sustainability-focussed integrative and inter-faculty educational courses such as minors, MSc, honours programs and graduation studios. Joint Interdisciplinary Projects (JIPs) fall into this third layer and are used to give students the opportunity to work on a business case, related to making the university, city or region sustainable.

As also mentioned before, following the roadmap, prior to integrating sustainability into education, a person will be appointed to study sustainability education needs and to identify the current gaps in sustainability education and opportunities for sustainability education at the university. As a second step, this researcher should develop a 'teach the teacher' module for incorporating sustainability education, based on best practices at TU Delft and other universities. In addition, to quantify the roadmap, a tool will be developed in collaboration with the GreenTeams to grade current master and bachelor programs by sustainability. In the future, this rubric will be used in midterm reviews and other official course evaluations.

The Green Thread: sustainability woven into BSc and MSc programmes

Sustainability must be included in the bachelor and master programmes from all faculties. The Green Thread Initiative of GreenTU can help to achieve this. With this initiative, horizontal integration of sustainability is proposed for all curricula of TU Delft. Horizontal integration refers to the introduction of an educational theme throughout all courses, granting the opportunity to include immensely complex topics such as sustainability, without cramming the curricula. In line with the aforementioned roadmap, students will then gain relevant knowledge on the fundamentals, as well as discipline-specific topics of sustainability.

Faculty-specific action
GreenTU proposes that the faculty-specific GreenTeams identify enthusiastic professors and lecturers and, consequently, collaborate with a student assistant to aid these staff members with the process of implementing sustainability and climate action into their courses. The Green Thread is based upon the value of student (and teacher) participation, aiming to empower students, offer diverse perspectives on sustainability, and reduce staff workload.

Teacher community
At the moment most of the GreenTeams use the method of the Green Thread and this will eventually be applied at all faculties. When deemed necessary, GreenTU is going to collaborate with the Teaching Academy to set up a teacher community for those who have participated or are going to participate in the Green Thread. This could help centralise communication, improve education and generate momentum.

Other actions

New minors
Every faculty offers at least one minor that has a relation to sustainability. An LDE minor on sustainability is on its way. Further improvement is possible, for instance with the Green Thread initiative, just as for the bachelor and master programmes.

Joint Interdisciplinary Projects
Another option to implement sustainability better is in the Joint Interdisciplinary Projects (JIPs). A JIP is an interdisciplinary project between all 8 faculties, and in the future between multiple universities, where students and companies work on a business case to create an innovative impact. Currently, the business cases come solely from companies but this can also come from the university itself. The students can use actions and projects mentioned in the specialised theme chapters, as their business case. They can then conduct research into a current theme and contribute to their own learning environment.

Honours programme
With the honours programme, students can decide to broaden their horizon or do an in-depth study. Within this programme, students should also be given the opportunity to delve into sustainability issues related to their studies. A 15-EC specialisation on sustainability is planned.

PhDs and PDEngs
Most urgently, in order to respond to the current demand already, more sustainability courses need to be offered in the Doctoral Education programme. This should be discussed with the Graduate School.

Online education
Some faculties already offer multiple MOOCs focussing on sustainability. However, the share of sustainable MOOCs at other faculties is very low or close to none. For each faculty

and research area, it must be examined whether there are relevant sustainable subjects for which a MOOC can be developed.

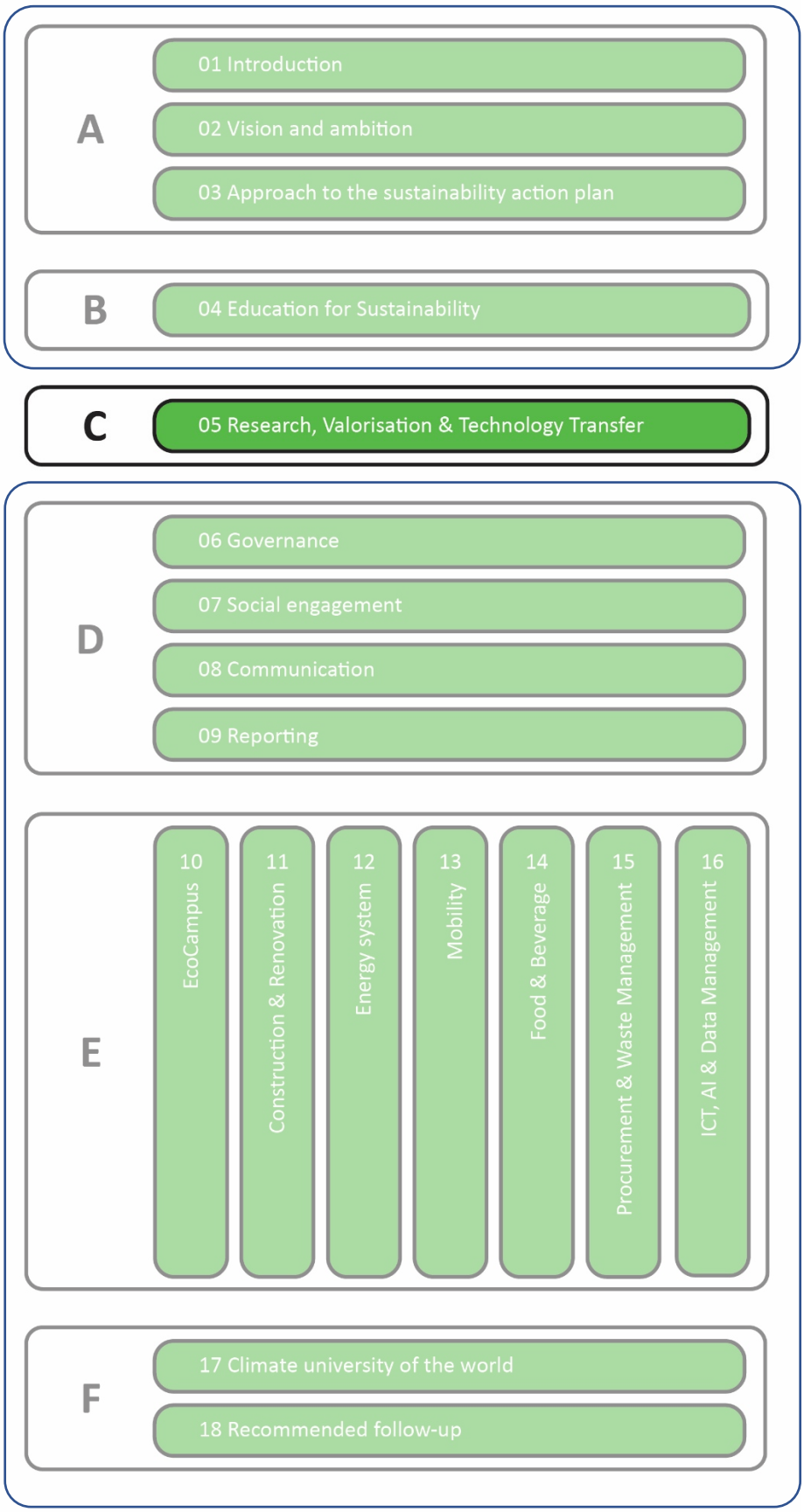
Extra activities

Beside implementing sustainability into the curricula, the university also offers the possibility to learn about sustainability outside the standard programme, such as a variety of lunch lectures organised by GreenTU and/or the GreenTeams about different topics related to sustainability. They also offer the possibility to work with them on several business cases. For example, in their current collaboration with GOM, a case on minimising the use of trash bags on the campus was presented. These extracurricular activities give students the opportunity to familiarise themselves with the skills and thinking processes required for tackling sustainability-related problems. Furthermore, it can inspire the students and illustrate how tangible and perhaps profitable sustainability-related topics are in their future work field.

TU Delft

PART C

RESEARCH, VALORISATION & TECHNOLOGY TRANSFER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05 Research, Valorisation & Technology Transfer

Team (in alphabetical order)

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- Anne-Lize Hoftijzer – I&IC
- Linda Kamp – TPM sustainability coordinator
- Martine Klijn – I&IC/TU Delft Campus
- Hubert Linssen – CRE sustainability coordinator
- Anne van de Poel – SD
- Herman Russchenberg – CEG/Climate Action Programme
- Pieter de Wit – F

Research, Valorisation & Technology Transfer
Main proposals

General aims and principles

- To include sustainability strongly in the **research profile** of TU Delft
- To develop interdisciplinary research related to all UN **Sustainable Development Goals**
- To integrate sustainability research with **education, campus and community**
- To **communicate** about sustainability research both within and outside TU Delft
- To create a strong **research community** focussing on sustainability-related research
- To implement **living labs** related to innovative sustainability research projects

To be investigated

- Defining what can be considered **sustainability research** and what not
- Making an **inventory** of all current sustainability-related research
- Developing a broad **interdisciplinary research agenda** involving all faculties

Projects, pilots and actions

- **Connecting** the sustainability research topics with student projects
- Explicitly including the **campus as a living lab** in the research agenda
- **Communicating** sustainability research via newsletters, website and (social) media
- Sustainability-focussed **seminars** for researchers, students and PhD students

This chapter describes the desired future situation and looks into the present state of research related to sustainability at TU Delft. Subsequently, specific actions, pilots and projects are proposed to reach this desired goal.

05.01 Desired future situation

In the near future, TU Delft will have established a strong research profile regarding sustainability, related to all United Nations (UN) Sustainable Development Goals (SDGs). This research is strongly integrated with education on sustainability and climate action, the sustainable campus and social engagement. The focus on sustainability in research and the results of this research are clearly communicated to both the TU Delft research and student community and the outside world.
The university plays a leading role nationally and internationally in valorisation, especially in technology transfer. TU Delft delivers ground-breaking scientific, technical, design solutions that contribute to a better society. The university facilitates multiple start-ups, consortia, field labs, entrepreneurships in education and partnerships with governments and other knowledge institutions which are key to accelerating (sustainable) innovation. This is all coordinated by the TU Delft Innovation & Impact Centre (I&IC), which has sustainability as one of its core themes.
The university has set up an incubator organisation or foundation to switch quickly between shareholders and stakeholders. In addition, the university applies for green loans for sustainable, innovative investments from sustainable banks. The banks are seen as partners in the campus transition.

05.02 Research at present

Performance

TU Delft's ambitions are closely aligned with the Sustainable Development Goals (SDGs) of the UN and has a strong research position related to six of them, shown in figure 05.01: Affordable and Clean Energy, Clean Water and Sanitation, Sustainable Cities and Communities, Climate Action, Industry, Innovations and Infrastructure, Responsible Consumption and Production. Good Health and Well-being should be added to these.

Overarching research programmes

TU Delft research is clustered into four Delft Research-based Initiatives (DRIs), which are also closely linked to SDGs. Within these DRIs a number of research institutes are positioned, such as the Wind Energy Institute, the Urban Energy Institute and the TU Delft Climate Institute. In 2021, TU Delft started the Climate Action Research Programme.

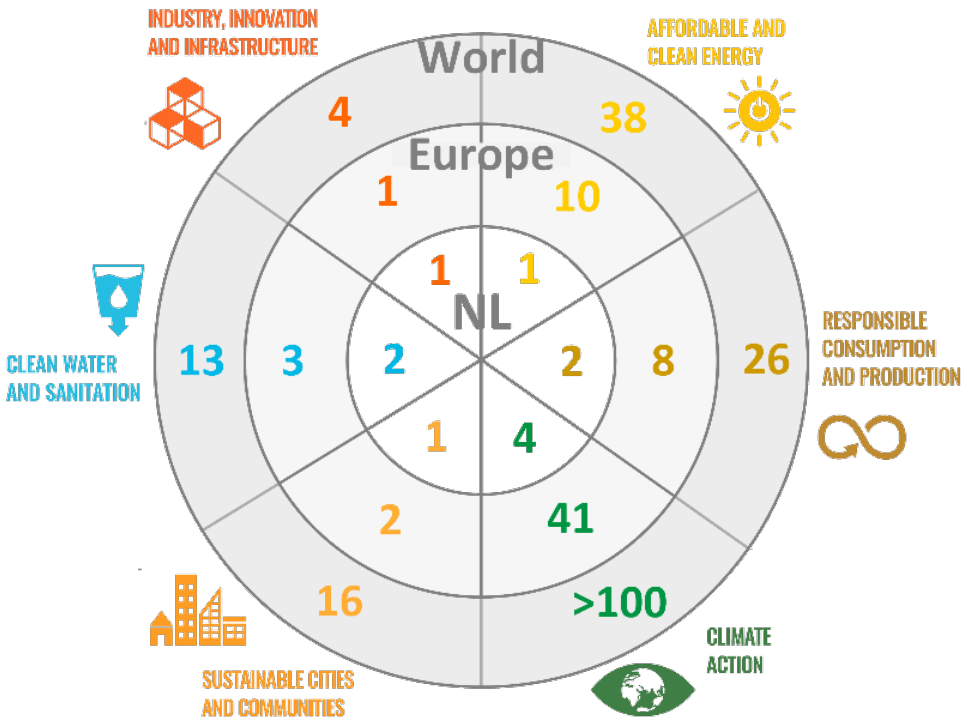


Figure 05.01: Position TU Delft in Elsevier ranking most active academic institutions based on numbers of publications (2014-2019) in defined SDG areas.

Delft Research-based Initiatives

The DRIs were developed to contribute to solving problems society is facing, catalysing collaboration and debate between scientists and students and between TU Delft and businesses, government agencies and politicians. The main aim of these DRIs therefore is to solve societal problems in multidisciplinary cooperation and in partnership with governments and other research organisations such as 4TU and other (IDEA League) universities. There are four DRIs: Delft Health Initiative (DHI), Delft Global Initiative (DGI), Delft Deltas, Infrastructure and Mobility Initiative (DIMI), and Delft Energy Initiative (DEI). The DEI has 4 main pillars: The Wind Energy Institute, Urban Energy Institute, PowerWeb Institute and the e-Refinery Institute.

TU Delft Climate Institute

The TU Delft Climate Institute was initiated to bring together the expertise from researchers focussing on climate. The five research themes of the Climate Institute are: Urban Climate, Radiation Balance, Ice & Sea Level Change, Water Cycle, and Geo-engineering.

Climate Action Programme

The Climate Action Programme is a university-wide programme, focussing on four themes: Climate Science, Climate Change Mitigation, Climate Change Adaptation, and Climate Change Governance, with AI as an overlapping theme. Eight initial research projects have been identified in the Programme, with contributing researchers from the different TU Delft

faculties. The goal is a climate-resilient world. The programme supports the transition to non-fossil resources and helps the environment to adapt to the effects of global warming.

Dreamteams and Spin-offs

Beside these research groups, TU Delft supports students to join a Dreamteam or to initiate a start-up company after their study.

Dreamteams

The Dreamteams are student teams that design innovative sustainable technical systems and represent TU Delft at national and international competitions. Examples are Delft Hyperloop, The Brunel Solar Team and the Solar Boat Team.

Spin-offs

A number of Cleantech spin-offs have originated from TU Delft. Examples are Kitepower, which works on high altitude wind power systems, and Physee, which develops sustainable building facades.

Innovation & Impact Centre

Based on the conviction that collaborations with multiple parties are the key to accelerating innovation, the TU Delft Innovation & Impact Centre (I&IC) coordinates the facilitation of start-ups, entrepreneurship education, setting up research consortia, the development of the innovation ecosystem around TU Delft and numerous partnerships with the business community, governments and other knowledge institutions.

The Green Village and VPdelta

Sustainability is an important theme in this regard. For example, Climate & Energy is one of the focus themes within the organisation. In recent years, the I&IC has set up various field labs and innovation clusters that focus on sustainability, such as The Green Village, the testing ground for sustainable innovations, and the Delta Technology & Water (VPdelta) valorisation programme.

Sustainable entrepreneurs

The I&IC plays an important role in setting up public-private partnerships around sustainability. There is also a lot of attention for stimulating sustainable entrepreneurship. The portfolio of Delft Enterprises, which invests in university spin-offs on behalf of TU Delft, includes several start-ups that focus on sustainability. In addition, TU Delft is a global partner of Climate Launchpad: the world's largest green business ideas competition.

05.03 Impact for a better society

More than ever, a strong sustainability profile is needed in the research done at TU Delft. The start of the Climate Action Programme, with serious financial support from the Executive Board, will help to bring a stronger focus on climate-related research, a desire

expressed by the Rector Magnificus to make TU Delft a climate university. TU Delft's motto 'Impact for a better society' is a vow that may be considered in a broad sense, but the greatest societal challenge arguably is climate change and the ecological crisis affiliated with it. TU Delft can create impact by contributing to new knowledge, methods, processes, concepts, technology, products and designs that help to avoid a crisis resulting from runaway climate change.

Living labs

The living labs proposed in this report will help to test concepts that are not mature enough to be applied in society, but that are close to being there. Using the campus as one large laboratory is expected to speed up the experimentation, evaluation and implementation of new solutions that contribute to the sustainable development goals. Links to public organisations and private companies are needed to take the step to disseminate results in the market.

Start-ups, spin-offs, spin-outs

The success of research can be directly measured not only by the knowledge, methods, processes, concepts, technology, products and designs developed on the campus, but also by the start-ups, spin-offs and spin-outs based on these innovations. Therefore, TU Delft should remain closely linked and create even further the right conditions for companies that can bring sustainability knowledge to the market and – even more importantly – to society. This is one of the aims of I&IC. In addition, the university itself also works closely together with the start-ups, spin-offs and spin-outs to test and apply their innovations on campus.

05.04 Specific projects, pilots and actions

Although TU Delft already has a number of sustainability-related research programmes, initiatives and institutes and ranks high in terms of research related to six UN SDGs, more can be achieved. This is reflected in the actions needed to achieve the future vision for research related to sustainability.
An interdisciplinary research agenda needs to be developed with research topics related to all UN SDGs in which researchers are involved from all faculties. Part of this research should be done in cooperation with governments, corporations and other research organisations. This research agenda and the outcomes of this research should be communicated clearly to both the TU Delft community and to the outside world, e.g. via online newsletters, the TU Delft website and (social) media.

For the creation of a strong research community focussing on sustainability-related research across the different sustainability-related research initiatives, programmes and institutes, the above-mentioned communication channels can also play a role. Besides, seminars can be organised for researchers working on different sustainability related topics. Also, students should be able to attend these seminars and contribute in the discussions. Part of the research should explicitly focus on aspects of the sustainable TU Delft campus, which

will then play the role of living lab. Here, The Green Village can also play a role. In this way, all aspects of the TU Delft sustainability transition will be tied together: research, education, community and the campus.

Starting the team

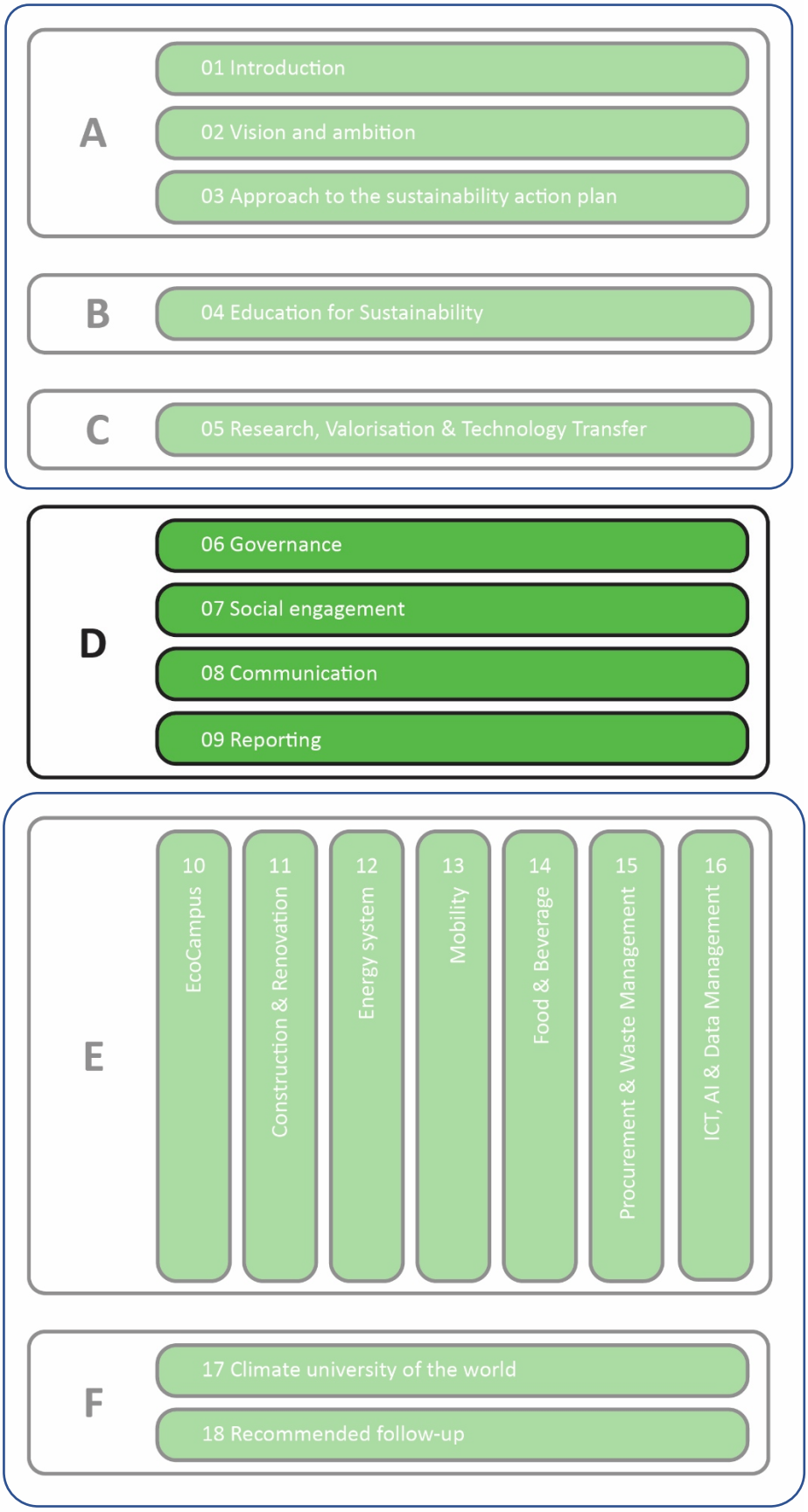
The theme of Research, Valorisation & Technology Transfer gets limited attention in this report, partly because we could hardly do right to the scale of sustainability research at TU Delft and partly because the Climate Action Programme (CAP) is working on an elaborate research programme.

Regarding the many programmes and projects already in place, introducing a new scheme is only relevant for what is happening on the campus, at The Green Village and in the living labs that will be started. From this moment on, the realisation of these projects, pilots and living labs on the campus requires a team that focusses on the policy, specification, valorisation and funding of these projects. Therefore, the Research, Valorisation & Technology Transfer team came together for the first time on the 23rd of November 2021. This team will also support the research agenda of the Climate Action Programme, especially in regard to projects on the campus.

TU Delft

PART D

COMMUNITY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06 Governance

Core team (in alphabetical order)

- Abel van Beest – GreenTU
- Stijn van Boxmeer – CEG, GreenTeam coordinator
- Thomas Burdyny – AS, GreenTeam coordinator
- Andy van den Dobbelsteen – TU Delft sustainability coordinator
- Irene Fernandez Villegas – AE sustainability coordinator
- Deirdre van Gameren – TU Delft sustainability researcher
- Yumiko Henneberry – IDE sustainability coordinator
- Loes van Hove – EEMCS, GreenTeam coordinator
- Linda Kamp – TPM sustainability coordinator
- Marjan Kreijns – I&IC/The Green Village
- Hubert Linssen – CRE sustainability coordinator
- Jordi van Opzeeland – SD
- Herman Russchenberg - Pro Vice Rector Magnificus for Climate Action
- Inge Snijder – Com
- Regine Vroom – 3mE, GreenTeam coordinator
- Pieter de Wit – F

Governance

Main proposals

General aims and principles

- To create a **solid foundation** that supports sustainability automatically
- To **embed sustainability** in each part of the organisation
- To use **backcasting** as a general approach for developments

To be investigated

- **Governance & policy review** from the perspective of a sustainable campus
- Implementing **total cost of ownership (TCO)** in all financial decisions
- Using a **carbon price of € 150** per tonne of CO_2-eq in financial systems and decisions
- Creating a **Sustainability Fund**, to be filled with internal carbon taxes
- Revealing **current research initiatives and living labs** already in place
- Defining a **living lab methodology** for campus projects

Projects, pilots and actions

- Sustainability budget for **living labs** and for **test pilots and projects**
- TCO pilot with a **big investment scheme** (Kluyver area)
- Carbon pricing pilot in new **construction** project (Kluyver area)
- Carbon pricing pilot in the **geothermal heat** project
- Carbon pricing pilot in new **supplier contract**
- Carbon pricing pilot in **waste management**
- Carbon pricing and nitrogen pilot in **campus greening** project
- True pricing pilot in one or more **faculty restaurants**
- **Circular contracting** pilot

Underlying or overarching all actions, pilots and projects proposed in this sustainability action plan are some structural changes to governance that form the foundation of a sustainable community. These refer to topics dealt within the core team.

06.01 Desired future situation

In the near future, TU Delft will have become an entirely sustainable organisation, an example for other universities, public institutions and cities, not only by the measures implemented on the campus and the resulting carbon footprint and circular performance, but also in the way the university is organised. TU Delft is governed with financial and regulative incentives (TCO as the basis, carbon pricing, circular contracting) that steer processes on the campus towards sustainability automatically. The mindset of people working and studying at TU Delft is focussed on contributing to a better world and everyone understands that in order to do so, they have to organise things themselves in the right way wherever they have an influence, starting at home and on the campus.

Education, research, operations on the campus are compliant with TU Delft's sustainability ambitions and societal function, and there is no more money leaking to unsustainable goals perpendicular to the university's efforts, as once was the case with staff's pension money. TU Delft has organised its governance in such a way that the university contributes actively and passively to the establishment of a sustainable world. When asked 'what have you done for our future', everyone can confidently respond that all has been done to create a better world.

The new governance has brought about an enormous human energy and creativity among the TU Delft community. It is a great and inspiring place to be, and the many students, PhD candidates and guest researchers line up to spend some years with the world's most sustainable university.

06.02 Organisation at present

TU Delft is a public benefit institution whose main task is to provide scientific education, conduct scientific research, transfer knowledge to society and promote social responsibility. Figure 06.01 shows the organisational units at the university. In order to become the world's climate university, as desired, sustainability needs to be intrinsically embedded in all parts of this organisation.

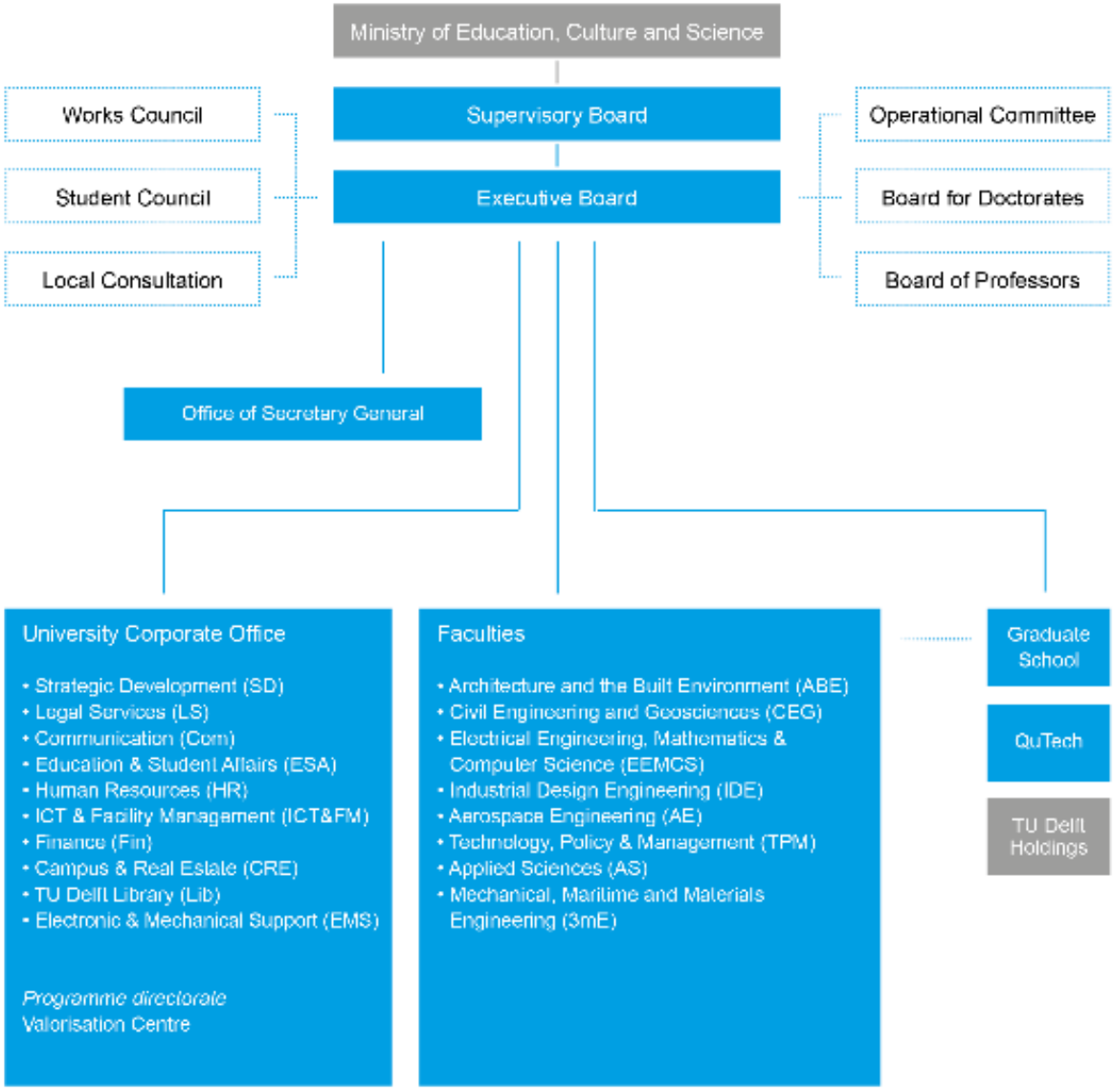


Figure 06.01: Organogram of TU Delft

The TU Delft Campus

Sustainability also needs to be integrated into every part of the campus. TU Delft Campus is larger than the inner city of Delft, stretching over 161 hectares. Almost 35,000 TU Delft students, scientists and employees, as well as visitors and external companies travel across the campus daily.

The campus is a rare place where education, research, business and government can find each other. It does not consist of university buildings alone: it also contains buildings of external companies. There are more than 250 national and international companies settled at the TU Delft Campus. Since they are part of the community, this group are also included in the sustainable vision, ambition and action plan.

06.03 New principles

Comprehensive sustainability governance

With not much time left, everything decided on should be measured against impact, and with the contribution to TU Delft's sustainability targets. Therefore, backcasting needs to become a generic approach to new plans and to decisions on investments.

Sustainability targets to all levels

In order to embed sustainability in the organisation, sustainable targets should be translated in a concrete manner in yearly agreements made with faculties and supporting divisions, and thereby in yearly plans of these bodies. This can simply be comparable to the financial targets of faculties, departments and chairs at present, but then including targets of carbon emission reductions, extent of circularity and health-related parameters. With the sustainability dashboard, these goals can be made visible via screens in every faculty and division buildings. All parts of the organisation should define certain Key Performance Indicators (KPIs). These KPIs provide targets to reach for and give insight that helps with making better decisions. By using these KPIs, impact can be defined and measured.

Especially the management level

The challenging sustainability ambitions require a strong adoption in the layers of management, including the workflow on decisions, indicators and critical reflection. Managers must see it as their task to guide TU Delft's transfer towards 2030. This means that annual plans, individual projects and evaluations should all be contributing to this transition and be challenging to employees to run that extra mile. Sustainability and climate action should be a standard discussion point on the agenda of boards and management teams. In order to support the sense of urgency, someone should be appointed responsible for the implementation and control of sustainability goals, in management, business control, design & build teams, etc.

Decision processes

Furthermore, there is a need for transition in decision processes, the criteria used and the securing of a holistic approach. This extends to the inclusion of sustainability in the TU Delft Strategy 2022-2024 and beyond, and to scenarios selected for multi-annual investment plans. Modest scenarios have become pointless with TU Delft's sustainability ambitions. It is therefore important to adjust these instruments of governance to the new objectives.
To be investigated: whether BVMs (decision preparation models) can have a sustainability paragraph, to be assessed and advised on by the sustainability coordinator or by a sustainability committee deployed for important decisions and reviews.

Financial room for living labs and pilots

Since TU Delft takes climate action seriously, and not all directions or solutions are 100% clear yet, there should be budget to test things. This can refer to living labs, for which an innovation budget will be created.

Total cost of ownership
In order to support sustainable decisions, suited financial assessment and control tools are also necessary. Perhaps the most important change in financial attitude can be achieved by the introduction of TCO (total cost of ownership), taking a long-term perspective on financial decisions. The difference with traditional financial decisions is not just the term, but also the inclusion of exploitation costs and benefits, as well as consideration of the residual value of a building or product and its materials. To be investigated: whether energy savings realised by investments can be put in a revolving fund.

TCO_2
Interestingly, with TCO, the capitalisation of environmental impact is also possible. This can be done by means of environmental costs or the introduction of an internal carbon tax, which is what we propose. TCO then becomes TCO_2. The value thereof is determined below.

An internal carbon tax

So long as it is not officially installed in the Dutch or European economic system, TU Delft can include its own carbon tax to support sustainable decisions in great investment schemes (new buildings, contracts, programmes) but also in every-day business of faculty budgets, choice of travel modes and the price of food.
The university will not be the first organisation implementing this system. The World Bank Group [2020] states that in 2019, 915 companies were planning to use internal carbon pricing in their organisation and 699 companies were already using it. Most companies use internal carbon pricing to stimulate low-carbon investments, energy efficiency and sustainable behaviour. In addition, the internal carbon price is used to identify low-carbon opportunities. The height of the internal carbon price differs per company, from US$ 1/tCO_2e to US$ 906/tCO_2e.
The internal carbon fee can be used as shadow price, as internal carbon fee or trading system, or in combination with purchasing offsets. The last option uses the fee to raise funds internally. Companies that already use an internal carbon price to become net zero or carbon negative are Microsoft, Infosys, Nedbank limited and La Poste. Beside these companies, there are also already some universities that use an internal carbon price such as Yale (carbon neutral 2050), Swarthmore College (carbon neutral 2035) and Arizona State University (carbon neutral 2025).

Part of the financial system
The main goal is to use a carbon tax to activate and motivate people towards sustainable decisions and behaviour. In order to do so, carbon pricing should become part of the financial cycle, linked to budgets. It can be used in a ‘negative’ way, paying for environmental damage caused by the decision, but the flipside is that this money can then be invested in ‘positive’ initiatives and projects that imply a reduction of carbon emissions or environmental load. Reduction of space use can also lead to positive carbon budget (after all, fewer square metres mean less energy use) to be used for other targets, for instance energy renovations or sustainable education.

The inclusion of carbon taxing in the financial system needs to be further studied by a working committee, in order for it to be effective in what it is meant to achieve.

€ 150/tonne of CO_2-eq
We propose to start working with a carbon price at € 150 per tonne of CO_2-equivalent and to use this value for an internal carbon tax at TU Delft. The reasoning for the value of a tonne of carbon is explained in Appendix A.

To be investigated: the ways that TU Delft can apply its internal carbon tax:
- Building projects: using TCO_2, comparing alternatives and competing designs by energy, water, material use and the carbon embodied therein.
- Energy system: using TCO_2, assess all decisions on the basis of long-term perspectives, with the carbon tax included.
- Procurement: using TCO_2, choosing the supplier with the lowest combined price of 'real' costs and carbon tax.
- Food: adjusting the price of food (bonus/malus) based on the carbon impact, hence the carbon tax imposed.
- Deliverables towards carbon neutrality: define carbon budgets for organisational units in tiered levels between 2021 and 2030.
- Personal carbon budgets: see below.

To be investigated: personal carbon budgets (#myCO_2)

To create more awareness about carbon emissions and their relation with our daily behaviour, it is recommended that TU Delft investigate the option of personal carbon budgets: a maximum CO_2 emission budget per person per year.
The personal carbon budget can be arranged per faculty or supporting division and per employee or student. Organisational units and people can spend this budget the way they want to. For instance: person A prefers to take the car to work but then compensates this by eating vegan, while person B takes the train but likes to eat animal products for lunch. It is still a theoretical exercise, because issues of measurability and privacy are involved. Most probably a personal carbon budget cannot be enforced onto people as a restrictive measure, but providing insight into personal carbon emissions can help to change behaviour and support conscientious decisions.
By doing this, people will get insight into their private (albeit TU Delft-related) carbon emissions and learn how actions relate to one another.

Determination of the carbon budget
The carbon emission budgets can be based on a decreasing, incremental scale towards carbon neutrality, assuming that a certain quantity of carbon emissions will not be avoided on campus but compensated elsewhere, also in the year 2030. This will be discussed in chapter 17. The share of unavoidable carbon emissions could be the basis for annual 'carbon allowances' per organisational unit or person. In the course towards net zero carbon, the value thereof will decrease from around 80,000 tons in total in the year 2020, to the

unavoidable, compensated quantity in 2030, divided by the total number of fte on campus. The determination of carbon budgets requires additional research.

06.04 Specific projects, pilots and actions

Implementation of sustainability in management

In order to implement sustainability in every-day practice some structural change is needed in the organisation and management of TU Delft and its faculties and supporting divisions.

Local sustainability coordinators

Each faculty or supporting division has been asked to appoint or assign someone with the task to secure the embedding of sustainability in their organisation. These local sustainability coordinators should develop a faculty- and division-specific sustainability plan that correlates to this campus-wide action plan. In addition, the faculty-specific GreenTeams, that work on making the faculty sustainable bottom-up, should collaborate with the local sustainability coordinator and with the faculty management to coordinate all actions and initiatives and to form one team. It is recommended that sustainability coordinators are included in the MT of faculties and supporting divisions.

Central sustainability coordinator

The TU Delft sustainability coordinator has been given an annual budget for communication and small pilots and projects on the campus.
To be investigated: whether the TU Delft sustainability coordinator can be included in the Groepsraad, along with the Executive Board, deans, directors and vice-rectors.

Financial proposals and pilots

TCO_2 pilots

In order to get used to the new method, a few TCO_2 pilots are recommended, preferably with a large investment scheme, for which the Kluyver area development seems a good case. A research subsidy has been allocated to examine circular aspects of the Kluyver area, covered in the TCO_2 (together with partners such as ASR or ABN AMRO and Erasmus University).
Another interesting case for TCO_2 is the operational lease of building components as compared to the common purchase, maintenance and replacement of components by TU Delft itself. The residual value of materials, logistics/market place for materials on regional level.
The pilots regarding TCO_2 should be linked to the Climate Action Plan (CAP) led by Professor Herman Russchenberg. One of the flagship programmes from CAP is ‘Climate Finance’. This TCO_2 pilot would greatly fit within that programme. Within the Climate Finance flagship, the university can test this pilot as a combination of TCO and carbon tax. The outcome of this pilot would be of great importance for the university and the industry.

Carbon pricing pilots
With the carbon price of € 150/tonne CO_2-eq, TU Delft can start several carbon pricing pilots:

- The new construction projects of the Kluyver area
- The geothermal heat project
- A new supplier contract
- Waste management
- Faculty restaurants: raised prices for food that has a great carbon emission and reduced prices with environmentally sound food
- Carbon pricing and nitrogen pilot in the campus greening project

To be investigated: Sustainability Fund
The internal carbon tax needs to go somewhere. It could stay within the respective management unit, or flow into a central Sustainability Fund. This fund could be used to support sustainable initiatives, or to fund sustainable student travel. This needs to be investigated further and tested on campus.

07 Social Engagement

Team (in alphabetical order)

- Katharina Biely - TPM
- Fatima Boutoutouh – Com
- Samantha Copeland – TPM
- Andy van den Dobbelsteen – TU Delft sustainability coordinator
- Machiel van Dorst – ABE
- Deirdre van Gameren – TU Delft sustainability researcher
- Loes van Hove – EEMCS
- Naomi Hubert - GreenTU
- David Keyson – IDE
- Martine Klijn – I&IC/TU Delft Campus
- Jotte de Koning – IDE
- Ruth Mugge – IDE
- Abby Onencan – IDE
- Nika den Ouden - GreenTU
- Sven Pfeiffer - AE
- Gerdien de Vries – TPM, Energy Transition Lab

Social Engagement
Main proposals

General aims and principles

- To create a **resilient community** on campus, focussing on diversity and inclusiveness
- To involve **all students, staff, external companies and visitors** using the campus
- To use **different strategies and media** for different target groups
- To **change the usual way** of thinking and standards
- To stimulate **sustainable behaviour**
- To give more floor to **motivated people** (frontrunners)
- To **take away barriers** for sustainable choices
- To **communicate** actively about sustainability, the goals and steps

To be investigated

- **Preferences and ambitions** of the TU Delft community in regards to sustainability
- **Barriers** towards more sustainable behaviour
- Determining the **carbon emission budget** per person, faculty or supporting division
- Creating **guidelines** for sustainability on campus and at home
- Introducing **apps** that stimulate sustainable behaviour
- Implementing a **reward system** for sustainable behaviour
- Implementing **sustainability awards**, e.g. for student projects, suppliers and staff
- Developing **green gifts**, such as TU Delft tiles and miniature faculty buildings

Projects, pilots and actions

- Getting the **new sustainability policy and projects** started in September 2022
- Providing **open and earnest information** about sustainability features and processes
- Using the **sustainability website** to engage the community
- Using **displays and posters** in the buildings to engage the community
- Using the **EcoCampus** projects to create awareness about sustainability
- Presenting and discussing **sustainability reports, documents and handbooks**
- Organising **workshops, lectures, debates, shark tanks and hackathons**
- Introducing a sustainable futures **philosophy café**

Everyone working, researching and studying at TU Delft must understand the importance of becoming a sustainable university, acknowledge his or her responsibility, and feel that they can contribute. A top-down and bottom-up approach is needed to achieve this. Multiple projects, actions, and events are proposed in this document to engage students, employees, and external companies to become more sustainable. Beside these actions, this chapter gives an overview of the TU Delft Campus community at present, defines the target group, and outlines an approach.

07.01 Desired future situation

The future campus community is a resilient community, which focusses on diversity and inclusiveness, bridging between people on campus through sustainability. Togetherness is a key term: we have to innovate together, no one can do this on their own. The 'Impact for a better society' strategy of TU Delft will have been realised by strengthening the campus community. TU Delft, as a sustainable community and as a sustainable campus, sets an example for people within its organisation but also for people outside. The university is known as the leading university with climate action and sustainability implementation in all its actions and projects.

The first big step was taken in September 2021, when the previous draft of this document was communicated with the whole community. When the community returned to campus after the corona crisis, the new policy was picked up and accepted relatively easily. Guidelines were set in place that made it easier to reject unsustainable practices, and sustainability was included in TU Delft's code of conduct, acknowledged by the community.

By approaching each target group with a bespoke plan, the entire community has now become aware of the impact of their actions on sustainability. Employees and students have their own personal carbon emission budgets. Within these boundaries, they can decide what to spend it on, e.g. travel, food, equipment. The community of TU Delft knows that they work for a sustainable organisation, have therefore consciously chosen the university, and have the same conscientious, innovative mentality. The entire community is motivated and stimulated to share their ideas for further improvement. A yearly 'shark tank' is organised to centralise this. Students can win awards with their assignments, design studios and projects, in order to stimulate continuous innovation and sustainable development in the study domains. People who live and work on or near the campus are regularly involved in small-scale living labs that give them opportunities to engage with new ideas and to improvise and innovate along with researchers.

The university actively shows and communicates research conducted on campus, in regards to sustainability in particular, the steps taken and lessons learnt. The entire community is informed by using multiple media platforms, some of them interactive. Information is also actively shared in the buildings through information screens and posters.

The entire community at TU Delft subscribes to the sustainability goals of TU Delft and behaves accordingly. Mistakes from the past, such as the squandering of energy in buildings after closing time, disposables, short service lives of equipment and fossil-fuelled transport have vanished and led to a more lively and liveable campus.

The university and its community together have ensured that TU Delft has become the most sustainable university in the world.

07.02 The campus community at present

Target groups

In this vision, ambition and action document, we involve everyone who works or studies on the campus, including external companies. This results in the following target groups:

- Management
- Supporting staff
- Scientific staff
- Tenure trackers
- PhD students and postdocs
- BSc and MSc students
- Spin-offs, start-ups and scale-ups (e.g. YES!Delft, NextDelft)
- Fieldlabs and other knowledge institutes
- External companies on campus (e.g. ASR, Firma van Buiten, 3M, TNO, etc.)
- Visitors of the campus, the global science community
- Global society (how do they perceive TU Delft and the campus?)

From oblivious to pro-active

Next to the difference between these target groups, a distinction can be made within a specific target group. People can be placed on a scale ranging from active involvement in sustainable development to absence of any interest therein. Therefore, different strategies must be drawn up to stimulate each target group. This may include raising awareness, creating incentives, nudging and enforcement. Research must be done into preferences and ambitions of the TU Delft community and into the barriers towards more sustainable behaviour: who is not interested and why?

Ongoing engagement plans and activities

The culture at TU Delft needs to change – and will change – when TU Delft wants to become a sustainable university. As expressed by Tim van der Hagen, Rector Magnificus, TU Delft wants to position itself as the world's climate university. Therefore, sustainable development should be part of the new culture and campus.

Faculty involvement

The university works effectively by deploying the university's faculties to the themes of their discipline. For instance, Aerospace Engineering is primarily engaged with sustainable air

travel; Civil Engineering & Geosciences is involved with ecological water systems on campus; Architecture & the Built Environment is included in renovation and construction projects. The same principle applies to all other faculties.

Ecosystem
The TU Delft Campus organisation, led by Anne-Lize Hoftijzer, works on developing a vibrant ecosystem with various partners willing to invest, collaborate, create and innovate. They are in contact with the companies located on the campus and other knowledge institutes and communities. This group of external partners must also be included and can help with reaching the sustainability goals.

Quality team
There is a quality team for the long-term vision for the campus, with Machiel van Dorst, Iris van der Wal and Jacques Vink. Paul Althuis (I&IC), Joost Ravoo (Com), Jaco van Noppen (CRE&FM) and Alexandra den Heijer (ABE) are also involved in this.
Some studies were already done on creating a more coherent community on campus, for instance by Machiel van Dorst and Shaida Freese.

Strategic group on social cohesion
At present, there are some plans and activities focussing on the social implementation of sustainability on campus. The strategic group on social cohesion, chaired by Dick van Gameren, together with Machiel van Dorst, David Keyson and Jordi van Opzeeland, is looking at the different social structures and investigates the 'shared culture' of TU Delft. At the moment this is not yet well described. Fatima Boutoutouh is leading the internal branding programme called #BetterTUgether.

Code of Conduct
It is recommended that sustainability be included in TU Delft's code of conduct. In the current code, there is limited reference to sustainability. A stronger reference to the sustainable character of the university and its campus will help to attract students and staff that support this aim and it will help to stimulate sustainable behaviour.

07.03 Proposed approach

A large part of TU Delft has a relatively short presence: the 27,000 students stay 2 to 7 years, postdocs 1 to 4 years and PhD candidates on average 5 years, and these groups make up a large share of the community on campus. They are target groups that can replace history quickly with a new reality. This also counts for all new employees, who can be informed by onboarding programmes. Therefore, if these groups are made aware of the urgency, the sustainable transition plan and responsible behaviour fitting these conditions, TU Delft is inviting them to engage and consolidate the new norms.

Vision

We believe that strengthening what we call the human campus community, in general, is of importance for the realisation of the TU Delft strategy (Impact for a better society). The strength and health of this community and henceforth its ability to realise the strategic goals of TU Delft – from strong connections within this community and between this community and TU Delft – can be supported and enhanced in many different ways. However, it is important to keep in mind the following:

- It is a human community. Investing in the quality of personal relations is a precondition.
- It is an academic community that only can and will perform this role if the strategy:
  - can be embraced by the community,
  - gives direction only on the main identity and goals,
  - shares progress and results,
  - leaves room for the community to actively contribute to and debate the strategy.

The topic of sustainability could be a strong catalyst for this process.

Raising awareness, creating incentives and enforcement

As explained, it is important to engage the entire TU Delft Campus community in the complicated challenge to become sustainable. A distinction must be made between the different target groups and the strategy must be adjusted accordingly, taking the different places on the scale of already active in being sustainable or not into account. As mentioned previously, this will lead to different strategies, e.g. raising awareness, creating incentives for action, nudging (making the preferred option the easy one) and enforcement.

The sustainable engagement scale

As said, people can have different positions on the sustainability engagement scale, varying from activist to oblivious attitudes. People will be stimulated to act sustainably with different instruments, such as enforcement and nudging, depending on their position on the sustainable engagement scale.

The enforcement category refers to interventions that are a given fact, the things TU Delft decides without consent of all users, such as making the buildings more sustainable. On another scale one can find the steps TU Delft can use to nudge her community, such as eating more vegan, taking the train, etc. Financial incentives and other forms of reward can also be used. Research is needed to find out which stimulus works best for which category.

Catering as example

An example can be given on the topic of food. Only offering certain environmentally sound food types is an example of enforcement. Carbon pricing can be seen as a financial incentive to stimulate more sustainable purchases. Offering better and more interesting dishes (‘the sustainability special’/’the healthy choice’), with an explaining why this food is better, is a more positive incentive raising awareness. Another stimulus could be giving away vegan food for free, as an introduction, or food leftovers, to inspire those who need inspiration to make better choices in the future. This would particularly benefit those who have financial or other constraints on trying alternatives.

The food supply at TU Delft can be better attuned to the cultural background of the ever-diversifying target groups. In the Dutch culture, having a simple cold sandwich will do as brief lunch but many other cultures prefer a warm, longer lasting lunch. The majority of another culture may also be vegetarian or vegan or religiously bound to certain limitations (e.g. halal or kosher food). Pilots can be held to investigate the preference for food per faculty, supporting division and external organisation on campus.

Positive stimuli

Positive stimuli, based on rewarding instead of limiting or punishing, as well as nudging are ways to direct a community towards behavioural change. The university should offer these positive stimuli and make a more sustainable choice the obvious one. TU Delft should ensure that barriers to make sustainable choices are taken away. Positive stimuli could be part of a promotional or reward system for the community; the rewards could be earned by sustainable behaviour (reaching certain goals), or bought as promotional gift.

Frontrunners and pioneers

Another important step in transitions is creating space for motivated people to act, the frontrunners or pioneers [Loorbach & Rotmans, 2009]. Frontrunners have an overly amount of energy and enthusiasm and want to act and overcome hurdles, but they need support and innovation space. This group of people can be reached by organising a yearly 'shark tank' for employees and students, where they can show and present their sustainable ideas and initiatives, or by engaging them in small-scale living labs to ensure that innovations take into consideration a wider scope of values, interests and needs. The best ideas can be tested and implemented on the campus. In general, positive sustainable initiatives, projects and events are stories that must be shared.

A different way of thinking

The community needs to change their usual way of thinking and their standards in order to achieve the ambition of becoming a climate university. Currently, most people want to have the newest computers, cars, e-bikes, etc. This must change: it must be "cool" and rewarded to keep your items in the best possible condition for as long as possible.

07.04 Specific projects, events and actions

We defined some specific projects, events and actions to inform the TU Delft community. These actions are divided into three categories: informing, facilitating, and activating.

Informing

TU Delft is working hard to become a sustainable university but has communicated too little about this in the past. This is a missed opportunity to engage TU Delft's own community and to inform the outside world. Therefore, the first step is to make sure the entire community is aware of the sustainable ambitions of TU Delft. Subsequently, the university should actively show what kind of research is conducted in the area of sustainability at the

university, which steps have been taken, and which goals have been achieved. The university should also actively show which pilots are running and what are their results. This must be shown on the sustainability website and can be also shown on the general website of TU Delft.

To be investigated: sustainability labels

An interesting aspect could be the competition element in achieving sustainability, for instance, a competition between faculties on the lowest carbon emissions. This competition could focus on which faculty and university service has the lowest carbon emissions that month or reduced their emissions the most in percentage in that month. Figure 07.01 gives an example thereof (actually based on real figures of energy use only).

How green is your building?

This week	Last week	Weeks on chart	Building name	Building no.	Weekly carbon emission (CO_2eq/m^2)
1	NEW	1	Pulse	33	0
2	1	10	Faculty of Aerospace Engineering	62	0.34
3	3	10	Faculty of Architecture and the Built Environment	8	0.35
4	2	9	Faculty of Industrial Design Engineering	32	0.40
5	4	8	Faculty of Electrical Engineering, Mathematics and Computer Science	36	0.43
6	5	8	Electrical Engineering, Mathematics and Computer Science	28	0.44
7	7	8	Faculty of Technology, Policy and Management	31	0.49
8	6	8	Faculty of Civil Engineering and Geosciences	26	0.62
9	8	7	Aula Conference Centre	20	0.67
10	10	7	Faculty of Mechanical, Maritime and Materials Engineering	34	0.68
11	9	7	Faculty of Civil Engineering and Geosciences	23	0.73
12	12	6	TU Delft Library	21	0.74
13	11	5	Applied Science	58	1.06
14	NEW	1	X	37 & 38	1.08
15	13	4	Physics	22	1.63

Figure 07.01: Example of a green chart of faculty buildings and their weekly ranking in carbon emissions

Currently, GreenTU is working on a sustainability label for student associations. This concept may also be used for faculties and university services. Each faculty and university service will then receive a sustainability label, which can be found at the entrance of each building showing how it scores on different sustainability elements such as waste, energy and food.

Website, social media and displays
A new TU Delft website for sustainability was finished in spring 2022. This website shows all the sustainability-related news and stories.
In addition, other forms of social media should be used to reach the community. Different platforms will reach different target groups. Instagram will mainly reach students, Facebook and LinkedIn will reach both, and Twitter will mainly reach employees.
TU Delft should also use displays in building hallways and in relaxing areas, e.g. coffee bars to inform people. The displays at the coffee bars could also be used to inform people about the waste treatment process of the coffee cups and the recycling procedure. This can also be done with posters.

Short future announcements
GreenTU is working on a new sustainability document, a sustainability guide for students, a handbook to become a sustainable student organisation, and a handbook to organise sustainable events. These are important documents to share and that can help our community.

Communication is further elaborated in chapter 08.

Facilitating

Guidelines and tools
Beside informing the community, the university should also help and facilitate. The university can recommend or develop tools (apps) that stimulate sustainable behaviour, e.g. eevie. In addition, guidelines and KPIs should be set up that make it easier to say no against unsustainable practices and projects.

Information and communication facilities
As mentioned before, people should change their standards and way of thinking. It should be ‘cool’ to have an old computer. Workshops as ‘how can you keep your computer well-performing’ can be designed around this. Also, augmented reality (AR) can be used to create awareness about sustainability and show the threatening situation by visualising future climate issues if no steps are taken. AR offer opportunities to create interactive and educational experiences. During this experience people are educated about the effects of climate change and see how they can act more sustainable.

Green environment
Green (plants, bushes, trees) and water have a strong link with sustainability and people see this relationship directly. The university should implement more greenery and water at the campus, to combat climate change on the one hand and to make the community aware of this on the other hand. Research also shows that a green environment reduces stress and improves the mental health of employees and students.

Activating/Engaging

Events
To engage and activate the community, workshops, lectures, debates, hackathons and other events can be organised on certain sustainability topics. To engage the community and make them part of the solution some of these workshops could be co-designed and co-design focussed.

Some initiatives already took place:
2021
- 9 Aug: Transitioning talkshow (hybrid working, transition in education)
- 9 Nov: COP26 Climate Drinks (on climate action at TU Delft)

2022
- 14 Jan: Opening 24-7 Lab, The Green Village
- 14 Jan: Dies Natalis (theme: energy transition, with Frans Timmermans)
- 14 Jan - 9 June: Energy Challenge (for students)
- 11 Feb: Warm/Favourite Jumper/Sweater Day
- 16 March: National Tree planting day (Boomplantdag).
- 7-13 March: Meatless Week
- 23 March: Sustainability Day
- 11 May: Sustainable Food System symposium
- 20 May: Bike to Work Day/ Sustainable Travel Day
- 27 April: Kings Day second-hand market on campus

In addition, other events that promote sustainable behaviour, such as clothe swaps, thrift shops, blind vega(n) food tasting, vegan cook-off, and potlucks should be organised community wide. The favourite recipes from the food tasting, cook-off and potlucks could be shared on the sustainability website or used by TU Delft's caterer.
These events help to create awareness. For example, the Warm Sweater Day can be used to communicate how TU Delft is saving energy, explain how heaters and the heating system works and to activate to the community to participate by a challenge. The same applies for the meatless week. This should be used to communicate about the environmental impact of food and the actions on campus. The event should focus on the positive side of healthy, local, seasonal, plant-based food.

Symposia and living labs
GreenTU also organises a yearly sustainability symposium in October; this is a great moment to spread awareness. Another way to engage the community is by organising a sustainability philosophy café. At the moment, PhD candidate Lieke Brackel is setting this up. For students, there should be the opportunity to win a sustainability award in design courses. This will stimulate students to make a sustainable design and at least make them aware of the possible connection between sustainability and their study.
Creating more connections between student work and sustainability could be done by setting up living labs on the campus to showcase and test student results. These living labs

can be used for research and education. To engage students and staff even further, a shark tank can be organised once a year. Furthermore, TU Delft can create more room for informal developments and actions by students and staff.

EcoCampus
The EcoCampus provides a fantastic source of activities that stimulate social cohesion, of the TU Delft community internally but possibly also with the outside world. Installing new plants and animal boxes on the campus – also part of the advice of the Strategic Response Team for Social Cohesion to the Executive Board – can give exciting content to various post-pandemic team building and integration events for staff and students. Furthermore, the EcoCampus can support outreaching by for example inviting pupils of primary and secondary schools (of poor neighbourhoods) to use a part of the campus area for school kitchen gardens and to discover (protected and rare) Dutch flora and biotopes displayed by the Botanical Garden on the campus (see chapter 09).

To be investigated: personal carbon budget
As previously mentioned, a personal carbon budget will also help with making people more aware about their daily actions. Not only staff and students should be involved but the whole community, including the companies in TU South such as 3M, Exact, YES!Delft, Firma van Buiten, etc., as well as the municipality. The companies should at least comply with our minimal sustainability rules and can even help with achieving our ambitions.

Sustainability Survey

The university is not only sending information to the community but also collecting information from the community. A survey was designed to focus on sustainability at the campus. The goal of this survey is to find out which topics the community finds important and what actions they think the university should take. The results of this survey will be used to specify and develop workshops, events and information sessions according to the needs of the community.

08 Communication

Team (in alphabetical order)

- Fatima Boutoutouh – Com
- Andy van den Dobbelsteen – TU Delft sustainability coordinator
- Deirdre van Gameren – TU Delft sustainability researcher
- Inge Geuzebroek – Com
- Naomi Hubert – GreenTU
- Marc de Kool - Com
- Nika den Ouden - GreenTU
- Inge Snijder – Com
- Eelco de Vries – Com/CRE
- Annelien Wehrmeijer – Com/ICT-FM
- Yvonne de Zeeuw – Com

Communication
Main proposals

General aims and principles

- To profile TU Delft as **Climate University**
- To support **communication** around sustainability projects and processes
- To support activation and community building around **sustainable behaviour**

To be investigated

- Developing **sustainability dashboards** (see Chapter 09, Reporting)
- A **corporate policy** for all sustainability topics, including the SDGs and climate action

Projects, pilots and actions

- Getting a new **sustainability website** started
- Setting up an **activity calendar** with important communication moments
- Coordination of multiple **communication platforms**
- Communication about sustainability through the **#BetterTUgether programme**
- Communication about **big projects and researches**, e.g. the flagship projects
- Communication about **smaller news items** related to sustainability
- Communication to create **awareness and behavioural change**

TU Delft is good at conducting research and developing innovations. It is important to show the world what the TU Delft is working on and developing at the moment. It is not about what TU Delft has done in the past; it is about the choices we make now. This chapter describes the desired future situation and looks at how sustainability is incorporated into the current communication strategy and future plans. It also shows which communication platforms are used and outlines several communication moments from the past and in the future.

08.01 Desired future situation

In the near future, the communication division and the sustainability coordinator and his team will work closely together to ensure that communication on the theme of sustainability runs smoothly.
There are sufficient tools for the communication division to attach sustainability-related themes. The #BetterTUgether programme is also used for this. Both small and large projects and actions are communicated to the inside and outside world. The different media platforms are used correctly and reinforce and complement each other.

08.02 Sustainability in communication at TU Delft

Communication at TU Delft can be roughly divided into internal and external communication. The communication division informs the community, the general public, policy makers, and alumni about the outcome and status of academic research.

Brand monitor
A 'merkenmonitor' (brand monitor) study was conducted among different target groups and companies. Sustainability and energy came clearly forward as qualities of TU Delft as knowledge institute and as institute for innovation. Furthermore, TU Delft is considered to be present strongly for desired collaboration.

Sustainability communication line
TU Delft uses 5 different themes in the external profile of the university. Sustainability is reflected in 2 themes: climate action and energy transition. The communication division also uses these themes in internal profiling. Multiple themes connect to the Sustainable Development Goals (SDGs). However, communication indicates that, without a clear corporate policy on SDGs, they cannot constructively follow up on this. That is why they currently use the climate action and energy transition theme. A clear policy needs to be made for all sustainability topics, including the SDGs, climate action, energy transition, etc.

Communication perspectives
Two perspectives are used to address sustainability in internal communication: the sustainable campus (sustainable business operations) and the sustainable human. The first

perspective focusses on the principle of 'Practice what you preach' and uses the Climate Action Programme and agenda as guidelines for communication. The second perspective deals with creating awareness, behavioural change, advocacy, and community building.

Climate action
Within the climate action theme, the Communication division wants to profile TU Delft as a climate action university, both internationally and within the Netherlands. The Climate Action Programme will be the starting-point of the communication strategy in 2021. The focus is on 'practice what you preach' and on the climate hub and link to The Hague. Internally, the Communication division organises itself from different levels around the sustainability coordinator's activities. They support with information, activation, and community building around sustainable behaviour. Both internally and externally, the Communication division focusses on the sustainable flagships on campus: the new education building Echo (energy-providing), the parking garage on the Rotterdamseweg, the Kluyver area development, the Brains 4 Buildings project, and the geothermal well, for example. Externally, the image is conveyed of TU Delft as a climate university, and the focus is on politics and business-as-usual stories about climate research.

Energy transition
Research into renewable energy and energy transition serves as a catalyst for collaboration and discussion between TU Delft and the business community, governments, and politicians. The university wants to accelerate the energy transition and it therefore gives extra attention to this subject by making energy transition the theme of the 2022 lustrum.

#betterTUgether
TU Delft has set up an internal branding programme, called #betterTUgether, to reinforce the identity of TU Delft and to strengthen the bond within the organisation and with society. The focus of the programme is on commitment and connection. There are three different ways to communicate about this:
1. Regular internal media: Stories of Support, TU Delft 'video snacks', Portraits of Science;
2. Facilitate dialogue (bottom-up, top-down, and in-width): target group lunches, a cup of coffee with the Executive Board, theme groups;
3. Major interventions: Family Day, TU-wide town hall meetings, Dies Natalis, Opening of the Academic Year.

08.03 Communication platforms

TU Delft has several communication platforms: the general TU Delft website, including the sustainability page and the Instagram account, @tudelftcampuslife.
Additionally, there is a campus development website managed by CRE Communication (https://www.tudelftcampus.nl/campus-development/), which also includes sustainable projects and activities. It is important that the websites are properly coordinated, that they refer to each other at the right times, and that they reinforce and complement each other.

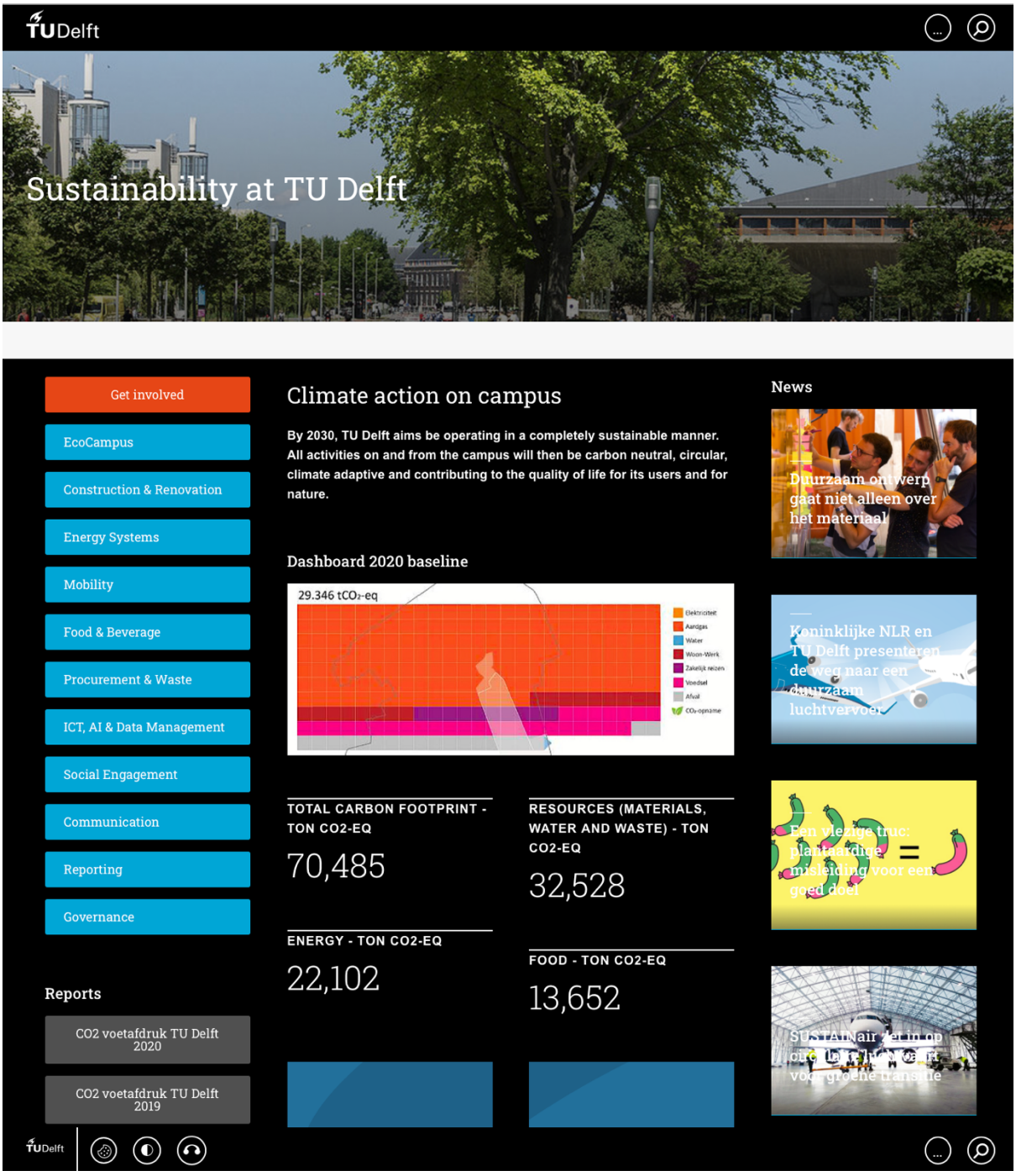


Figure 08.01: The new Sustainability website design, main page

Sustainability website

The sustainability website of TU Delft was recently renewed. Figure 08.01 shows the main page of this website. The previous website was not engaging enough nor up to date. The website now shows the 12 themes discussed in this document (Social Engagement & Communication being joined). Each theme has its own webpage to showcase the problems

in that field, the achievements and the future plans. News about sustainability, blogs, dashboard, and sustainable stories and interviews can also be found on this main webpage. Beside the main page, there are 5 sub-pages: Vision, Education, Research, Operations and Community. Throughout those pages, the visitors can see ongoing living labs and pilot projects at TU Delft and go to sustainability-related pages from the Dreamteams, GreenTU, The Green Village, Yes!Delft, etc. It will also be the place where students can learn about sustainable masters, minors, and MOOCs, as well as LDE, IDEA League, and 4TU collaborations. In addition, people can find a digital bulletin board where they can leave ideas. Lastly, it is also the place where people can find sustainability-related events and guides. In Chapter 16, we suggest that more research is needed into the development of sustainable websites. This webpage can act as a pilot project.

Dashboard

The Sustainability Dashboard, further explained in chapter 13, is drawn up around the 17 SDGs in which a distinction is made between economic, environmental, and social performance, see figure 08.02. This dashboard can be found on the website and at screens in the faculties and university services and is updated every month. This dashboard helps to create awareness among employees and students.

Figure 08.02: Example of the draft dashboard

08.04 Specific projects, events and actions

To be investigated: sustainability policy
The Communication division has indicated that it would help if a corporate policy on SDGs is in place. Without such a clear policy, they cannot constructively follow up on this. That is why a clear policy is of vital importance for all sustainability topics, including the SDGs, climate action, energy transition, etc.

#BetterTUgether
The #betterTUgether branding programme should also be used to communicate about sustainability. TU Delft as a whole should become sustainable. This affects everyone on the campus. If everyone at TU Delft becomes aware of the climate problems and challenges, we can become #betterTUgether.

Events
The work for this report was done in corona times. In the years 2020 and 2021, employees and students were absent from the campus approximately 75% of the time. They returned in 2022. This is the moment to set up events around sustainabity. A good communication plan must be made to inform the whole community about the new sustainability policy and activities. Together with GreenTU, a digital calendar is developed to sum all upcoming events and to ensure communication about them.

Communication moments

Activity calendar
To ensure that communication moments or other milestones are not missed, a sustainability calendar is drawn up with important data. The Communication division, the theme teams, GreenTU and other divisions will have access to this document. In consultation with the communication division and especially the content room, the theme teams can put important milestones on the agenda themselves and this can then be communicated internally or externally.

Communication moments until June 2022
There were already a few communication moments from this team before this document was published:

- The 2019 carbon accounting report
- ABP action letter
- Story of support related to the week without meat
- Climate Action Programme
- Vegetarian restaurant of Architecture and the Built Environment
- Story of support about CIRFOOD and the new food policy
- The 2020 carbon accounting report
- Stories of support focussing on sustainability
- Stories of science on the sustainable theme teams

- Launch of the new sustainability website
- Personal stories: on the website
- Opening of the Academic Year 2021
- Energy Transition Lustrum

Communication moments in autumn 2021

After the first draft of this report, autumn 2021 had many moments to communicate and discuss the ideas with the TU Delft community and interested external parties:

- 21 June: AE townhall (online)
- 24 June: Utrecht University (online)
- 13 July: Collegelunch (CvB & B&W, Lijm & Cultuur)
- 14 July: ASR Real Estate (online)
- 14 July: Delft Startup Community (online)
- 3 Aug: OWEE (Aula, recordings, online later)
- 20 Aug: CEG MT (online)
- 25 Aug: IDEA League Summerschool, Aachen (online)
- 31 Aug: ABE MT (ABE)
- 3 Sept: Opening Academic Year (Aula/online)
- 2 Sept: CRE College (online)
- 14 Sept: UvA masterclass (online)
- 28 Sept: TPM MT (online)
- 28 Sept: 3ME MT (online)
- 29 Sept: KLM (ABE/online)
- 4 Oct: IDE MT (IDE)
- 5 Oct: Stadsakkoord Utrecht (Utrecht)
- 6 Oct: Urban Energy Institute (3ME)
- 7 Oct: AS MT (AS)
- 8 Oct: UPV (Polytechnic University of Valencia, online)
- 13 Oct: Green TU (Library)
- 14 Oct: International conference QiR (Jakarta, online)
- 22 Oct: FAUP, University of Porto (Porto)
- 25 Oct: Groepsraad (AS)
- 2 Nov: Prometheus (CCC@TGV)
- 3 Nov: Wonen Midden-Delfland (Maasland)
- 9 Nov: COP26 Climate Drinks (CCC@TGV)
- 12 Nov: NOC-NSF / Chef de Emission / Delft Sports Engineering Institute (CCC@TGV)
- 15 Nov: Nachhaltige Hochschulen (Detmold, online)
- 19 Nov: SWP roundtable ‘Energietransitie op de campus’ (online)
- 30 Nov: Drenthe Woont Circulair (Assen, online)
- 6 Dec: Finance MT (online)
- 9 Dec: ICT-FM MT (online)
- 9 Dec: ICSBE2 conference (Eindhoven, online)
- 15 Dec: CRE project leaders (online)
- 21 Dec: Let’s talk about X podcast (X, to be broadcast in January)

This round along students, staff and external parties created a solid ground of support for the sustainable transition of TU Delft.

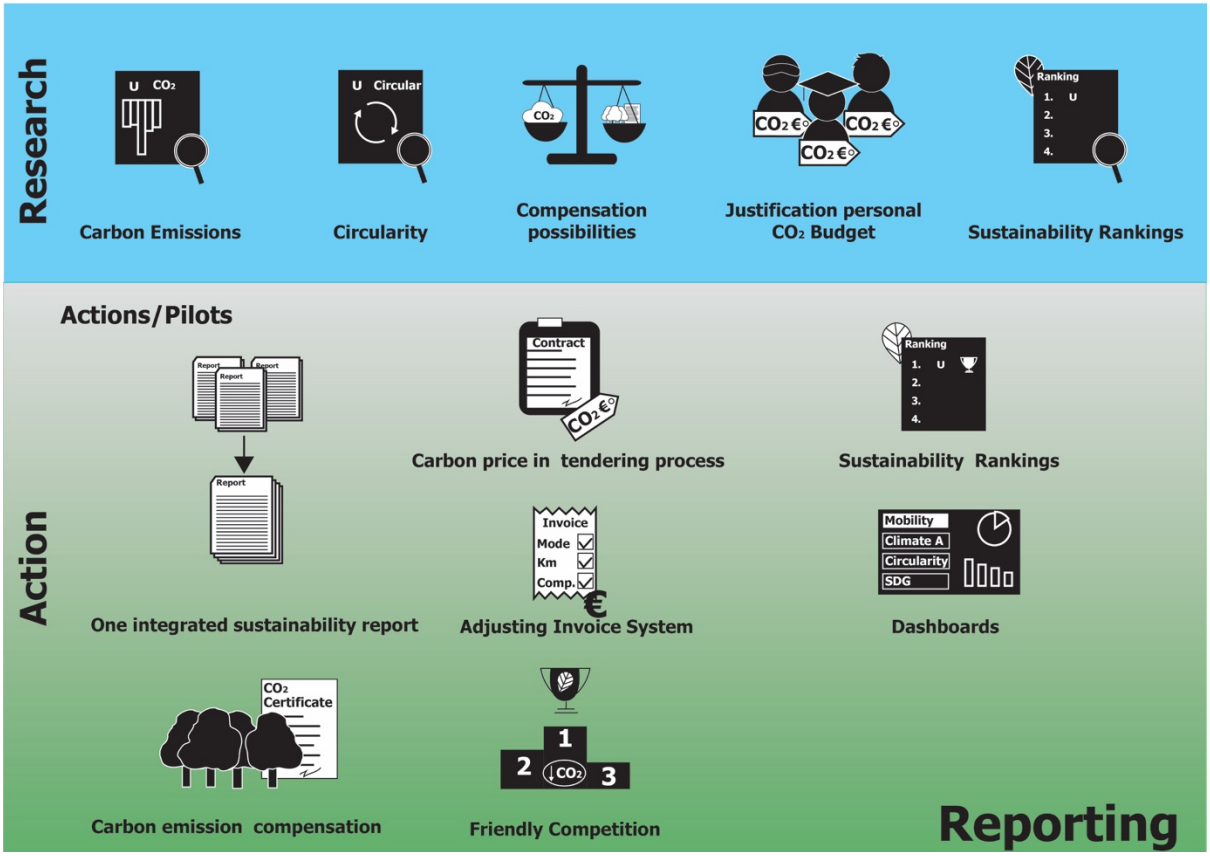
Communication moments in the near future
The university should not only communicate about big projects but gives also attention to smaller news items regarding sustainability. The following moments should be used:

- TU Delft's sustainability action plan
- Dashboard: big changes or achievements
- Stories of TU Delft Campus: employee or student efforts in living more sustainably
- Flagship projects: the Rotterdamseweg parking garage, Echo, Kluyver area
- Specific projects: Brains for Building, geothermal well, campus PV roll out, EED+ analyses
- Living labs and pilot projects

09 Reporting

Team (in alphabetical order)

- Andy van den Dobbelsteen – TU Delft sustainability coordinator
- Deirdre van Gameren – TU Delft sustainability researcher
- Naomi Hubert – GreenTU
- Cassandra Tax – F
- Pieter de Wit – F



Reporting
Main proposals

General aims and principles

- To gain insight into the **carbon emissions** of activities on and from the campus
- To account for **all activities** that emit greenhouse gases, including scope 3
- To report **progress and ambitions** of TU Delft concerning sustainability
- To **take action and change strategies** where needed, based on the annual reporting

To be investigated

- Selecting appropriate sustainable indicator **assessment methods**
- Clarifying the **carbon emission developments** over previous years
- Determining the influence of **Covid-19** on carbon emissions and other indicators
- Studying **compensation possibilities** for the fraction of unavoidable carbon emissions
- Determining and justifying the **personal carbon budget**
- Gathering data (by survey) to obtain more information about **commuter travel**
- Gaining insight into the travel movement of **suppliers**
- Developing **registration and invoice systems** that support the sustainable transition

Projects, pilots and actions

- Producing the first **integrated sustainability report** of TU Delft, over the year 2021
- Commencing **carbon emission compensation**
- Including the **carbon price** in tendering processes
- Developing **dashboards**: SDG, climate action, circularity, and mobility
- Introducing **competitions** to stimulate change in the TU Delft community

Reporting is an important step towards a sustainable TU Delft Campus. Reports present transparently the sustainability actions, goals and achievements of TU Delft to her stakeholders of the internal and external community, to be used as justification. Moreover, the reports show whether TU Delft is making progress and which areas need further action. At the moment, TU Delft works on four different forms of reporting: the GRI report, the sustainability report of GreenTU, carbon accounting reports, and dashboards.

09.01 Desired future situation

In the near future, TU Delft's performance will be visible continuously, through dashboards, online or in the buildings on campus, and the university presents annual reports to justify sustainable investments, progress in carbon emission reductions and plans to enhance this process. The honest reporting process has enabled the university to truly profile itself as a Climate University.

09.02 Carbon accounting reports

In order to be carbon neutral by 2030, TU Delft had to gain insight into the carbon emissions coming from activities on and from the campus. This can be made transparent through a carbon footprint. Some data is difficult to obtain, but certainly necessary to gain insight into the footprint.

CO_2 Roadmap

The first analysis of the carbon footprint for the years 2017 and 2018 was presented in the CO_2 Roadmap TU Delft [Blom & Dobbelsteen 2019]. From 2019 onwards this task has been performed by the Finance division of TU Delft. The Financial Control department calculates the university's carbon footprint annually, in accordance with the method of the 'CO_2-prestatieladder', which follows the international Greenhouse Gas Protocol.
The carbon footprint report for 2019 was presented in early 2021. The one for 2020 was published during the national climate week in November 2021.

Incomplete or inaccurate data

The financial division succeeded in retrieving a lot of information that is required to be able to draw up the carbon footprint. This is currently well mapped for electricity, natural gas, and water. However, the information required to calculate the CO_2-eq emissions for mobility (business travel, commuter travel, and travel movement of suppliers) and procurement needs work.

Mobility
There is a good overview of air travel because this is mostly booked through the travel agency. However, when employees do not book through the travel agency (part of the flights and business trips are by private car, train or taxi) and invoice this later, it becomes

more difficult to trace. At the moment, the financial administration is connected to a financial amount to calculate the number of kilometres. This is inconvenient and inaccurate. Furthermore, at present, students do not book their flights through the travel agency, making a large part of annual flights invisible.

Food
The carbon emission calculations for food are currently based on average figures of the Netherlands. These figures need to be more accurately determined for TU Delft to get a more precise overview of the carbon footprint of food consumption on the campus.

Procurement
For the carbon accounting reports, the financial division of TU Delft had no insight into carbon emissions from procurement, until a recent study by Herth & Blok [2021] provided insight into this, adding the same amount of CO_2-eq to the figures presented earlier.

Developments in carbon emissions

Excluding procurement, over the years 2017-2019, the carbon footprint decreased a bit, from 50,366 tons of CO_2-eq in 2018 to 49,165 tonnes of CO_2-eq in 2019 (two years that were assessed by the same method)[15]. In 2020, the carbon footprint decreased even further to 29.346 tons of CO_2-eq. This is mainly due to the corona crisis. In 2020 COVID-19 dominated everyone's life, also on campus. Students and employees were not allowed to work at the campus most of the time. Therefore, there was a reduction of carbon emissions for mobility, food, procurement, and waste management. It can be seen that in buildings the energy use went down but not as much as it should have, due to nearly full operation of a lot of the buildings. Research should be conducted into this to reduce unnecessary energy usage.

Avoidable and unavoidable carbon emissions

TU Delft has set the goal to be carbon neutral by the year 2030. Initially, this goal was defined for energy use by buildings on the campus and the overall energy system. As described in the introduction chapter, the sustainable transition of TU Delft should however account for all activities that emit greenhouse gases. Looking at the different scopes of emissions, especially Scope 3 is the hardest to influence. Some of the emissions residing under Scope 3 can be controlled by TU Delft itself – for instance, the choice of business travel, food & beverage, procurement and waste management, etc. – but the entire supply chain of modes of travel, the food system, and products are defined in other places. Therefore, contracts with suppliers become ever more important, in order to engage them in TU Delft's sustainable ambitions.
A certain extent of carbon emissions is expected to be unavoidable. Think of the fact that even vegan food has a carbon footprint, and that the carbon content of products cannot always be brought to zero. Therefore, for the year 2030, we need to account for a fraction of unavoidable carbon emissions, which need to be compensated for before the university

[15] For comparison: the University of Utrecht had a carbon footprint of 62,780 tons of CO_2-eq (2019), and Wageningen UR had one of 42,587 tons of CO2-eq (2018). Both use the GHG Protocol (ISO 14064-1).

can be called carbon neutral. Compensation can be done by extra green on campus, (re)forestation elsewhere, or by buying carbon allowances (and preferably destroying these, to reduce the total allowance on the market).

Personal carbon budget

As introduced already, to be investigated further is the possibility to use the unavoidable amount of carbon emissions as the basis for a personal carbon budget of people using the campus. This carbon budget could be the basis for annual personal carbon emission allowances, to be spent on travel, food, or equipment, to name a few options.

09.03 Sustainability reports

Sustainability report of GreenTU

GreenTU wrote a first sustainability report in 2020 and is recently finished that of 2021, which builds upon the first report and includes achievements made since its initial release. The GreenTU reports are published per academic year (not calendar year), in line with the yearly appointment of the student board. These reports are structured around the four domains of the TU Delft vision, ambition and action plan for sustainability (education, research, community and operations). As such, the reports include an overview of the current situation at the university in all four domains and of the projects GreenTU is involved in. The reports also expand on GreenTU's vision per domain, which comprises both its own future as well as TU Delft as a whole.

Vision

Education is a major focus point of GreenTU's vision, with comprehensive goals to provide all students with some sustainability knowledge. Moreover, in the domain of operations, the 2021 report includes an energy model to forecast various emission scenarios. Furthermore, because of its position as a student board, GreenTU has heavily invested in social engagement among students as well as with and between various societies, associations, and other (student) groups. The organisation of events, as well as the GreenTU Sustainability Label, are important tools to increase social engagement. Lastly, the topic of research is primarily included to highlight the range of different initiatives contributing to sustainable development at TU Delft. Several of the recommendations made in the 2020 report have since been (partially) implemented.

Third report

The third edition of the GreenTU report will cover the 2021-2022 academic year. This third report will expand on the two previous reports, focussing on progress and notable achievements made per domain by the 2021-2022 board and faculty-specific GreenTeams. Unlike the second report, this new edition will not contain a new energy model, as references can be made to the more extensive models included in other TU Delft reports (mentioned in this chapter). However, the third report will contain (amongst other additions) a comprehensive overview of TU Delft researchers working on sustainability at

the different faculties, so sustainability-oriented students know where to look for e.g. thesis supervisors. Other additions include the continuation of the Green Thread project (education) and the expansion of the Sustainability Label (social engagement).

Global Reporting Initiative

The Global Reporting Initiative (GRI) is an international organisation that helps organisations understand and communicate their impacts on issues such as climate change, human rights and corruption. With the GRI's framework for sustainability reporting, organisations can report in a comparable and more transparent manner about their environmental, economic, and social impacts. This enables informed dialogue and decision making around sustainability impacts. The environmental, economic and social focus of the framework is in line with the Social Development Goals (SDGs) as set by the United Nations (UN).

Corporate Sustainability Reporting Directive

At this moment the European Commission adopted a proposal for a Corporate Sustainability Reporting Directive (CSRD). In this directive, all large companies, including TU Delft, need to report on sustainability information. This includes a mandatory requirement for external assurance on the information provided. CSRD will be effective as of January 2023 and will cover Environmental, Social and Governance (ESG) elements.
The GRI's sustainability reporting framework is the sustainability-related framework most widely used in the world. It is anticipated that elements of this framework will be used in the CSRD. This underlines the importance for TU Delft to prepare a GRI report.

TU Delft's integrated sustainability report

As discussed in the Reporting team, TU Delft's annual sustainability report should combine the best of both the carbon accounting reports, the GreenTU report, GRI reports, dashboards, and this vision, ambition and action document. The general sustainability report will be a joined effort of the financial division, GreenTU, and TU Delft's sustainability coordinator and his team. The financial division will update the chapter on dashboards and the carbon footprint. GreenTU will annually revise the chapter about sustainability in education and research. Lastly, the sustainability coordinator and his team will keep track of developments within the themes that are set up in this document and see whether the goals can be achieved within the set period, before 2030.
If this does not seem likely, new actions and/or projects are proposed to get them back on track. Moreover, the sustainability coordinator and his team are responsible for the integrated report and ensure that all chapters are included and representative. The decisions, actions, and strategic directions on annual reporting are not just based on carbon emissions, but also come from the intrinsic motivation of the team and the TU Delft community.

Formal requirement

From Finance, and prompted by legislation and regulations, as well as the accountancy sector, the overall sustainability report must be drawn up that complies with the GRI requirements. This sustainability report must eventually, from 2023 onwards, be integrated

into the annual report and will then function as a TU Delft sustainability report for all stakeholders who read the annual report. This report contains the summary of TU Delft's sustainability report, with the most important developments regarding the carbon footprint, the GreenTU report, the dashboards, and the themes. The Reporting team started with this integrated report in January 2022. In collaboration with the financial division, the sustainability coordinator has written a small section about sustainability for the annual report of 2021.

09.03 Dashboards

TU Delft plans to monitor its impact on the 17 SDGs. The general, the SDG-based dashboard makes a distinction between economic, environmental, and social performance. It will present all SDGs that are relevant to the university.

Regular updates
The sustainability dashboard should be updated monthly, eventually daily, and publicly accessible on the sustainability website and on screens in the faculties and university services.

Absolute figures with relative values
Next to absolute figures, we recommend making a dashboard per fte, per faculty and per supporting division. As a result, students and employees become aware of their personal emissions and can compare this with other faculties or services. Attaching a form of competition to this can encourage the department to pay more attention to their daily actions, which (in)directly affect their carbon emissions.

Thematic dashboards

Beside providing insight into the dashboard per faculty and service, the dashboard can also be divided into various themes. Next to the general dashboard, three types of dashboards can be developed.

Climate action dashboard
A second dashboard can be made focussing on climate action, in collaboration with the Climate Action Programme. This dashboard shows the CO_2-eq emissions (total and per fte), distance to the set target (total and per fte), division of carbon over sources of emission, and the development of each topic over the years.

Circularity dashboard
The third dashboard can focus on circularity. This dashboard shows the percentage of circularity and flows analysis of energy, water, materials, products, food, etc. It also shows how much waste is collected, the recycling percentage, and the development over the years.

Mobility dashboard
Lastly, the fourth dashboard can focus on mobility. This dashboard shows the number of flights made per year and per faculty, and how many miles (see figure 09.01, for example).

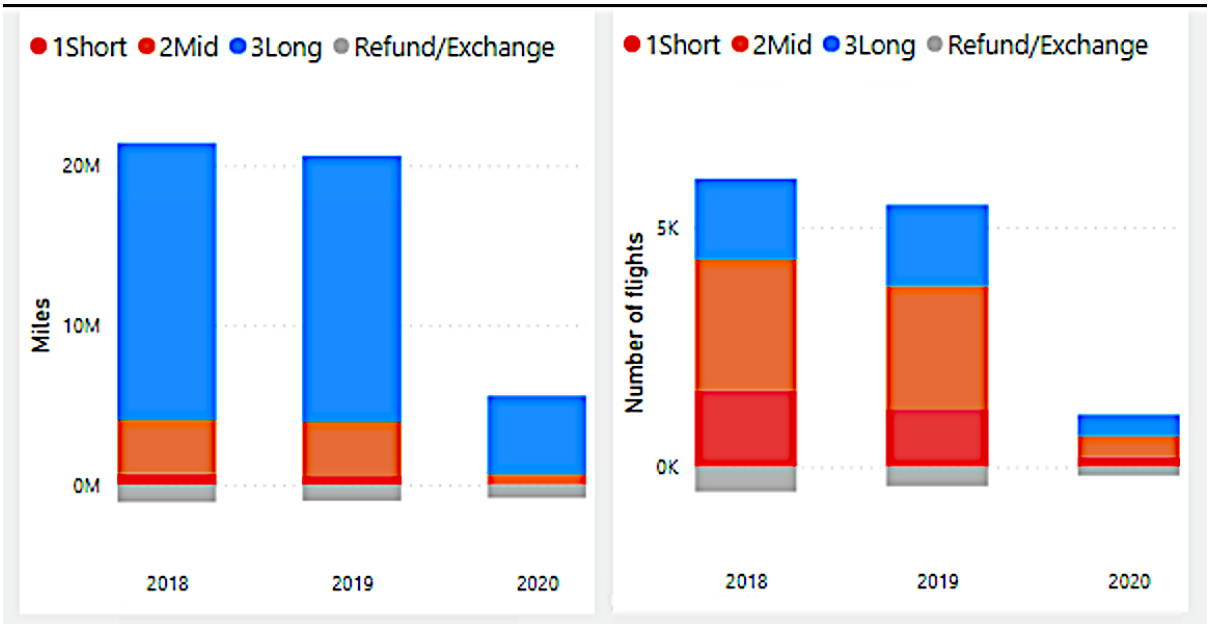


Figure 09.01: Example of the draft mobility Dashboard

By designing these four different types of dashboards, the development and status can be seen of the entire university, per faculty and university service, and per fte. This platform is needed to achieve the ambition: a circular and carbon-neutral campus.

09.05 Conclusions and further actions

TU Delft's sustainability report

In the year 2022, one integrated sustainability report will be produced containing the information from the carbon accounting report, the GreenTU report, the GRI report, the dashboards, and this vision, ambition, and action document. As a result, all information will be clearly arranged together. A summary of this document will be included in the annual report of TU Delft.

Dashboards

Several types of dashboards are being developed, the general SDG dashboard, one that focusses on climate action, mobility and one that focusses on circularity. For each of these dashboards, two separate versions will be made, one with information of the entire university, and one per fte, so that a distinction can be made per faculty and supporting division. In order to stimulate the community, this dashboard should be visible on the sustainability website and on screens in the faculties and supporting division buildings.

To be investigated: better insight into certain data

International travel
For accurate insight into mobility, all international trips (flights, trains, boats, taxis, etc.) must be arranged through the travel agency. The current invoice system (controlled by the Finance division) must also be improved so that it becomes clear how many kilometres are declared, with which vehicle, and for how many people. This has already been brought to the attention of the developers of a new invoice system. More information about this proposal can be found in chapter 12.

Commuter travel
Surveys are needed to obtain more information about the commuting of students and employees; this can be done in collaboration with HR and CRE&FM. It is not yet possible to map out which form of transport is used, for how far, and how often. In addition, the taskforce of the financial division will talk with suppliers to map out their travel movement. All the proposals related to mobility can be found in chapter 12.

Food
Better registration of procurement by the caterer, including carbon figures, is needed to get insight into the food consumption on campus. This must be done together with CRE&FM and CIRFOOD, and they need to process data information requests to their suppliers. More information about this proposal can be found in chapter 13.

Procurement
As a follow-up to the study by Herth & Blok [2021], more accurate information can be obtained by talking to suppliers. TU Delft can ask suppliers to implement the CO_2 price of their product or service during the tender process. Consequently, the carbon emissions for all products and services used by the university become clear, also during tendering processes. Since October 2021, a postdoc has been appointed for three years to look into the reduction of the carbon footprint of all TU Delft's purchases.
When implementation of the carbon price becomes the standard, carbon emissions for all products and services used by the university become clear and action to reduce these can be easier, see chapter 14.

To be investigated: unavoidable emissions and the personal carbon budget

A certain extent of carbon emissions is expected to be unavoidable. This means the university must compensate for this fraction of unavoidable carbon emissions to become carbon neutral in 2030. This can be done by extra green on campus, (re)forestation elsewhere, or by buying carbon allowances. Another option is to use the unavoidable amount of carbon emissions as the basis for a personal carbon budget. More research is needed into avoidable and unavoidable waste and the possibility and method of a personal carbon budget.

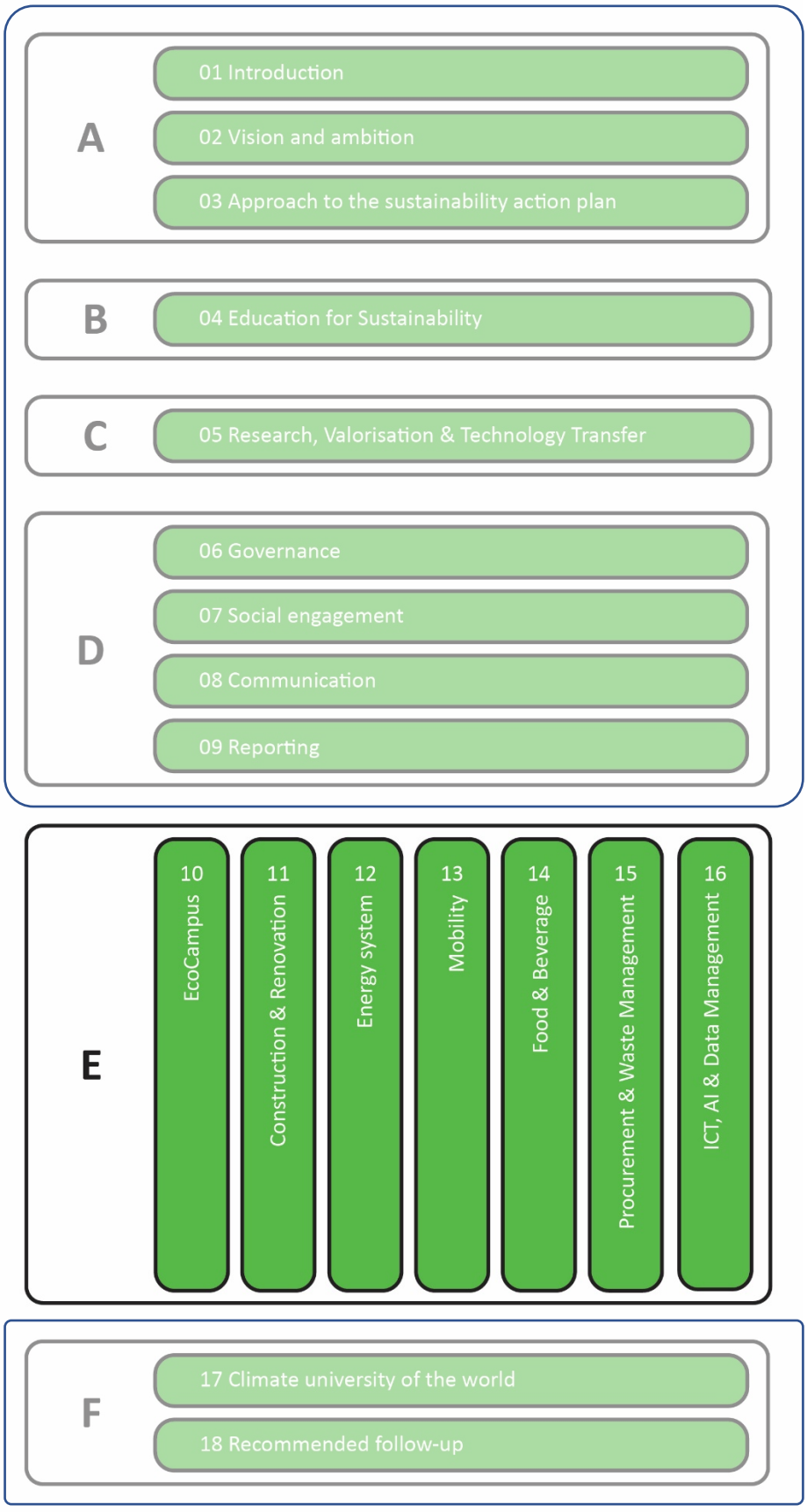
Sustainabily Rankings

Every year, the university participates in several rankings such as Times Higher Educations (THE) and QS Ranking. Currently, a special team is formed that is going to focus on the sustainability rankings. This team will be a beacon that collects all information regarding TU Delft and sustainability and knows within the organisation who to approach for a certain question. By following this action plan and setting up this team we believe that the university will be positioned higher in future rankings.

TU Delft

PART E

OPERATIONS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03 Approach to the sustainability action plan
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04 Education for Sustainability
C
05 Research, Valorisation & Technology Transfer
D
06 Governance
07 Social engagement
08 Communication
09 Reporting
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10 EcoCampus
11 Construction & Renovation
12 Energy system
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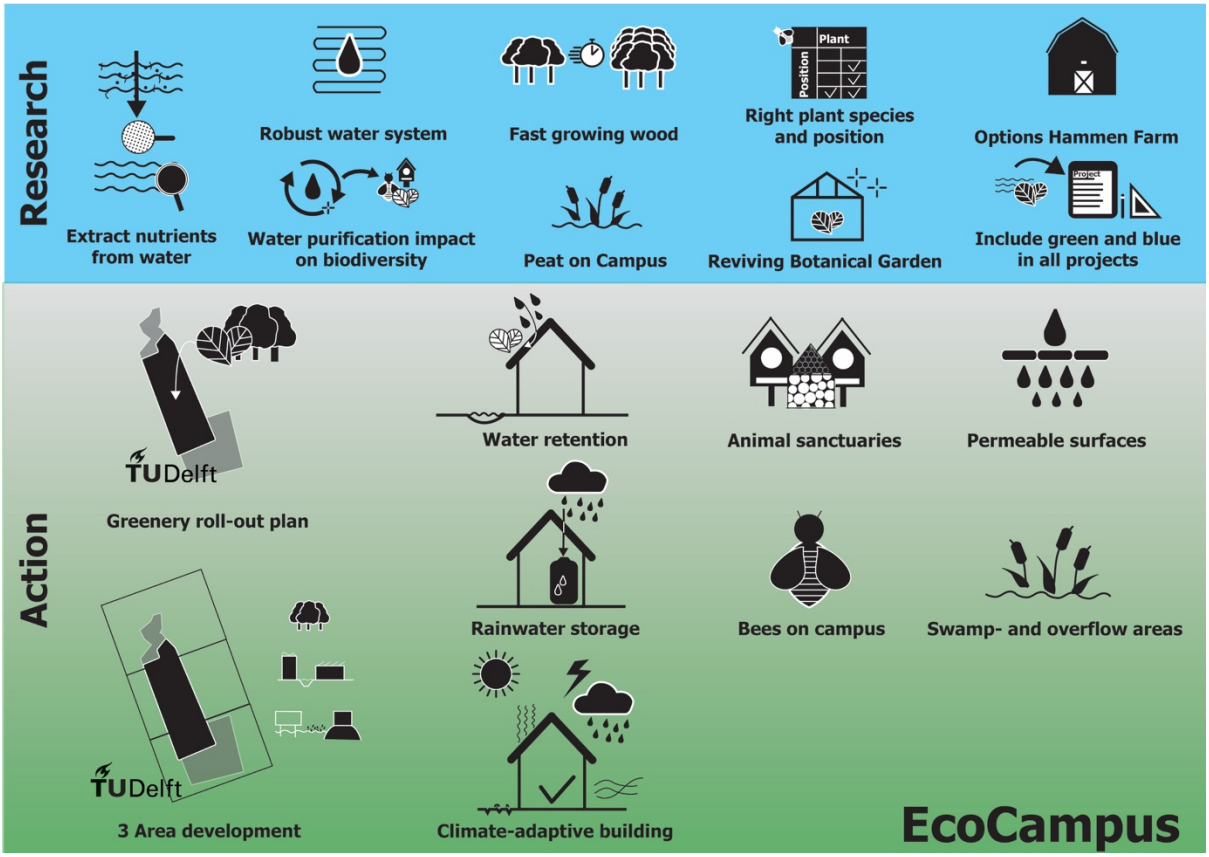
14 Food & Beverage
15 Procurement & Waste Management
16 ICT, AI & Data Management
F
17 Climate university of the world
18 Recommended follow-up

10 EcoCampus

Team (in alphabetical order)

- Henri van Bennekom – ABE
- James Byng – Botanical Garden, Director
- Harald ten Dam – Hoogheemraadschap Delfland
- Andy van den Dobbelsteen – TU Delft sustainability coordinator
- Neelke Doorn – TPM
- Deirdre van Gameren – TU Delft sustainability researcher
- Geneviève Girard – SD
- René Hoonhout – CRE
- Birgit Hopff - CRE
- Arjan van der Hulst – OR
- Marjan Kreijns – I&IC/The Green Village
- Hubert Linssen – CRE
- Olivia Meng - GreenTU
- Marc Ottelé – CEG
- Martine Rutten – CEG
- Nico Tillie – ABE
- Bob Ursem – AS/Botanical Garden



EcoCampus
Main proposals

General aims and principles

- To create a **climate-adaptive** campus
- To increase **water retention** and usage on campus
- To increase the **biodiversity** of trees, other plants, and animals
- To **connect** to green and blue outside the campus

To be investigated

- Investigating the best way to extract **nutrients** from wastewater and open water
- Studying types of **water purification** systems and their impact on biodiversity
- Exploring possibilities of **peat on campus** and its impact on CO_2 and water retention
- Exploring possibilities of **fast-growing wood** as carbon absorber
- Finding the right **plant species and position** for insects and other animals on campus
- Determining how to create a more **robust water system**
- Defining how to **include green and blue** in every project on campus
- Reviving the **Botanical Garden**
- Investigating options for the **Hammen Farm**

Projects, pilots and actions

- **Greenery roll-out plan** for the campus
- **Animal sanctuaries**: bird boxes, bat boxes and insect hotels on campus
- **Bees on campus**: placement of beehives and appointment of a beekeeper
- **Water storage** on campus: underground water storage, swamp areas, overflow areas
- **Permeable surfaces**: green or semi-open terraces, green or semi-open pavement
- **Water retention** on and in buildings: green roofs, polder roofs, sponge roofs, cisterns
- First projects of **rainwater** collection, storage and usage in buildings
- **Aquathermia** pilot: open water, wastewater and drinking water for thermal energy
- **Climate-adaptive building** pilot: a building dealing with heat and water

The TU Delft Campus has changed and improved a lot over the years. From now on, the guiding principle should be that every project contributes to biodiversity. We strive for a natural, biodiverse campus where people and nature co-exist. However, not only the biodiversity must be improved; the campus must also become climate adaptive, circular, healthy, and eventually climate positive. This chapter looks at the desired future situation and the campus and present. Consequently, specific actions, pilots and projects are proposed to reach this desired goal.

10.01 The sustainable campus of the future

In the future, the TU Delft Campus will be a natural, biodiverse, circular, self-sufficient, climate positive campus where people and nature co-exist. The campus will be embedded and connected to the green and blue structures around it. It will have a high biodiversity and will be an ideal place for trees and other plants, as well as for animals, especially insects. The right conditions have been created for them to ensure that they thrive. The campus has become less affected by flooding, drought and heat. In addition to using nature to become climate adaptive, various innovative projects are being conducted to guarantee this in the future as well. Projects test how to design climate-adaptive buildings, for example on stilts, floating, on mounds, or modular and movable. This is necessary to guarantee the viability of the campus in the future. The campus will become a living lab; researchers and students will see how the built environment is going to change within the next few decades due to climate change. TU Delft will internationally position itself as the place where researchers can test new necessary ways of – for instance – construction.

Figure 10.01: Example design of the sustainable campus of the future [image and design by Suxin Liaw]

10.02 The campus at present

The TU Delft Campus can be divided into three parts: TU Delft Campus North, TU Delft Campus Central, and TU Delft Campus South. The campus itself is larger than the inner city of Delft, stretching over 161 hectares. Mekelpark, the centre of the campus, has a green and park-like character and is only accessible on foot, bike, or public transport. Cars can use the campus ring road, which circles the entire campus; see figure 10.02.

Figure 10.02: Campus map of TU Delft

TU Delft Campus North
TU Delft Campus North is the most northern and oldest part of the TU Delft Campus. This area has been designated as a protected cityscape. The buildings are located between three green elements, the historical Botanical Garden (see later), the De Vries van Heijst park and the Jaffa cemetery, surrounded by the Zuidplantsoen. Not many new buildings will appear in TU Delft Campus North. An exception to this is 'yellow chemistry'. Here, a residential area will appear and the International School Delft is going to construct on this spot. In five years' time, RoboHouse will also leave its current location next to the Botanical Garden and move into its new building at TU Delft Campus South. Their current building should be renovated and can then be used as the location for Mercurius, the 'Waldorf school' of Delft.

TU Delft Campus Central
TU Delft Campus Central is the area around the Mekelpark and is the heart for all activities. Most of the faculty buildings are located here. X (Sports and Culture) and The Green Village also fall in this area. TU Delft Campus Central is also seen as the recreational area of the campus. A place where employees and students can go during their break or free time.

TU Delft Campus South
TU Delft Campus South is the area south of the Kruithuisweg. In the past, this area was mainly allocated to external companies, with the faculty of Aerospace Engineering, Reactor

Institute Delft and some labs as university facilities. TU Delft is currently expanding to this area itself, the Kluyver area becoming an important part of the campus. In 2021, CRE drew up an ambition document, in collaboration with Copper8. Andy van den Dobbelsteen and Deirdre van Gameren were also part of this team to ensure that sustainability is included, also regarding climate adaptation and nature inclusion. Flood Proof Holland is also located on TU Delft Campus South; this is a test and showcase location for temporary flood defenses and dike sensors.

Water management

Delfland, the region TU Delft is situated in, is the most urbanised water board area in the Netherlands. The campus is part of a larger polder system, the Zuidpolder and the Wippolder, in which the water needs to be regulated; see figure 10.03.

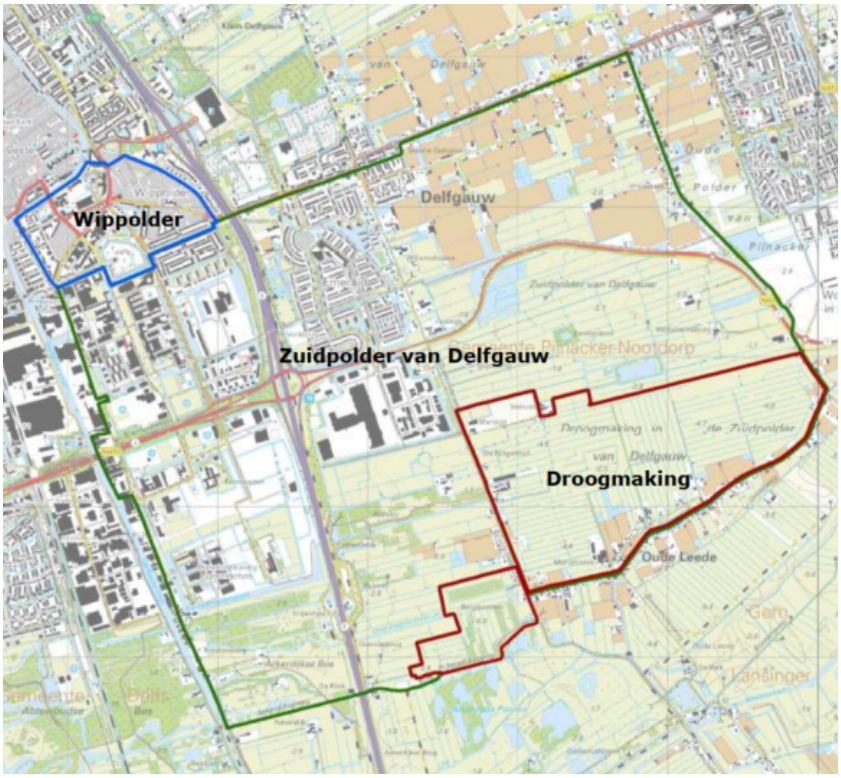


Figure 10.03: Polders connected to the campus

The polder must meet certain chemical and ecological water quality targets. The two polder pumping stations of the Zuidpolder and Wippolder are located to the west of the campus, making the campus the last part of the discharge area for the Zuidpolder of Delfgauw; see figure 10.04.
The southern part of the campus is lower than TU central. During dry periods, Delfland has external water sources outside the management area, but for a locally more robust water system it is desirable to also stimulate local freshwater supplies through innovations such as underground water storage.

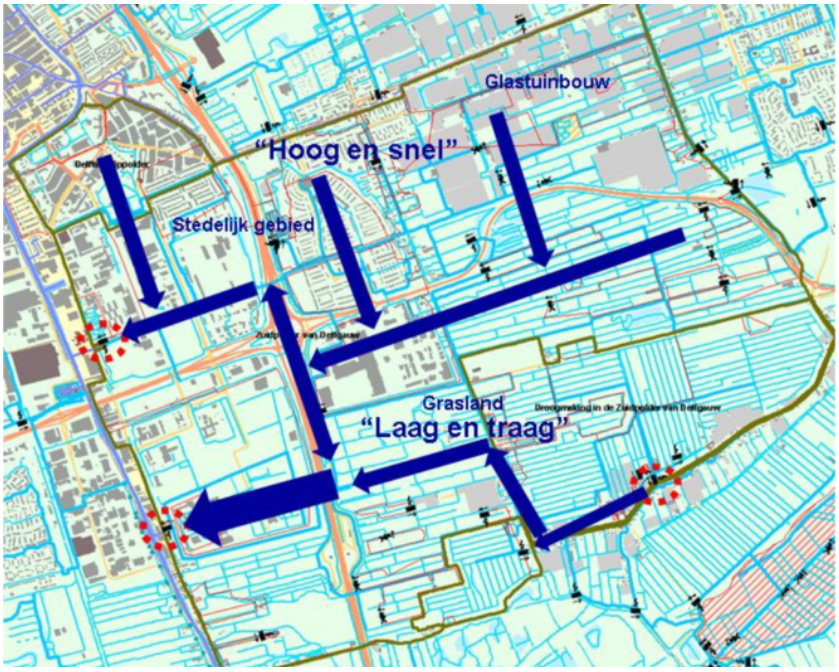


Figure 10.04: Schematic representation of the water system

Water-related living labs

Hitteplein
The 'Hitteplein' (heat square), a project on The Green Village, is currently testing three different innovations that can mitigate the effects of extreme heat and drought. 1. Rainroad: collects excess rainwater under the sidewalk or parking lot and allows it to evaporate in times of heat to moderate the temperature. 2. Bluebloqs: collects rainwater and purifies this with a biofilter. 3. Nature-Inclusive Shed: this shed has a green roof and collects rainwater. It offers space for insects (including butterflies) and bats and brings nature back into urban areas.

Waterstraat
Another project running on The Green Village is 'Waterstraat' (water street); this street can collect between 250-500 litres water per m^2. Dunea, Arcadis, and VPdelta have formed the Dutch 50-litre house coalition. Their ambition is to find affordable solutions that ensure a reduction in the need for drinking-quality water at home. The goal is to design a house where each person uses a maximum of 50 litres of water per day, which is now about 120 litres.

Polderdak
'Polderdak' (polder roof) is a current research project, from the water management department from Civil Engineering, which is conducted on the roof of their building. This research looks into designing the climate adaptive city, by creating a green-blue roof that can absorb heavy rainfall and combat drought. It also looks at energy savings and the possibilities of urban agriculture.

New water
There are two new open water bodies between the faculty of Civil Engineering & Geosciences and The Green Village. One is a water retention pond with ecological functions, the other is a straight water canal for hydraulic research.

Green on campus

Including the Botanical Garden, there are 2568 trees spread around the campus and there are 548,653 m^2 of plants and grass. This greenery can absorb 206 tons CO_2-eq [BTL 2016, as cited in Blom & Dobbelsteen, 2019]. In addition to absorbing carbon, trees also provide cooling.
There are already several green areas that can be seen as stepping stones through the campus. There are two green connections north to south, starting at the Botanical Garden: one via the Schoenmakersstraat and one via the De Vries van Heijst park, Architecture and the Jaffa cemetery, down along the Mekelpark, X and The Green Village, and then to the South Polder. The Botanical Garden is essential therein.

Biodiversity
Currently, the majority of the campus is quite low in biodiversity given its size. For example, a recent Bomenwacht report (10 November 2021, accessible via René Hoonhout) assessed the quality of all the trees on campus. This report lists 1040 trees representing 73 species, excluding the botanical garden. Of the 73 species of trees, 30 are cultivars. The botanical garden adds another 384 trees species, of which 15 are cultivars. Natural species, as opposed to cultivars, are most suited for use by wildlife, and planting them will increase the chances of attracting animals. In addition, the importance of increasing the diversity of species planted, whether native, non-native or cultivar, is more apparent now than ever before. Single species dominance locally, which is very common on campus and in the city of Delft, predisposes these urban forests to potentially devastating effects from the increasing number of pest and disease outbreaks.

Botanical Garden

The Botanical Garden plays a crucial role in the connection of greenery between the city and the campus. It connects to the city of Delft via the 'Singel' and the Schie canal. Nonetheless, this part of the TU Delft Campus was listed to be abandoned, which is a decision we propose to recall.

A brief history
In 2018, the Executive Board made a decision to (possibly) sell the Botanical Garden. The accompanying ambition document stated that the Botanical Garden no longer had any scientific value for TU Delft, which means that the current status and financing of the Botanical Garden will be finite for TU Delft (in the long term). At the time, this statement was based on the view that the education and research of the Faculty of Applied Sciences was not dependent on the Botanical Garden or that there was no use of the Botanical Garden. However, education and research opportunities of other faculties, of Delft in general, and of other partners involved in the garden were not considered. In recent years

there has been increasing appreciation of the Botanical Garden, especially by members of the faculties of Applied Sciences (AS), Architecture and the Built Environment (ABE) and Civil Engineering & Geosciences (CEG). This has resulted in a multi-faculty Task Force being given the official task in 2022 to explore several potential scenarios, with respect to retaining or selling the garden.

A sanctuary
The Botanical Garden is the most biodiverse area of the whole campus. There are 7092 living plant records representing 4985 plant species; 35 bird species have been recorded in the garden. The garden is an important stepping stone and connecting point of biodiversity, and the people connected to it have great knowledge about biodiversity. The Botanical Garden has been established and safeguarded by the Council of State as a highly valued area for the university as well for the city of Delft.

Open lab
It is used as an open lab for BSc, MSc and PhD students to carry out research, mainly by students from Architecture and the Built Environment and from Civil Engineering & Geosciences, but also from Leiden University and other research organisations. The Botanical Garden is also used for cradle-to-cradle studies and life cycle analysis. The advantage of the current location is that this research can be done in a protected environment, close to the city; it already is an open-air museum showcase for the general public, and has a strong historical collection.

Living labs related to green

Efforts have been made on campus to try and already improve biodiversity at the communities and ecosystem scales by not using chemicals to control weeds. In addition, flower mixtures are sown in certain areas, with flower types that naturally occur in this area, which makes a positive contribution to the insect population. More insects lead again to more birds. The campus is allowing nature to take its course, in places that do not have a destination yet, for example, letting sheep graze at TU Delft Campus South.

Climate arboretum
A climate arboretum has been built at the faculty of Architecture and the Built Environment. Research is conducted into the effect of different types of trees on the urban environment. Air and radiation temperature, humidity, and the evaporation of the trees are measured here. This project ends in 2022, at that moment the trees will belong to René Hoonhout from the management and maintenance department of CRE. He will plant the trees on campus.

Carbon impact

As mentioned in the Green on Campus chapter, it was calculated that in 2018 and 2019 the trees and plants on campus absorbed annually 206 tonnes of CO_2-eq. However, this is only 0.4 % of the total CO_2-eq emissions from activities on and from the campus. In order to achieve the target of being carbon neutral by 2030, part of the emissions emitted must be

compensated for. There are avoidable and unavoidable carbon emissions, compensation is needed for the unavoidable emissions. This can be done in various ways, one of which is planting trees.

10.03 EcoCampus approach

Climate adaptation

The environment is changing due to anthropogenic greenhouse gas emissions that impact the global climate system. Climate mitigation and climate adaptation are needed to keep the planet and our campus viable in the long term. Several challenges arise due to climate change. In the near future, the campus has to deal with extreme weather conditions that will cause drought, flooding, heatwaves, and extreme wind conditions. The long dry periods will cause a reduction in the water table, which leads to extra land subsidence. The TU Delft Campus has already experienced subsidence over the past decades, due to which pavements had to be renewed (heightened and repaved) several times. This happened most recently underneath and next to the faculty of Civil Engineering & Geosciences.

Figure 10.05: A different map of the Netherlands due to climate change: a future possibility

The water challenge
Due to climate change the water level will rise and it is possible that in the long run the Netherlands will be partly flooded; see figure 10.05. As a technical university that wants to maintain its position, it is our responsibility to help solve this societal problem.

Figure 10.06 (by Landscape Architecture graduate Suxin Liaw) shows that TU Delft Campus South and a part of TU Delft Campus Central are more prone to flooding. It also shows that paved areas contribute to the urban heat island effect. Another change found in the ecosystem is the displacement of original nature by exotic species. The campus, landscape and buildings are not designed to cope with this, but they will have to be in the near future. The elaboration of a sustainable water system – in collaboration with the Delfland water board (Hoogheemraadschap Delfland) – will therefore be one of the priorities in the coming years.

Figure 10.06: Water and heat key challenge map [Liaw, 2021]

To be investigated further: EcoCampus design

Looking beyond 2030
On the 7th of December 2021, the EcoCampus team came together for a co-creation workshop. During this workshop, we discussed a new campus vision partly based on the plans of Suxin Liaw. The technique of backcasting was used, just as in this document. It is important to realise that a campus vision should not be focussed on the period until 2030 but on the coming 100 years, taking into account spatial adaptability. During the session, the participants' initial focus lay on adaptations to the current system, while climate change

requires a new view on the overall plan, for which taking a step back was necessary. This became the starting-point of the workshop.

Four targets

Four 'technical' targets were defined for the campus' future: climate adaptive, carbon regenerative, biodiverse and sustainable in real estate. These targets will have to go hand in hand with the involvement of the campus community, as elaborated in the eponymous part of this report. In the new plan, these four goals need to be reached in interaction with each other, understanding they have different speeds. For example, at present, there is an urgent need for student housing but later, high water may come. Nonetheless, it is crucial that future circumstances are already taken into account so that in a few years' time no extra investments are needed to either renovate the buildings or to demolish them and build new flood-proof ones. This means that real estate strategy on the campus needs to be approached already today with the perspective of the three other targets.

Three zones

Based on the analysis of Suxin Liaw, the campus is divided into three zones; the marshy lowlands of Campus South, the largely petrified area of Campus Central, and the lush forests of Campus North. See figure 10.07.

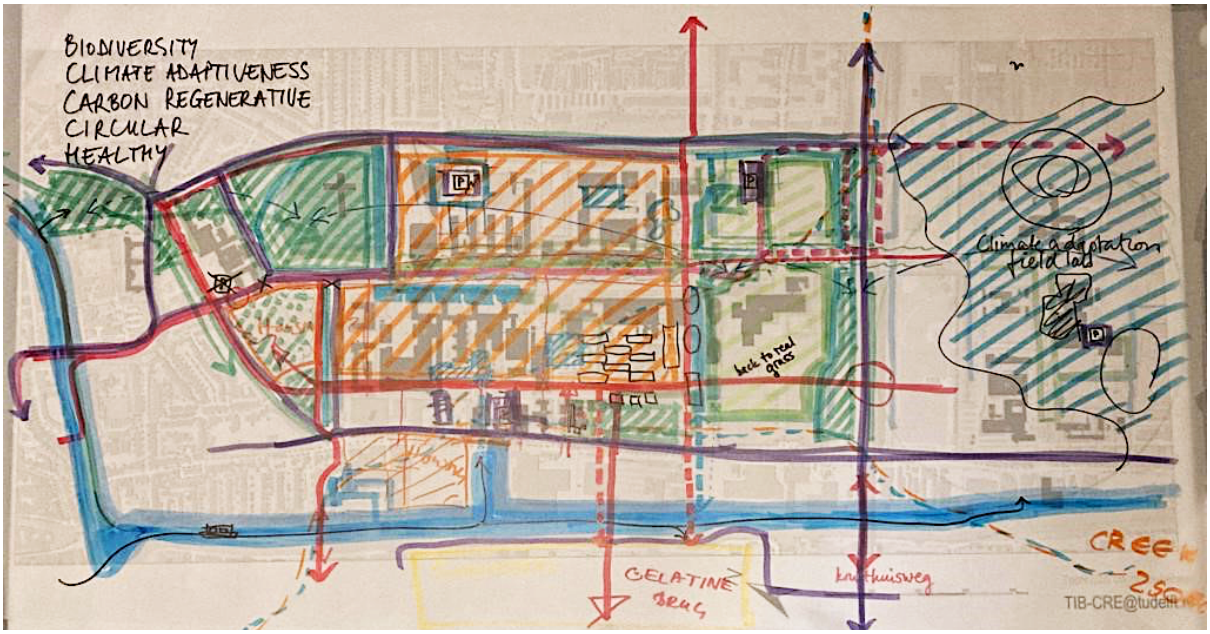


Figure 10.07: Sketch map of the EcoCampus workshop [Liaw, 2021]

Campus South

The university could use Campus South, which is lower than the other parts, to learn about climate adaptation, as a true living lab. Multiple faculties and researchers can conduct research into topics such as climate-adaptive buildings and infrastructure. By not controlling

the water, the university will internationally become the place for climate-adaptive research.
The sports area, which lies between Campus South and Campus Central, should use real grass for better water management. Around the edges, biodiversity must be increased.

Campus Central
At present, Campus Central can be defined as the stony, desert-like area with most of the sustainable real estate. All buildings here must meet the 4 targets mentioned above; especially the retention of rainwater and realisation of more urban greenery deserves attention. In addition, buildings should be designed in such a way that they can be used for multiple purposes: housing, offices, schools, etc. Campus Central is designed as a slow area for pedestrians; the road around the centre is for cyclists (red lines in figure 10.07) and cars (purple lines). To improve traffic flows, Leeghwaterstraat will become a bicycle path that is connected to the other side of the Schie (with the new 'Gelatine bridge') and to Campus South (through or around the Kruithuisweg dike). In addition, the Schie can also be used for transportation by taking the electrical water taxi, which is currently tested to connect Delft Central Station to the campus. Next to heavy rainfall the campus must prepare for very dry summers and it needs to store more water. Especially Campus Central would be a good place for this, for example by adding water squares just as in Rotterdam, by introducing multifunctional cisterns, or by implementing technology successfully developed on the Waterstraat of the Green Village.

Campus North
Campus North offers large trees and parks that ecologically connect TU Delft, via the Botanical Garden and Schie canal tree lines, to the Delftse Hout woods. The Julianalaan, also the residential part, should be mainly a bicycle route, linking the city centre and eastern part of Delft to the campus, the Leeghwaterstraat in particular.

10.04 Specific projects, pilots and actions

Already lot of research and education activities related to water management take place on the TU Delft Campus. This is less so for non-water related climate adaptation, green and biodiversity. A first general recommendation would be to elaborate the plans initiated by the EcoCampus design workshop. The projects, pilots and actions proposed here come in addition to what is already happening.

Every project from now on
In every area development project, renovation project, or new construction project research must be done into the possibility of adding greenery. All buildings must be scrutinised and consideration must be given to green and blue interventions.
Utrecht University has a special biodiversity officer; perhaps TU Delft should appoint one too.

Water management

Water buffering
Measures in the area of water are needed to improve the sustainability of the campus, especially to make the campus climate-adaptive. The campus must be able to buffer larger quantities of water. This is necessary to prevent flooding and the water stored can be used in times of drought. We recommend that the university invests in water storage, overflow areas, and adding greenery to increase water storage, to reduce the run-off speed and to limit flooding. The Botanical Garden is a relatively vulnerable area of the water system. If it stays in its current place, research can be locally done into making the area more robust.

Swamp areas
There are already some wadis on campus, but these are now used as overflow and not as real wadis. In addition, certain areas of the campus should be designed as swamp areas to collect rainwater. Campus South would be the ideal place for this because this area is most prone to flooding. It will also improve biodiversity on the campus. This experiment or living lab can be executed in combination between Flood Proof Holland (led by Martine Rutten) and the ECOCampus 2.0 course (led by Nico Tillie).

Flood-proof buildings
As discussed in this chapter, the university must build and design climate adaptive buildings. At the moment, the construction projects and processes are still very traditional, with traditional foundations. Research must be done into the design and construction of climate-adaptive buildings, on stilts, floating, on mounds, or modular and movable. This is necessary to guarantee the continuity of the campus.
Starting today, plans for renovation of existing buildings of new buildings on the campus should result in a showcase for climate-adaptive estate and thereby position the TU Delft as a world leader in climate action. A pilot project could be started that looks into the possibility of building flood-proof student homes in the lowest area of the campus.

Water collection on buildings
In addition, the roofs of the buildings can be used to collect rainwater. This reduces the run off, which is beneficial for management of excess water. The water collected can be used to reduce the demand for clean drinking water used for flushing toilets, cleaning, watering plants, etc. Of course, this solution needs to be technically elaborated and attuned to every specific situation and building.

Valuable extractions
Valuable substances can be extracted during the cleaning of waste water. For example, algae can clean waste water and produce biodiesel at the same time. Biogas and CO_2 can also be extracted by adding a digester. This results in 20% of water saving [Blom & Dobbelsteen 2019]. Research must be done into the best way to extract nutrients from water.

Circular water system

For her master thesis, Suxin Liaw looked into the possibility of making a biodiverse, climate resilient and playful TU Delft Campus. She designed a closed-loop circular water system that the principles mentioned above: local storage, purification and storage and reuse. With this plan, the campus becomes a living water machine, see figure 10.08. The master thesis of Suxin should be carefully looked into in the next development stage of the campus.

Figure 10.08: Campus water system map [Liaw, 2021]

Thermal energy

Thermal energy can be extracted from open water with a heat exchanger, in combination with a heat pump and a thermal energy storage system; see figure 10.09.

The Schie canal, pumping station Zuidpolder, and the sewage pumping stations at Watermanweg and Zuidplantsoen are examples of locations to extract aquathermal energy. A thermal energy storage system is needed due to the fact that the temperature of the surface water is opposite to the seasonal demand. The extraction of heat from open water

in summer contributes to the improvement of water quality and to cooling of the adjacent urban area [Kruit et al. 2018]. In winter, the extraction of aquathermal energy (e.g. for space heating) increases the probability of frost, which makes ice skating a possibility. The Schie canal has a cold potential of 4,000 MWh_{th} per year, due to her depth of 2 metres and a width of 27-45 metres. The pumping station has a cold potential of 10,000 MWh_{th} per year [Scholten 2018, cited in Blom & Dobbelsteen 2019]. Thermal energy can also be extracted from waste water from the sewage (mainly heating) and from drinking water (mainly cooling).

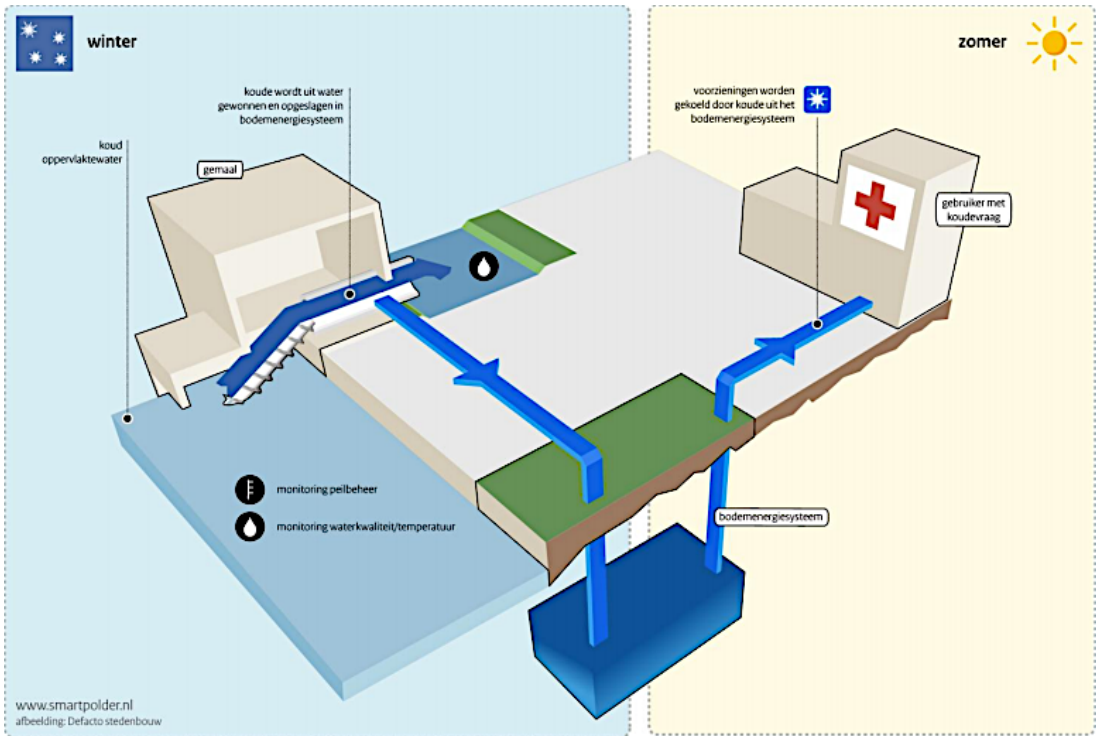


Figure 10.09: Principle of smart pumping station [source: www.smartpolder.nl; Defacto stedenbouw]

Water purification

Useful components can be extracted from waste water. Research must be conducted into the different types of systems, helophyte filters, aeration, digesters, algae, and other types of filters and how these systems can increase the biodiversity of the environment.

Biodiversity

There is a dire need to improve biodiversity of the campus in order to have a healthier ecosystem. Diversity means a variety range or difference, and as such exists among alleles, individuals, populations, ecotypes, taxa, communities, and ecosystems. Biodiversity is frequently used as a shorthand reference to species diversity, but diversity should be considered at all levels. Species populations need genetic variation for survival, good growth and viability in the long term. It enhances resistance to acute and chronic stressors, such as pests and diseases, and the effects of climate change. An integrated approach to increasing biodiversity by planting multiple individuals of the same species with variable genetic

diversity could add a dynamic element to a green campus. This would make Delft a true green living lab where not just every building is part of a long-term study, but also every plant. This could create future studies on the climate adaptability of the urban green biodiversity and complement projects such as the climate arboretum.

Connection to the campus

Two green axes are extended to the Kluyvergebied. Currently, these connections are made from the inside out. However, TU Delft must create green and blue connections from the outside in: use the biodiversity that is found in the Akkerdijkse polder, Abtwoudse polder and Delftse Hout, and create stepping stones from the outside to the campus inside (see figure 10.10). Delft Campus train station is currently under development. This idea of creating green and blue stepping stones must be included in those plans.

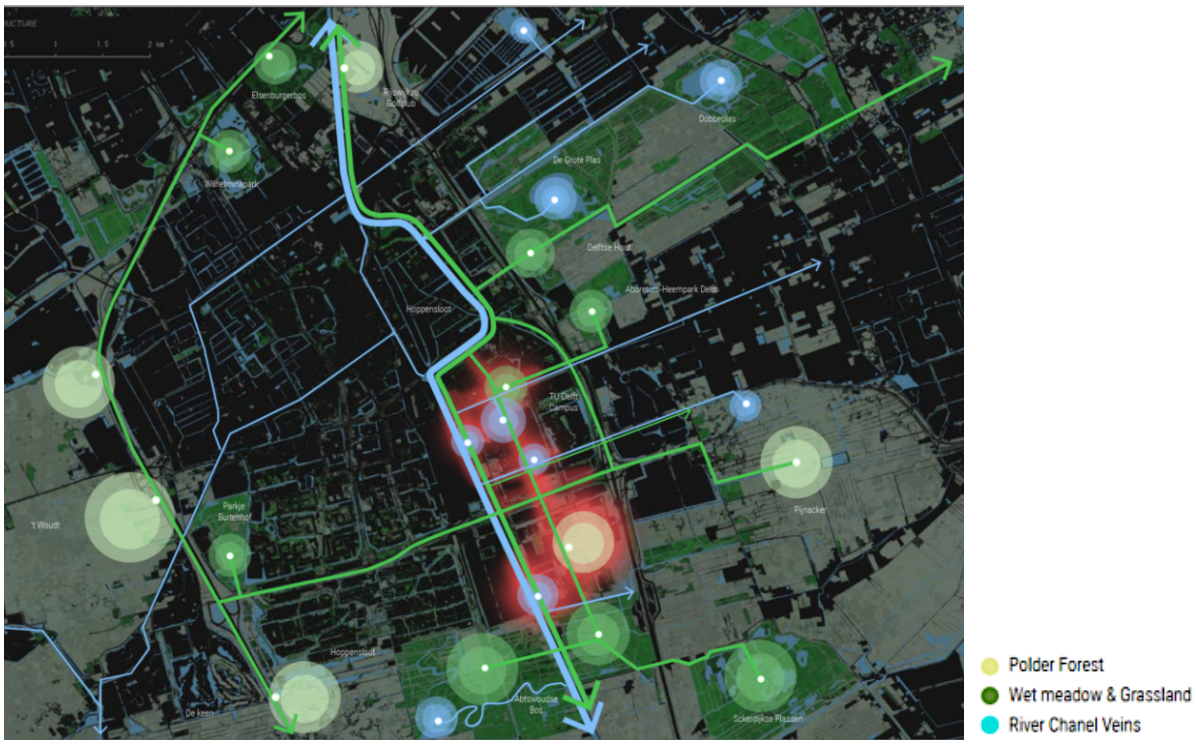


Figure 10.10: Delft city green-blue network vision [Liaw, 2021]

Green and blue corridors

Suxin Liaw created a design that strengthens green and blue corridors within the campus that connects the campus to the surrounding landscape; see figure 10.11.

At Utrecht University 6,000 indigenous trees and shrubs are being planted to enhance biodiversity. A similar approach should be undertaken in Delft to enhance the green connections across the campus.

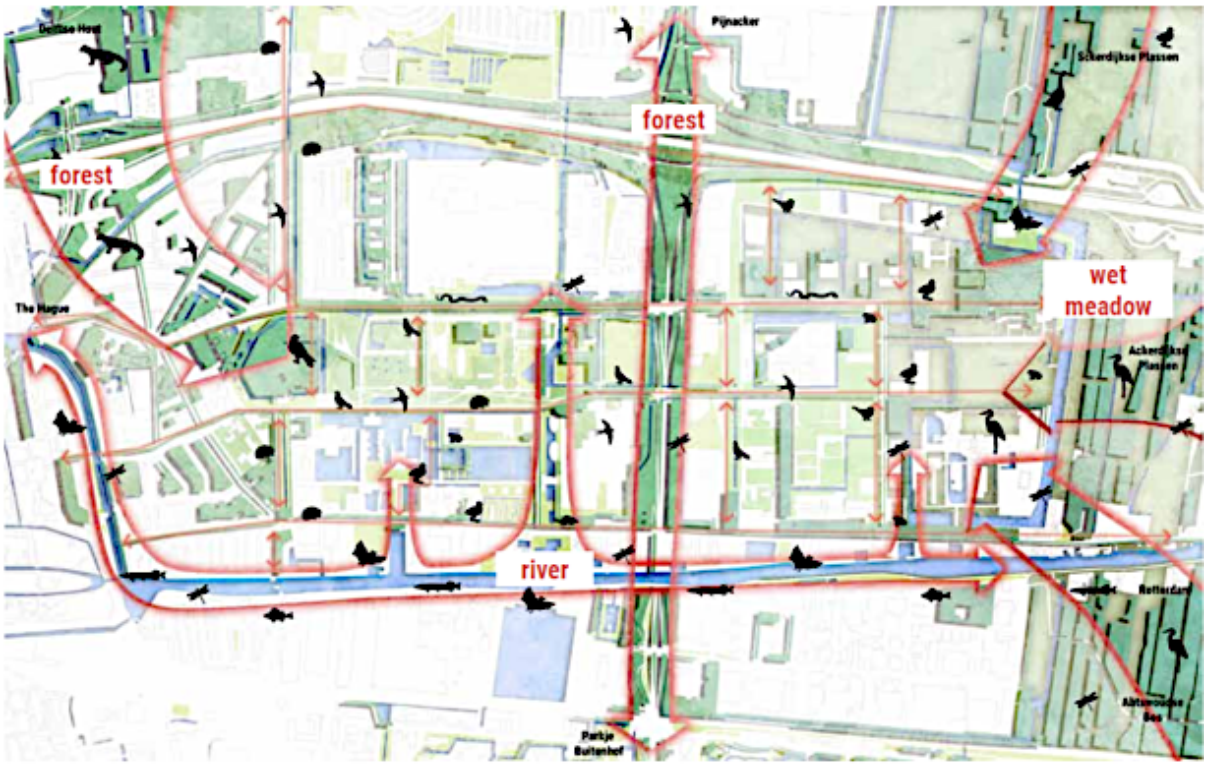


Figure 10.11: Ecological campus map [Liaw, 2021]

Integrated approach
The university should develop and adopt an integrated approach to increase the diversity of trees, and other plants, and animals, among which insects. Research must be done into the right plant species, where to plant them, and their relation to animals and insects. Bird boxes, bat boxes, and insect hotels must also be placed on the campus. Special attention must go to the orientation and location of the various boxes and hotels.

Bees
The university could even appoint its own beekeeper. However, current research shows that it is likely that the honey bee competes with wild bee species for the limited food resources provided by flowers. The university should therefore not focus on the honey bees but on creating the right circumstances for the wild bees, first and foremost by favouring the growth of multiple and diverse local wild flowers at high scale. If there is already limited food (flowers), adding eaters (honey bees) will not help, so the growth of extra flowers is essential [Goulson 2020].

Other fauna
Together with the Netherlands Institute of Ecology (NIOO-KNAW) the university also conducted research into the great titmouse. Around 40 bird boxes were placed, which are currently all full. Further research is needed into the expel of original nature by exotic species e.g. American crayfish, tiger mosquitos.

Green as carbon absorber

As previously mentioned, there are already a few green stepping stones at the campus that currently absorb 206 tonnes of CO_2-eq annually. In addition, more unavoidable carbon emissions can be absorbed by adding peat on the campus.

Peat

Peatlands actually have enormous power for carbon storage, much more so than forests: this biotope can potentially absorb 5-9 tonnes of CO_2-eq per hectare per year with an average water level of 5 cm below ground level. Restoration of peatland is therefore attracting worldwide attention in efforts towards climate action [Gewin 2020].
At present, there is no peat on the campus. Research should be done into the possibilities of adding peat on the campus and its benefits of absorbing CO_2, retaining water, abating soil subsidence, creating a biotope suited for this geographical location.

Fast-growing trees

Some trees grow faster than other trees. These fast-growing trees are used to create coppice forest. TU Delft should research the possibilities to use this forest as a carbon absorber. Prerequisite for net carbon absorption is that if this wood is cut, it will not be incinerated as fuel but used for bio-based products (for example included in real estate plans for the campus), while new fast-growing trees are planted. This is the only way to create a negative CO_2 emission balance.
Currently, it is impossible to bike at certain places on the campus when there is extreme wind. Adding trees can also help to diverge this wind and create better circumstances.

Green in urbanised areas

Greenery should not only be planted in nature, but also into hard surfaces such as green roofs, green facades, green terraces, open (green) paving, and residual greenery.

Heat stress reduction

Adding greenery in (urban) areas also prevents heat stress. Heat stress is common in urban areas due to the fact that these areas are largely made up of asphalt and concrete, which are materials that retain heat. This is enhanced by heat from traffic and air conditions. To combat this extreme heat, the university must create green-blue buffers. Trees, shrubs, and grass have a cooling effect because the greenery absorbs less heat and creates shade. Also, water features provide cooling.

Green pavements

Cattail (‘lisdodde’ in Dutch) and olivine can be used for open paving, for example. In addition to increasing biodiversity, this will also reduce the runoff speed, which is good for the water system. Research is needed to find out whether the CO_2 absorption of olivine outweighs the transport from Italy.

Composting
The remaining food waste, organic waste, from the campus, can be turned into compost. The compost can for example be used as fertiliser on the campus, not just for campus facilities but also for the users of the campus, bringing their organic waste to campus. Currently, this process takes place outside the campus because the quantity is too small. The TU Delft could collaborate with primary schools to increase the quantity and use this as in pilot project to show how this principle works.

Student projects
As already mentioned in this document, Nico Tillie offers a course called ECOCampus at the faculty of Architecture and the built environment. During this course, the students use the TU Delft campus as a case study. In the past year, his student developed several plans for the campus including ideas for a peat garden and a Greenwall or green roof for the Bouwpub. There should be an interfaculty EcoCampus studio where all the plans, including the ones from the graduation studio Delta Future Lab, are collected and linked to CRE's plans and overarching campus strategy.

TU Delft Hortus Botanicus

As previously mentioned in this document, the Botanical Garden is an important stepping stone, ecologically and societal, between the city of Delft and the TU Delft campus, thereby a hub of possibilities for outreaching activities. It also represents, by far the largest source of biodiversity on campus. Finally, it is playing an increasingly important role in climate action-related research. The Botanical Garden therefore appears as a unique green vitrine for TU Delft's climate action.

New energy, new plans
In July 2021, the Botanical Garden appointed a new managing director, James Byng, who developed several plans for the garden. James renamed the Botanical Garden to TU Delft Hortus Botanicus. Plans to improve the hortus include:

- strengthening the connection to the canal and the city by placing an entrance on the Kanaalweg;
- a sustainable hospitality service providing freshly roasted coffee beans to other coffee outlets on campus;
- renovating the historic glasshouses;
- replacing the smaller glasshouses with innovative solar-panelled roofed glasshouses (rooms for events and lectures);
- converting a storage unit into a small carbon-negative shop, toilet, and office block with green wall.

James Byng envisions the Hortus Botanicus complimentary to The Green Village and would like it to become a better showcase for TU Delft because of its ideal location and its important outreach functions with the general public.

Meeting place
The new plans show that the TU Delft Hortus Botanicus could be designed and advertised in a way that, like many other urban botanical gardens, it will become an important meeting place for staff and students during the week (with a beautiful venue for high-key guests), and for the public during weekends (without increasing the yearly budgeted costs) thereby playing an important social role.

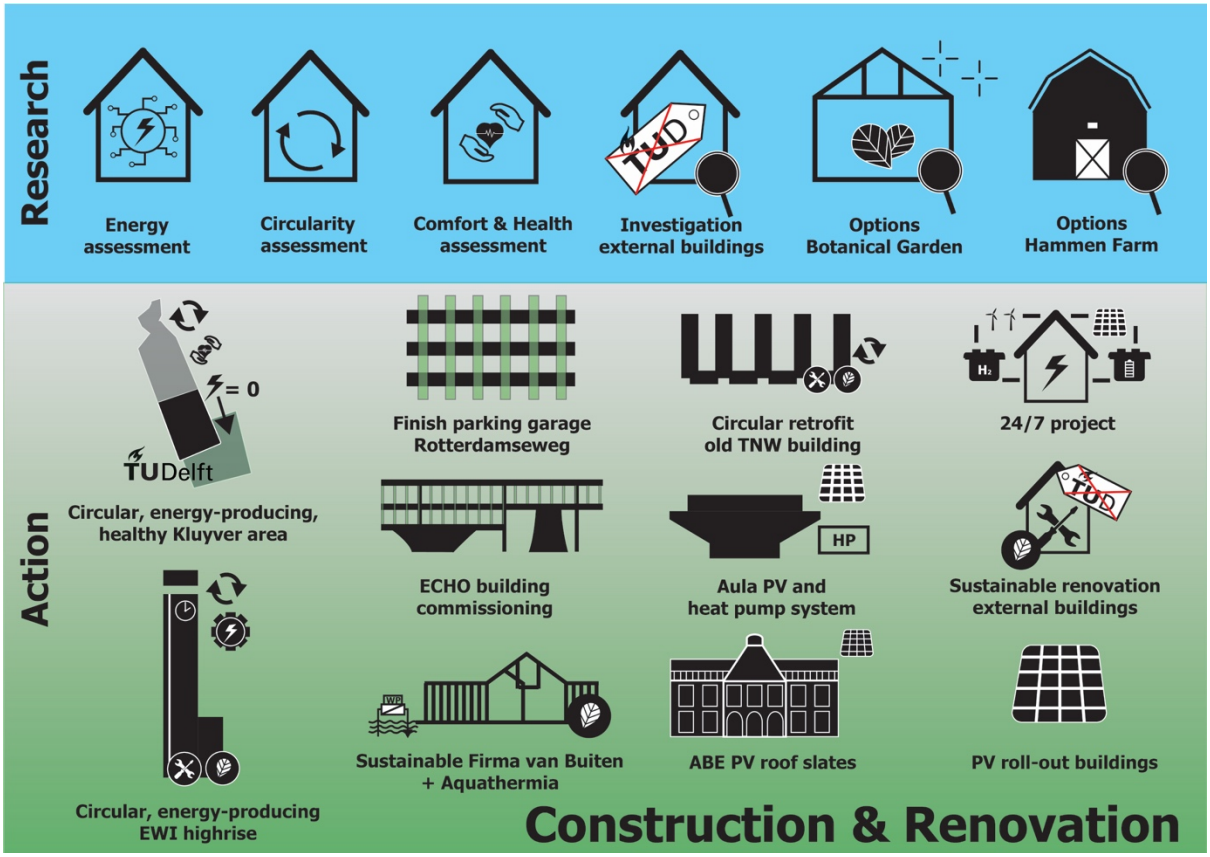
Research related to climate, health, biodiversity and biobased materials
The garden can focus on societal and scientific challenges such as climate adaptation (water retention and heat mitigation), air purification, carbon sequestration, microclimate improvement, new biobased (circular) materials, biodiversity and conservation, and (wild) genetic diversity, and climate change, by introducing species that fit the new future climate scenarios better. The TU Delft Hortus Botanicus must be linked better to ongoing research projects of the university, in addition to existing links, nationally and internationally. Additional capacity for research projects has already been achieved by converting a room in the historic glasshouses for lab space, to be used by students whilst working on projects in the garden. In December 2021 this space was filled daily with students from Technology Policy & Management (TPM), Civil Engineering & Geosciences, and the Naturalis Biodiversity Centre. Further research projects are expected from Architecture and the Built Environment, which is a growing stakeholder in research performed at the Botanical Garden in the field of sustainability, with substantial societal impact. Examples are the Urban Forestry and Urban Ecology groups, the current Climate Arboretum project, and fine dust and ultrafine dust research related to environment and health, by the Architecture Engineering + Technology department.

Of great importance to TU Delft
Given that the two greatest crises facing humanity today are environmental – the biodiversity crisis and the climate crisis – a botanical garden is of huge value to a technical university searching for solutions to both of them. In addition, the TU Delft Hortus Botanicus is the biodiversity hub for the city, which can showcase the university and is a perfect location for students, staff and city residents to reduce stress in difficult times amongst a green setting.
The Task Force constituted to investigate the future of the TU Delft Hortus Botanicus will present their advice in 2022, followed by a decision by the Executive Board.

11 Construction & Renovation

Team (in alphabetical order)

- Ruud Balkenende – IDE
- Andy van den Dobbelsteen – TU Delft sustainability coordinator
- Deirdre van Gameren – TU Delft sustainability researcher
- Bob Geldermans – ABE/CRE
- Tillmann Klein – ABE
- Hubert Linssen – CRE sustainability coordinator
- Gilbert de Nijs – CRE
- Barbara Olde Bijvank - CRE
- Sander Snelleman – CRE
- Gillis de Wit - GreenTU



Construction & Renovation
Main proposals

General aims and principles

- To make buildings on campus jointly **'Paris proof'**
- To make **new buildings** energy producing, circular and climate adaptive
- To **avoid demolition** on campus
- To renovate **existing buildings** to (nearly) zero energy
- To make 50% of buildings on campus **energy neutral**
- To renovate existing buildings in a **circular** fashion
- To make **technical maintenance** circular
- To involve **external parties** on campus in the sustainability plans of TU Delft
- To use **total cost of ownership (TCO)** for financial decisions in building projects
- To create possibilities for (temporary or permanent) **living labs** in all buildings
- To involve **researchers and students** in building projects

To be investigated

- Executing an **energy assessment** of all buildings on campus (WEii)
- Performing a **circularity assessment** of all buildings on campus
- Performing a **comfort and health assessment** of all buildings on campus
- Investigating **external buildings** on campus
- Investigating options for the **Hammen Farm**
- Extending the **24/7 project** to TGV and campus
- Contributing to sustainable renovation of **external buildings** on campus
- Investigating the circular retrofit of the **old TNW building** with new purpose
- Elaborating the **Aula** PV and heat pump system
- Using the **ABE faculty building** as PV slate roof pilot
- Designing experimental **hospitality pavilions** in the Mekelpark

Projects, pilots and actions

- Finishing the **Rotterdamseweg** parking garage project
- Delivering the **ECHO building**
- Making **the Kluyver area** energy-neutral, circular, climate adaptive, with living quality
- Contributing to the sustainable **Firma van Buiten** building project
- Executing recommendations from the **PV on campus** study
- Deliver the **EWI highrise** as circular, energy-producing tower
- Writing **individual action plans** by all faculties and supporting divisions
- Starting up the **Innovation Budget** and commissioning first co-funded projects

The TU Delft Campus continues to develop. In order to achieve the set ambitions by 2030, carbon neutral, circular, climate adaptive and contributing to quality of life, both current buildings and new ones must be carefully examined and designed. This chapter looks into the desired situation and the current performance of the buildings on campus. Subsequently, renovation is compared to demolition and new construction. Finally, an analysis is presented of the buildings at present, a new policy is put forward, and specific projects and actions are proposed.

11.01 The desired future stock

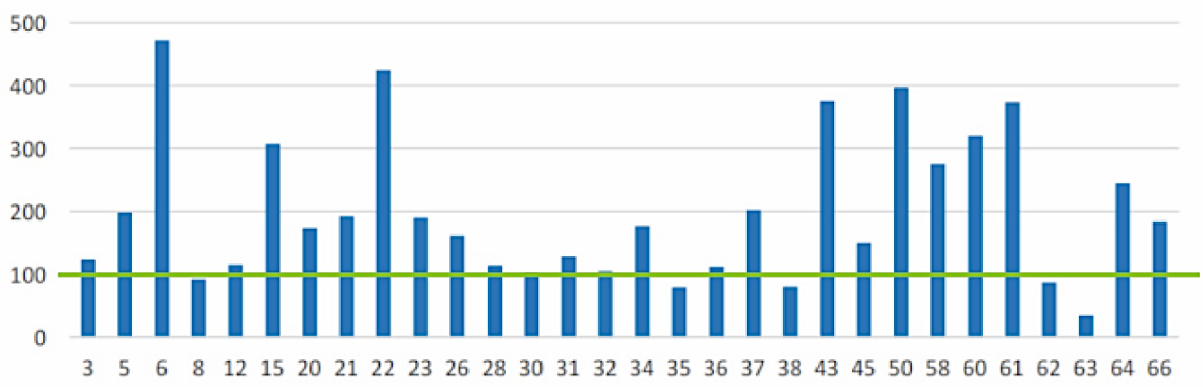
In the near future, all new buildings built at TU Delft are carbon-neutral, circular, climate adaptive and contributing to quality of life (nature and health). Existing buildings have been renovated to the highest possible sustainability standards. This means that they meet the set KPIs for climate action. The buildings on campus use a smart, self-learning building management system that optimises the energy demand and supply. This system monitors the performance continuously and makes adjustments when needed. There is also a strong focus on health and comfort, as well as user satisfaction. The problem of cooling has been tackled in several ways. Various innovative techniques are used, both passive and active, such as aquathermal energy from open water, absorption cooling, and plants on for example facades and roofs.

11.02 Performance of buildings at present

Energy use

The energy consumption of the 33 buildings of TU Delft is measured every month, divided into gas consumption, heat supply, and electricity consumption. The total energy consumption per square metre of the main faculty buildings monitored in 2018 are shown in figure 11.01. The majority of buildings does not comply with the KPI of 100 kWh/m^2 and there are great differences [Blom & Dobbelsteen 2019].

It is not clear how much energy is used for which purpose: appliances, air-conditioning, light, computers, etc. This should be further investigated for all faculty buildings, supporting division buildings, and labs.
Next to TU Delft's Energy Monitor, which keeps track of the energy use by the different buildings, three external companies – Van Dorp Installaties, Spie and JP van Eesteren – are currently conducting an EED (European Energy Directive) analysis to determine a more detailed image of the energy use per building and potential quick wins.
It is ever more important not to concentrate on the designed energy performance, but to look at the real use of energy and act by that information. WEii can be a useful tool. WEii is the Dutch acronym for 'Werkelijke Energie-Intensiteit Indicator' (true energy intensity indicator), an energy intensity indicator tool that uses the measured energy use and floor space of the building. Figure 11.02 illustrates this performance by building label colours.



3.	Science Centre Delft	34.	Mechanical, Maritime and Materials Engineering
5.	Robovalley - Robo House	35.	Education Building
6.	Botanical garden	36.	Electrical Engineering, Mathematics and Computer Science
8.	Architecture and the Built Environment	37.	X
12.	Chemistry Building	38.	Culture Centre
15.	Kramers Laboratory	43.	Combined Heat and Power Plant
20.	Aula	45.	Low-speed Wind Tunnel Laboratory
21.	TU Delft Library	50.	Reactor Institute Delft
22.	TNW Physics	58.	Applied Sciences
23.	Civil Engineering and Geosciences	60.	Logistics and Environment
26.	Bouwcampus	61.	Delft Aerospace Structures & Materials Laboratory
28.	Mathematics & Computer Science	62.	Aerospace Engineering
30.	Campus and Real Estate	63.	SIMONA Research Flight Simulator
31.	Faculty of Technology, Policy and Management	64.	Aerodynamics and Propulsion Laboratory
32.	Industrial Design Engineering	66.	The Fellowship

Figure 11.01: Energy use per m^2 of the faculty buildings

Carbon impact

At the moment, the energy use on campus is the second greatest factor in TU Delft's carbon emissions, and this energy is primarily used – directly or indirectly – in the buildings. According to the CO_2-prestatieladder calculation rules, the electricity purchased from wind power has no carbon emissions to be accounted for TU Delft[16], so all emissions from energy use are related to the use of gas – directly, in boilers, or indirectly, in the cogeneration plant that feeds the heat network of TU Delft – and other fossil fuels (petrol and diesel, e.g. for vehicles). Although the carbon emissions are zero according to the CO_2-prestatieladder calculation rules, it does not mean that that the energy of wind farms is carbon neutral. Carbon is for example still released during the production of the windmills themselves. It is likely that in the future more companies want to buy wind energy to compensate for their carbon emissions as well. This means that the price for wind energy will go up. The university must invest in other ways of sustainable energy to make sure she can generate her own energy and is not dependent on other suppliers. This can be done for example by installing photovoltaics (PV) on the campus and using geothermal heat. More information about this can be found in chapter 12.

[16] In the earlier method used for the CO2 Roadmap TU Delft, some emissions were accounted for the production of wind turbines. These are now only allocated to the energy company.

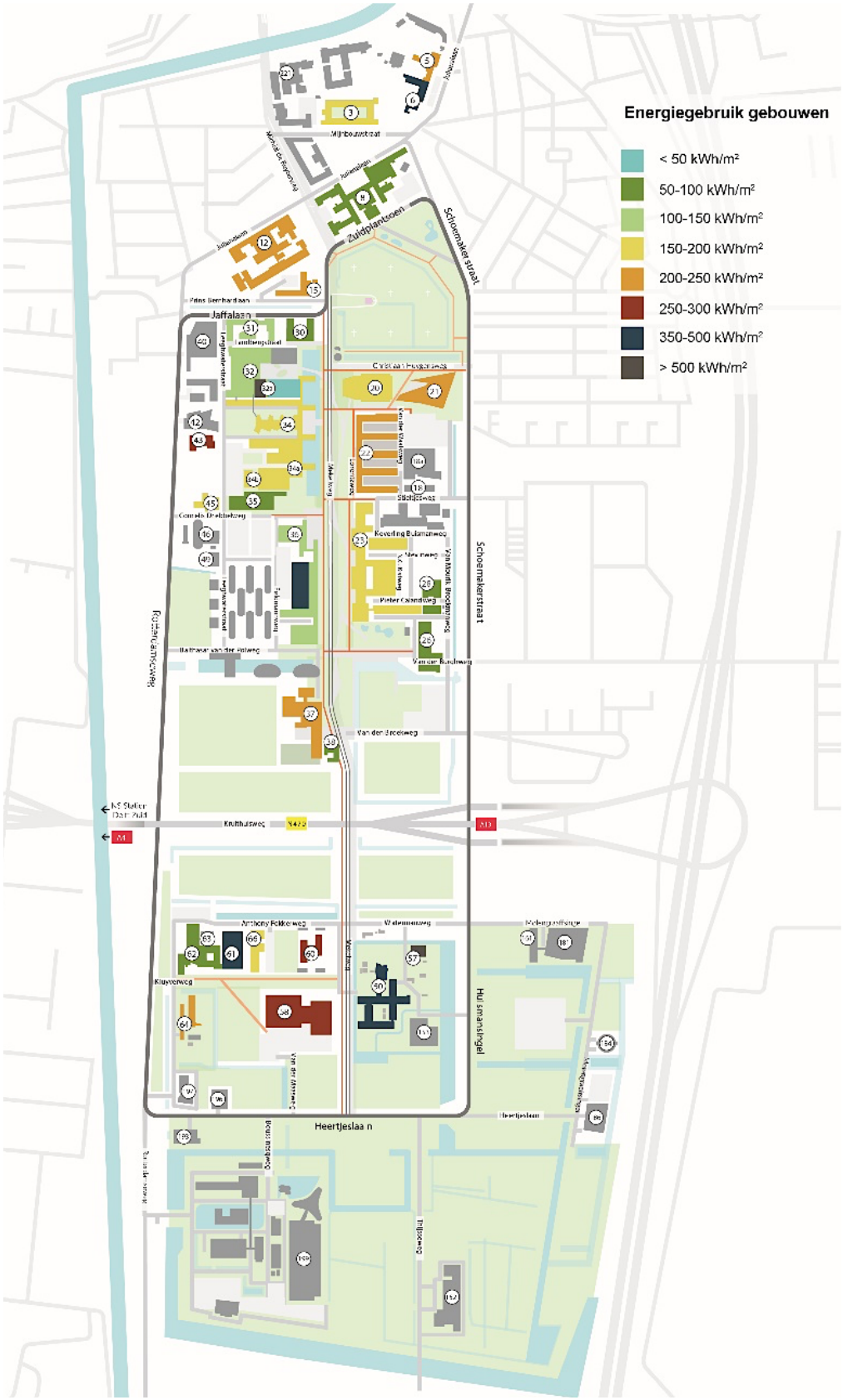


Figure 11.02: Energy use per faculty buildings

So, it is fair to say that by estimation, the buildings on campus are responsible for the greatest emission of CO_2, and therefore need to be seriously tackled by reducing the energy demand by means of changing human behaviour, smart building management and energy renovations that make buildings efficient and more energy-producing. Furthermore, energy-neutral or energy-producing new buildings should replace energy-consuming old ones.

Material use in buildings

Currently, there is no clear overview that shows the type of materials and quantity of materials used in the buildings of TU Delft. For the building of Electrical Engineering, Mathematics & Computer Sciences (EEMCS), Metabolic has made an inventory of materials and potential reuse routes, while comparing the impact of different design and renovation choices. Essentially, in order to get a complete overview of the materials used by – and embodied in – TU Delft, an inventory is needed for all other buildings[17]. Such 'material-ID cards' facilitate a streamlined material exchange, according to the most optimal circular strategy at a given time.
New materials need to be designed, produced, and applied with circularity in mind, and materials from existing buildings should be processed in a circular manner during maintenance cycles and end-of-use stages. This way, the circular potential of materials, products and buildings can be valorised. The R ladder (see Chapter 13) must become a standard tool to guarantee circularity in material flows, together with pace layering. With pace layering (so-called 'S layers'), a building is seen as a dynamic set of components with different timescales and durations of use. A connection must be made with national initiatives, in particular CB'23, to develop a harmonised system that is used by everyone. In order to make this work, harmonisation is also needed in terms of terminology and definitions.

Ventilation & Covid-19

Ventilation is an important aspect of the energy use of buildings, hence for carbon emissions, and for the comfort of their users. Moreover, the Covid-19 pandemic has made clear that attention must be paid to air refreshment and ventilation systems in TU Delft buildings, also for potential future pandemics. Research must show whether these meet the new requirements. Experts on campus, such as Atze Boerstra (Building Services Innovation) and Philo Bluyssen (Indoor Environment), will be approached for this.

11.03 Important deliberations

Renovation versus new construction

Blom & Dobbelsteen [2019] concluded that the construction of a new building means three times as many CO_2-eq emissions compared to a well-functioning building after renovating that building, see figure 11.03. This is because a large part of the embodied energy comes

[17] Such an inventory should be done step-by-step, starting with the buildings that are on the top of this list for renovation and deconstruction / demolition (see section 06.03)

from constructing the building, followed by the building envelope, and finally the building services and interior walls; see image 11.04 [Blom & Dobbelsteen 2019]. Therefore, in most cases (unless the technical state and energy performance of a building is really bad) renovating of transforming an existing building is environmentally better than replacing it by a new building. This was already found during the PhD research of Andy van den Dobbelsteen [2004], in which renovation was compared to demolition and new construction on the basis of environmental costs.

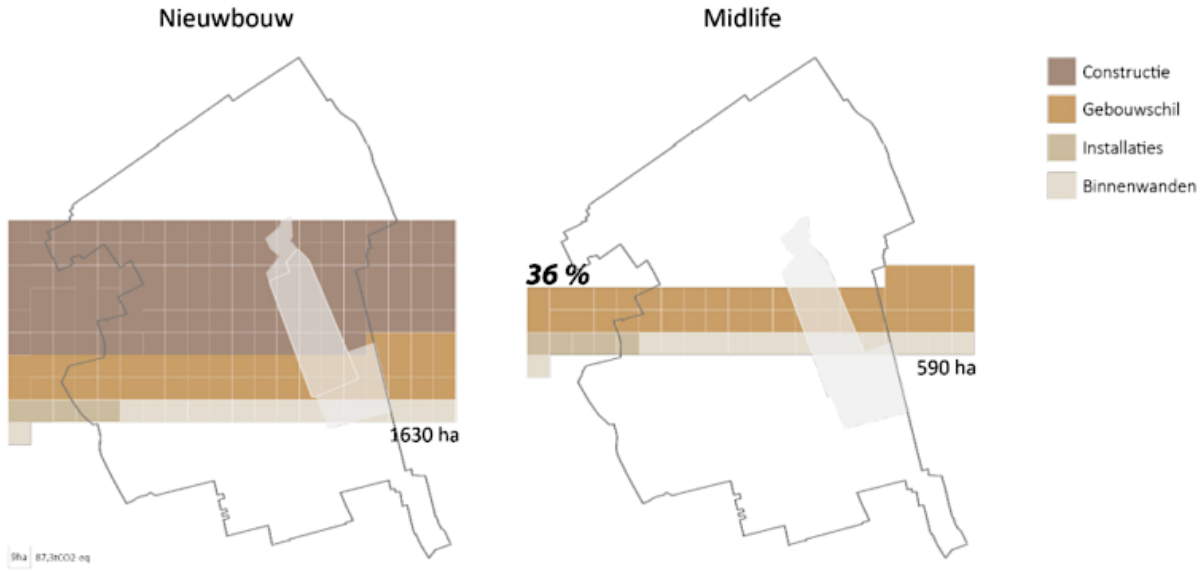


Figure 11.03: Difference in CO_2-eq when Architecture, TPM and CRE are replaced by new building (left) versus when these buildings get a midlife renovation, in this case the construction is preserved (right).

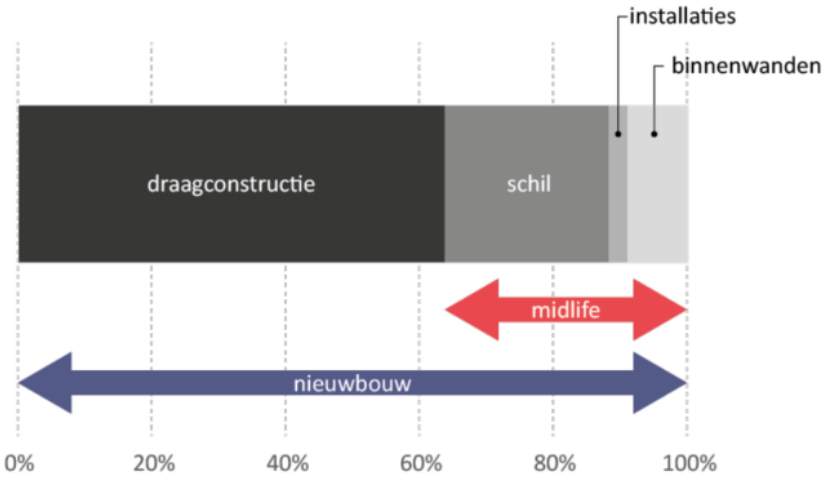


Figure 11.04: Share of embodied energy and CO_2 emissions of various building components in Pulse

An analysis of the current building stock is needed to find out which buildings are well-functioning and which not. Based thereon, it can be decided whether it is better to renovate the building or to demolish it and build a new construction.

Carbon sequestration in building materials

The process of capturing carbon from the atmosphere is called carbon sequestration. There are multiple forms of carbon sequestration. Biogenic carbon comes from natural processes such as photosynthesis in plants, trees and soil. Wood, bamboo and hempcrete are examples of low-carbon bio-based building materials. In addition, oceans and aquatic life can become carbon sinks when they sequester carbon through different chemical and biological processes. In both cases, the carbon is stored and not released into the atmosphere.

Artificial carbon sequestration, separating carbon dioxide from flue gases, is a newer method that looks into producing materials that store carbon dioxide within themselves. In some building materials, cement can be replaced with supplementary cementitious materials that captured CO_2. Other forms of artificial carbon sequestered materials are carbonated curing of concrete and the use of carbonated aggregates in concrete. Echo was used as a case study in the research by Building Technology graduate student Rahul Grover [Grover 2020] to find out if the embodied carbon emissions of Echo could be lowered. The carbon emissions of Echo could be reduced by almost 1900 tonnes of CO_2 if bio-based materials as glue-laminated wood for columns, planed timber beams, cross-laminated timber slabs, bamboo for façade awnings, and wood fibre insulation material were used.

11.04 Policy for renovation and new construction

To align with the TU Delft ambition for a CO_2 neutral and circular campus, Campus Real Estate & Facility Management (CRE&FM) has set the target that the total CO_2 emissions of scope 1 and 2 are 0 in 2030. Two objectives have been formulated to reach this goal: 1. Limit the energy demand, halve the energy consumption per m^2 compared to 2018 (heat and electricity) and 2. Use sustainable energy from renewable sources, generate 100% heat on campus, generate 50% electricity on the campus and 50% of what cannot be generated by the university itself must be purchased sustainably.

KPIs

In order to make these carbon savings measurable and to be able to manage them, various sub-targets were formulated in the form of key performance indicators (KPIs); see table 11.01. Separate objectives were formulated for new construction and midlife renovation, because major steps can be taken here; see table 11.02.

Section 02.03 showed the KPIs that were already set by CRE&FM and the KPIs we want to strive for with this document. In addition, for sustainability purposes we would like to get better insight into carbon emitted by buildings (and per m^2) and that a more strict, gradual scaling down in kWh/m^2 and CO_2-eq/building will be enforced.

When a building is renovated or built, we must strive for the highest label at that time otherwise, it must be renovated again within a relatively short time, which leads to additional costs. It is not possible to make all buildings CO_2 neutral by 2030. As a result, some buildings must produce energy. These buildings can then compensate for the buildings that are not able to reach this target.

Table 11.01: Energy KPIs for existing buildings

	KPI	Target	Reference
Efficient use of heat	Final heat demand per m^2	50 kWh/m^2 in 2030, linearly decreasing from 2018	100 kWh/m^2 in 2018, halving compared to 2018
Efficient use of electricity	Final electricity demand per m^2	50 kWh/m^2 in 2030, linearly decreasing from 2018	100 kWh/m^2 in 2018
Production of heat	Part of final heat use that is generated in a sustainable net way	In 2030 100%	0% in 2018
Production of electricity	Part of final electricity use that is generated in a sustainable net way	In 2030 50%, linearly increasing from 2018	1-2% in 2018
Life Cycle emissions	Total CO_2 emissions over the life cycle per m^2	To be determined	
Scope 3 CRE	Sub-targets	To be determined	

Table 11.02: Energy KPIs for new buildings

	KPI	Target	Reference
Efficient use of heat	Current final heat demand per m^2	15 kWh/m^2	Reference Pulse based on EPC calculations: heat demand 12 kWh/m^2 0 m^3/ m^3 (gas) 0 GJ/m^2 (heat)
Efficient use of electricity	Current final electricity demand per m^2	30 kWh/m^2	Reference Pulse based on EPC calculations: Building-related energy use: 24 kWh/m^2 User-related energy according to NEN 7120 for education: 17.5 kWh/m^2 BVO
Production of electricity	Production of sustainable electricity on or directly at the building	50 kWh/m^2, till 2020, linearly increasing to 70 kWh/m^2in 2030	Echo 50 kWh/m^2 Pulse (from EPC): 23 kWh/m^2 BVO
Indirect CO_2-footprint	Total CO_2 emissions in the construction chain	0.3 tons CO_2/m^2 till 2020, linearly decreasing to 0 in 2030 (for the time being)	
New construction	BREEAM	Excellent or Higher	Quickscans TNW (good), Pulse (excellent), Echo (excellent)

Criteria were also drawn up for circularity in construction, to make sure to reach the goal of becoming a circular campus; see table 11.03. These are also in line with the national Framework Circulair Bouwen from Platform CB'23.

Table 11.03: Circularity KPIs for existing buildings

Main criterion construction		
HB01.	Circular new construction	By 2020
HB02.	Circular existing construction	By 2020

Sub-criteria construction		
DB01.	New construction: Future-proof and no demolition • Circular potential incoming materials • Releasability of buildings • Appropriate cost / benefit of buildings • Application R-Ladder and Pace layering • Appropriate registration and monitoring systems • Thematic integration (CO_2, health, biodiversity, etc.) • Avoidance of waste	By 2020
DB02.	Existing construction: circular dismantling • Reuse of outgoing materials • Circular potential incoming materials • Releasability of buildings • Appropriate cost / benefit of buildings • Application R-Ladder and Pace layering • Appropriate registration and monitoring systems • Thematic integration (CO_2, health, biodiversity, etc.) • Avoidance of waste	By 2020

New strategies

Avoidance before repair: necessity of accommodation

Construction and renovation are a good example of multiple ownership. It is more than only the question of construction or renovation it starts with how to organise work. The question that needs to be asked is: Do we still have to design buildings with a 100% occupation rate? Currently, CRE&FM already has flexible workspaces. Research must be conducted into the m^2 needed per fte and into the possibility of creating flexible workspaces in all faculty and service buildings. During the COVID-19 pandemic, we also learned that employees and students can work from home. This affects the required m^2 and must be included in future plans.

The New Stepped Strategy

If a new building is needed it should be designed following the New Stepped Strategy. As presented in Chapter 3, this strategy commences with reducing the demand by passive, smart & bioclimatic design; subsequently, residual streams such as waste heat, waste water, and waste material are reused; finally, renewable sources are used to solve the remaining demand and only clean and nutritious 'waste' is let into nature [Dobbelsteen, 2008]. In addition, new buildings should be climate-adaptive to ensure that no major renovations or new buildings are required in the future.

The New Normal (Het Nieuwe Normaal)
The Dutch government has a strong ambition: Circular Netherlands in 2050. Together with researchers from the faculty of Architecture and the Built Environment, Copper8, Metabolic and Alba Concepts we looked at the minimal requirements and the required KPIs. The minimum limit is called 'The New Normal'. In the autumn of 2021, a process was started to refine and scientifically substantiate the methodology behind The New Normal. This primarily concerned the choice of themes and indicators on which performances were determined, selecting the right measurement method and fine-tuning the audit tool. By drawing up these minimum requirements, we hope that the university and also other companies and organisations will achieve these set ambitions.

11.05 Specific projects, pilots and actions

Present-day annoyances: quick wins

Technical misfits typically cost a lot of energy, but are usually not dealt with, although they are easy to tackle. Below are some of these present-day annoyances that should be tackled.

Thermostats
In most buildings, the thermostat taps on radiators are either switched to 5, when desiring heating (which means that the indoor environment is warming up to 24°C) – even in the hallway and toilets – or switched to 0, when desiring cooling (which means that the indoor environment is cooled to 16°C). In most cases, the thermostat should be kept at 2-3 (20°C). It is likely that people do not understand the principle of thermostat heating. This can be solved by locking the knobs or by providing information so that the thermostat principle is understood.

Lighting
Artificial lighting is often still on when nobody is around, even in the evenings and weekends. Solving this problem will significantly reduce the electricity use of all buildings. Detection sensors are the obvious solution but these sensors switch on lighting even when this is not needed – subsequently, lighting stays on for twenty minutes or longer. In order to prevent this, switching off lighting manually should always be possible, and sensor-incited switches need to be better programmed.

Sunscreens
Vertical screens in front of windows take away daylight, which in turn causes an unnecessary demand for artificial lighting and hence energy use indoors. The sunscreens in front of windows also trap heat, because of which opening windows will bring in undesired heat, requiring cooling and extra energy inside.
These vertical screens are useful on east and west elevations, where the solar angle is low, but on south façades, because of the high sun angles in spring to autumn, blinds or overhangs are a better solution. Low winter sun angles will bring in desired heat but may be

undesirable for glare, but this can be solved by (light-coloured) curtains on the inside of windows. Also, well insulating translucent screens on the inside are a good option.

Operable windows
Many working places have no options for (sufficiently) opening windows for fresh air or cooling. Especially with corona and potential future virus outbreaks, proper ventilation facilities are essential, and decentralised ventilation through operable windows or hatches seems the simplest and safest option. In the colder season, this might lead to heat losses, but there are good alternatives for decentralised heat-recovery units (e.g. Fresh-r or Climarad). The alternative is high ventilation rates in a centralised system, which requires a more energy and considerable ducting in the building.

Toilet flushing
At present, there is hardly any insight into the consequences of toilet flushing, and the corona crisis emphasises the importance of not touching contaminated surfaces. Therefore, sensors should be placed in all faucets in toilets and urinals to reduce water usage. Otherwise, stickers should be placed on toilets and urinals to showcase how much water is used (mostly 6 or 3 litres, c.q. the larger and smaller button on modern toilets, but old ones still might flush 9-12 litres).

End-of-Use/Disposal projects

The buildings mentioned below (with current building numbers on the campus) are – according to plans of CRE&FM – no longer or not to be used anymore by TU Delft and disposed of, or demolished [Blom & Dobbelsteen 2019]. However, when a building is demolished, the university is no longer allowed to speak of 'demolition': this becomes harvesting according to the urban mining concept. Before harvesting, an analysis must be made of how the R ladder can be optimally applied to the various parts. Bob Geldermans was embedding this in the dismantling manual of TU Delft.

Science Centre (3)
This building was already sold to Royal Haskoning DHV, who would like to make it the first listed ‘Paris-proof’ building in the Netherlands, something that TU Delft will also show w with its remaining buildings in the near future.

Biotechnology (5)
This building was renovated in 2019 to accommodate RoboValley and the Robohouse fieldlab. The energy performance of the building nonetheless is still poor and its location suboptimal. This is a building that could be abandoned and sold. There are interested parties. For instance, Mercurius, the new Waldorf school (‘vrije school’) of Delft will be needing a spot in a few years’ time.

Chemical Technology, 'Gele Scheikunde' (12) **& Kramer Laboratory** (15)
Chemical Technology was partly sold to a developer, who will demolish the building and replace it with apartments on the northern side of the complex, while the International School Delft will construct a new building to the south.
According to plans, also the Kramer lab is going to be demolished, except for the monumental entrance portal. The International School Delft is going to be accommodated in this place as well.

Mid-life renovation projects

The buildings that fall in this category have a high energy consumption, especially for heat production, and are in mediocre technical condition [Blom & Dobbelsteen 2019].

Applied Sciences (AS) (22)
According to the current real estate strategy, this building will be temporarily vacant but will get an office function in the near future. During this vacant period, the mid-life renovation can be carried out without causing too much inconvenience. The heat demand must be reduced by 80% to meet the KPI requirements. The entire building envelope and building installations must be replaced. Only the supporting structure will be retained. The heat demand can be reduced by creating closed atria between the wings and the new roof can offer space for PV panels. Research should be done into the most energy-efficient design.

Civil Engineering & Geosciences (CEG) (23)
For CEG, the heat and electricity demand must be reduced by 50% to meet the KPI requirements. This building uses a hexapod, which requires a lot of cooling. Research should be done into the possibility of heat exchange. Some buildings at the rear are a municipal monument, midlife renovation will not be possible for this part because the facade must be preserved.

Mechanical, Maritime and Materials Engineering (3mE) (34)
The high energy demand of 3mE is compensated by its large floor area. However, it must be reduced by 50% to meet the KPI requirements. A mid-life renovation is required, in which the building envelope and installations are replaced.

Electrical Engineering, Mathematics and Computer Sciences (EEMCS) – high-rise (36)
In order to reduce the energy demand of the EEMCS high-rise, a midlife renovation is needed in which the building envelope and installations are replaced.
Metabolic performed a zero measurement of the materials currently present in the high-rise, as well as the embedded impacts associated with the materials. 3.2 million kg of CO_2 is embedded per layer of the building.
The low-hanging fruits for reusability are the doors, light fixtures, and sun blinds, these have a relatively high impact and are easy to dismantle. Radiators and internal window frames also have a high impact but are difficult to disconnect with possible damage. Based on this research, the best scenario must be chosen for every topic.

Metabolic studied the effect of making the layout flexible, adding PV, and reuse of products. This showed that high-quality reuse can save more than 53 tonnes of CO_2 emissions.
When single glass is replaced by HR ++ glass, the heat demand per m^2 will decrease from 99 kWh/m^2 to 64 kWh/m^2, i.e. a reduction of 36%. This will save 170 tonnes of CO_2 emissions on an annual basis. EEMCS then still does not comply with the guidelines of TU Delft (15 kWh/m^2.year). The installation of solar panels will create a CO_2 impact of between 180-400 tons. This will be compensated for after 1-3 years.
The building uses two 20-year-old ATES doubles, mainly for cooling the laboratories, without the intervention of a heat pump. Research should be done into the possibility of using residual heat from the laboratories for heating the offices and teaching areas.
The EEMCS high-rise should also be used to test the innovative PV chimney (a TU Delft patented system of a solar chimney with PVT panels in it) as a pilot project. See figure 11.05.

Figure 11.05: PV chimney pilot project proposal for the EEMCS tower [Annebregje Snijders]

Datacentres and Labs
Figure 11.01 showed that there are great differences between the total energy consumption per square metre of the main faculty buildings. The differences are even greater when looking at figure 11.06, which also included the datacentres and the Else Kooi Lab. It can be seen that these datacentres and labs are energy-guzzling. The datacentres should only collect the needed data instead of all data to reduce the energy demand. A complete overview of measures can be found in chapter 16.

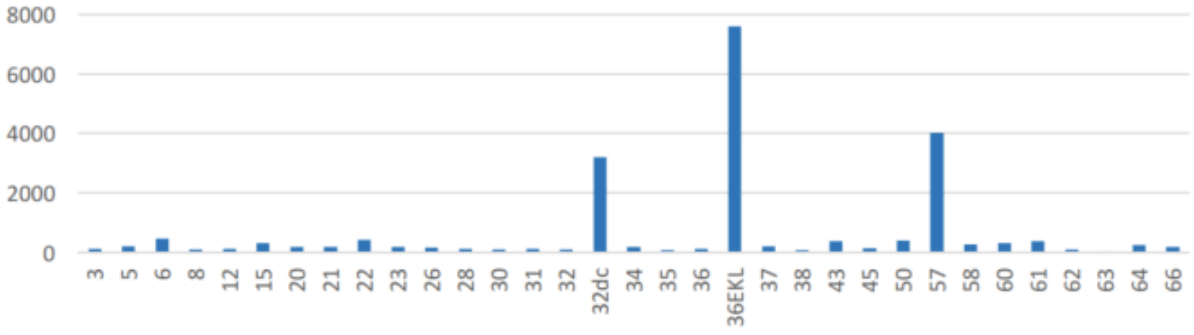


Figure 11.06: Energy use per m² of the buildings on campus, including data centres and labs

Light renovation projects

Aula (20)
The Aula is a national monument, which means that a rough midlife renovation, in which the facade is replaced, is not an option. But other interventions are certainly possible. The Getty Foundation commissioned Wessel de Jonge to draw up a Conservation Management Plan for the Aula. Eric van der Ham, Dr. Peter van den Engel and Peter van Heun worked on a plan for the technical installations and building physics aspects. Dr. Nicholas Clarke is currently finishing this CMP report. This report, including the building physics and services plan, should be included in upcoming decisions.
Many cold bridges can be found in the Aula, which should be taken care of. The roof is already well insulated, and the roof covering has partly been replaced. PV should be added to produce electricity. To reduce the energy demand, building services should be replaced and attuned more efficiently; home automation systems should be installed, and LED lights must be used. The Aula will then be connected to a low-or mid-temperature system.
Due to the fact that a lot of people can be placed in one room, special attention must go to the ventilation. As a measure of air quality and infection risks, it must be checked whether the CO_2 levels are acceptable. Heat can also be recovered from the ventilation systems and summer night ventilation should be used to reduce the energy demand even further.
As described in EcoCampus chapter, rainwater must be collected and used for toilets, watering, and cleaning. The Aula should also use a heat pump system to use aquathermal energy from the canal on the other side. The pipe structure for this is already there.
Finally, the outdoor space and the possibility to add greenery, water, and CO_2-absorbing materials should be investigated.

Library (21)
The energy consumption of the TU Delft Library must be reduced to meet the KPI requirements. At present, the library is connected to the heat network, in combination with an ATES system without a heat pump. Adding a heat pump is difficult due to minimal space for building services. These are currently fitted into floors and small installation spaces, which makes it difficult to optimise the building systems. In addition, there are strict climate requirements for the book storage and it should be noted that the library has the longest

opening hours: 08.00-24.00, 7 days a week. During renovation, lighting and where possible, the energy systems must be replaced, and home automation systems should be added.

Bouwcampus (26)
The Bouwcampus is not connected to the heat network, which means that it could either be connected to the geothermal well or use hydrogen boilers. Research is needed to see which option is the most sustainable. Besides, light renovation should be done to reduce the heat demand.

Technology, Policy and Management (TPM) (31)
The electricity and heat consumption of TPM should be reduced. The electricity consumption can be decreased by implementing a home automation system. The Rc-value is currently 4.0 m^2K/W, which indicates further isolation is not applicable. Research must be done to find out if the KPI requirements will be achieved by the replacement of building services or if further actions are needed.

Industrial Design Engineering (IDE) (32)
IDE needs a light renovation to match the energy consumption with the KPI requirements. This can be achieved through smart adjustments and the replacement of installations. The original skylights can be replaced with skylights that have transparent PV incorporated in them.

Electrical Engineering, Mathematics & Computer Sciences (EEMCS) – low-rise (28)
This building is already equipped with LED lighting and has a new building management system. A light renovation is needed to connect the building to the heat network when the geothermal source is realised. Limited adjustments are needed to connect the building to low-temperature heating.

Small adjustments

Architecture and the Built Environment (ABE) (8)
This national monument was renovated in 2014 and meets the current KPI requirements. The heat demand was reduced by 50% by providing double glazing for the entire building, using aluminium frames, partial insulation of the roof and floor, and by application of mechanical ventilation. In 2019 the building was equipped with LED lighting. The energy demand can be further decreased by better adjustments of light switches and sensors. In addition, PV-integrated roof slates should be placed for generating electricity.
Under leadership of the dean, Dick van Gameren, ABE has recently published a booklet that describes the way forward with the faculty building [Arkesteijn et al. 2021].

Campus Real Estate & Facility Management (CRE&FM), Jaffalaan (30)
As with the ABE building, the energy demand can be reduced by equipping the building with LED lighting and a building management system. Electricity can be generated by adding PV.

Cornelis Drebbelweg (35)
The Drebbelweg building has a very low electricity demand of 21 kWh/m^2 due to the optimal use of daylight and LED lighting. The heat demand is slightly higher than 58 kWh/m^2; saving on this is desirable.

Aerospace Engineering (AE) (62)
A building management system (BMS) pilot has been running in the building of AE and LED light is also used. To further reduce the energy demand the BMS should be optimised and PV should be integrated into the façade.

Special cases

The Botanical Garden (6)
CRE&FM put the Botanical Garden on the list of buildings and facilities to be abandoned. The people working at the now coined TU Delft Hortus Botanicus however would like to stay where it is currently situated. As discussed in the EcoCampus chapter, a renewal of both the activities and facilities of the Hortus Botanicus is planned, including many present-day challenges related to biobased products, climate-adaptive capacities of green and nature-inclusive building, to mention a few. The choice of disposing of the garden is currently reconsidered.

Hammen Farm
The historic Hammen Farm (constructed in 1608) is owned by TU Delft and has already been partially restored after it was left in decay for decades. The farm is situated along the Rotterdamseweg in between TNO and the 'Speeldernis' (wild playing ground). In the past, the the Hammen Farm was used as an individual farm. The site consists out of several buildings: the monumental Hammen Gate, the main house, the churn barn and the big barn. At the moment, CRE&FM is investigating various future scenarios of the farm as part of the new campus vision for 'middle west'. The Hammen Farm is a great asset for the university because it has a lot of historical value; it lies centrally, next to the future bicycle path crossing the Schie canal by means of a new bridge, and the site could be used for interesting collaborations between internal and external researchers and students, companies, X, and the government. CRE&FM and the sustainability coordinator are currently investigating if the farm can be used as a field lab for the food, energy, water nexus.

New construction projects
When a new building is commissioned, it should comply with the vision of TU Delft to become carbon neutral, circular and climate adaptive by 2030. This means that at the time of construction, the best circular materials and contracts available should be used. The building and installations should be designed in such a way that the building becomes energy positive. This starts with reducing the energy demand through passive, smart bioclimatic design.

ECHO
Echo is an inter-faculty education building with a wide variety of educational facilities. For ECHO a step further was taken by making it energy producing and by paying attention to circular design.

Rotterdamseweg parking garage
This parking garage is designed to be disassembled so that it can possibly be rebuilt somewhere else. Plants grow along the façades. Solar panels have been placed on the roof and it is still being investigated whether solar panels can be included in the façade.

Kluyver area
In the first half of 2021, Copper8, CRE&FM, and sustainability coordination worked on an ambition document in which the energy and circularity themes are well represented. After this, 'kansenkaarten' (opportunity maps) were drawn up for each project, in which the ambitions for each building were clearly defined. Next to this document, a list of KPIs was drawn up for the Kluyver area. As mentioned in chapter 6, the Kluyver area is a large project with a big investment scheme, which makes it a good case for a TCO_2 pilot.

Figure 11.07 shows the Kluyver area plan. The projects planned are:
- TNW Physics, TU Delft's new flagship of sustainable construction
- Generic Education Building
- QuTech
- Site area layout above ground level
- Site area layout below ground level
- Cleanrooms
- Parking spaces
- Space for additional TU programme
- Logics & Environment: current building will be disposed of in due time; new building will be relocated to Campus South.

To be investigated: consequences when sustainability targets are not achieved
As mentioned above an ambition document with KPIs was developed for the new buildings. Not meeting sustainability requirements should have consequences for the design teams working on projects, equally important as with financial boundary conditions. This will be elaborated.

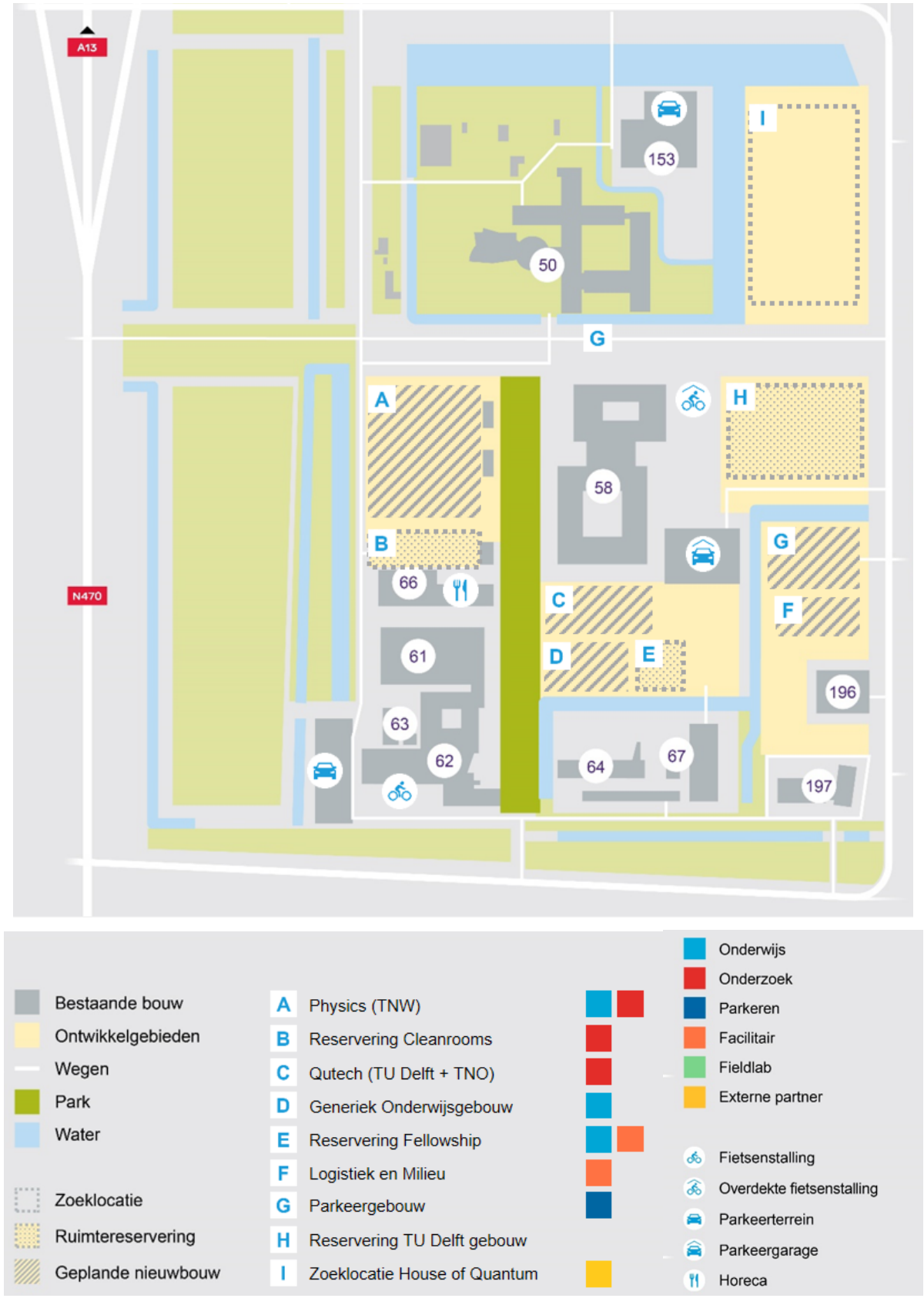


Figure 11.07: Projects planned in the Kluyver area

Compliance of Campus Strategy 2020 with the sustainability action plan

CRE&FM Campus Strategy

The previous Campus Strategy of CRE&FM shows which building of the current building stock will be renovated when and which new real estate projects are on the planning of the coming 10 years; see figure 11.08. In 2022, in collaboration with the sustainability coordinator, CRE&FM has presented a revised version of the Campus Strategy, which will be in line with the targets presented in this document.

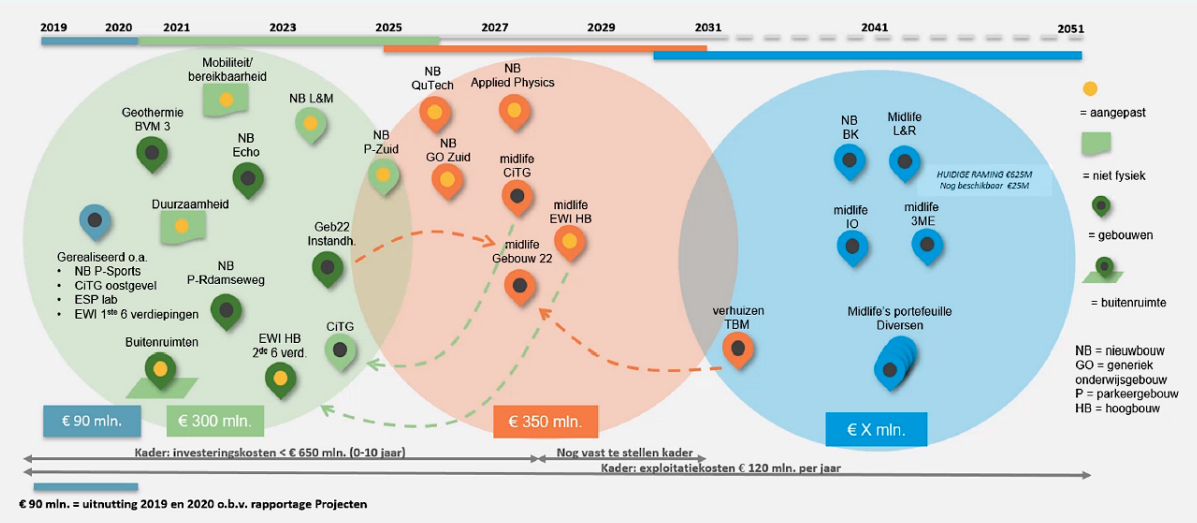


Figure 11.08: The previous Campus strategy, updated version of 2020, of CRE

New building and area development – South Campus

The current developments of the new buildings in the Kluyver area and the renovation of the EEMCS high-rise (36) are aligned with this vision. The sustainability goals and necessary finance are of will be integrated in the projects. This concerns, for instance, the new generic education building, the new faculty building of TNW Physics, the new QuTech building, the new Logistic & Environment building, and development of the terrain.

Mid-life developments – Middle on campus

The buildings that need a mid-life renovation, which are mostly situated in the middle of the campus, were not yet aligned with the Campus Strategy 2020 (CS2020). The sustainability KPIs formulated (necessary to achieve a circular and carbon-neutral campus) have now been incorporated in the revised Campus Strategy of 2022. This includes the mid-life renovation projects of AS (22), CEG (23), EEMCS low-rise (28) and 3mE (34). Most of the developments have not yet started (or only for parts of the buildings). The sustainability goals and necessary financial means are included in the new Campus Strategy.

Quick-wins of energy-reducing measures – All buildings on campus

The quick-wins resulting from research into energy-reducing measurements per building (the 'EED studies') as well as necessary follow-up research, as mentioned in section 10.02,

need to be implemented in the coming years. This includes the PV roll out and involves all buildings on campus. For most buildings, an accommodation plan is in the making or will be started soon. In this plan, the quick-wins can be included and implemented in the upcoming years. In order to do so, the financial means required for the implementation of the quick-wins need to be included in the upcoming process of recalibration of the campus strategy.

Relocation of housing programme or disposal – North Campus
As pointed out in section 10.03, renovating a building generally 'costs' less CO_2 in comparison with constructing a new building. This means that for the decision to build a completely new building instead of renovating one you need strong arguments why an accommodation programme cannot fit in its existing building anymore.
The revised Campus Strategy of 2022 supports sustainable decisions about real estate on the campus.

External Projects

The TU Delft Campus also accommodates buildings that are from companies or knowledge institutes that form part of the TU Delft Campus community. These buildings must also meet the sustainability ambitions of TU Delft.

Figure 11.09: Impression of the new sustainable accommodation of Firma van Buiten on TU Delft Campus South

Firma van Buiten
Firma van Buiten is a caterer that offers employment to people that have a distance to the labour market. Currently, they are realising their new building at TU South (figure 11.09). Firma van Buiten has the ambition to make it a sustainable building. TU Delft must use all possible means to support them with this. A project brief was drawn up by CRE and this

team to make sure Firma van Buiten can use aquathermal energy from the adjacent canal. With this pilot, we can test on a small scale, but with the right conditions in terms of water quality and flow as on the rest of the campus, whether this can be a solution for other new buildings. In addition, we are also investigating the possibility of leasing PV cells.
Firma van Buiten therefore will become a living lab where research can be conducted by students and researchers of the TU Delft.

International School Delft
Also, as mentioned, the International School Delft is going to build their new location on the campus, on the site of the abandoned (yellow) chemistry building. CRE&FM are in close contact with this party to make the building as sustainable as possible.

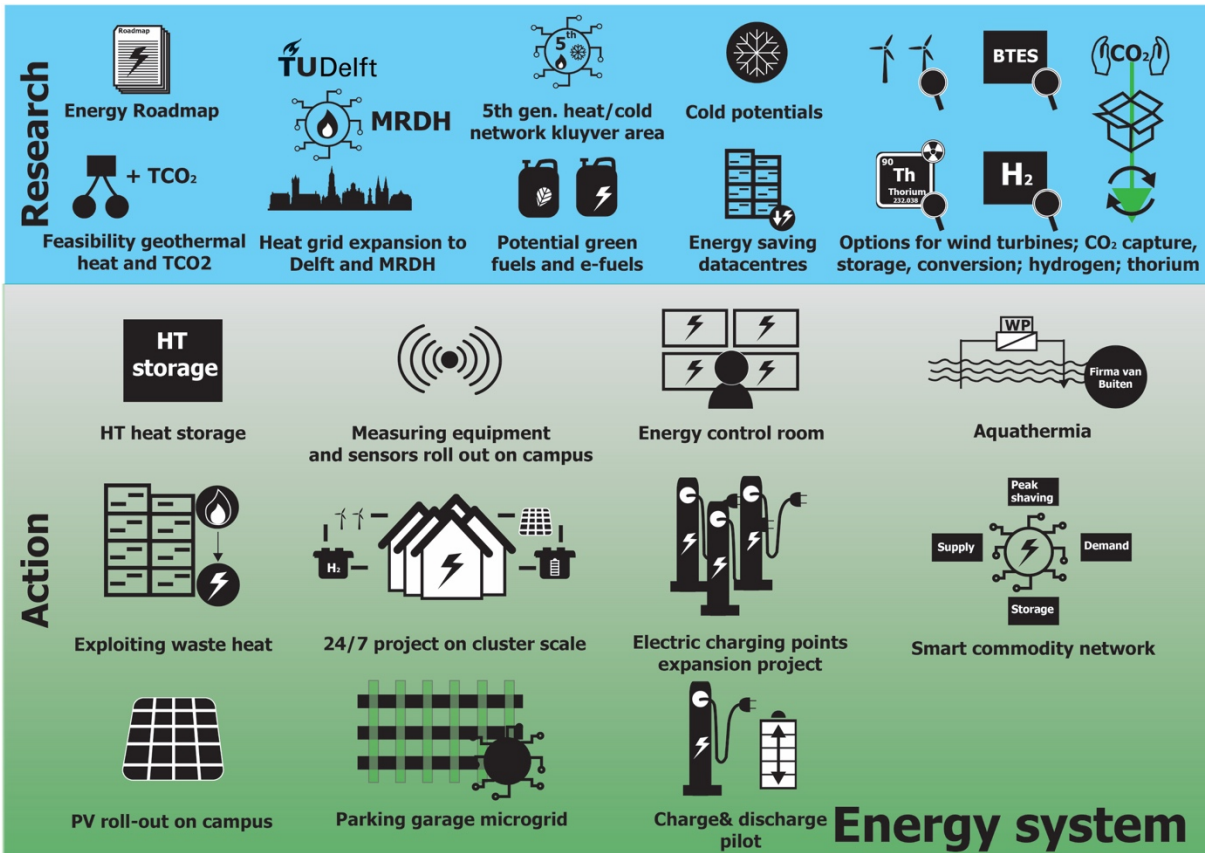
Others
Other external companies found on the campus are Koolschijn, Blindeerkoning, Yes!Delft, 3M Nederland, Exact, NMI Certin, VSL, ABB, NorthC, Deltares. The heat and cold storage facility is exploited for these companies.

From now on, before a company can settle on the TU Delft Campus, clear agreements about sustainability must be made. This may include, for example, the connection to an ATES system. Annelise Hoftijzer, Zwanet van Lubeck and Ruth de Vries should be involved when working on projects with external companies.

12 Energy System

Team (in alphabetical order)

- Paul Althuis – I&IC
- Martin Bloemendal – CEG
- Andy van den Dobbelsteen – TU Delft sustainability coordinator
- Deirdre van Gameren – TU Delft sustainability researcher
- Leo Gommans - ABE
- Wim Haije – AS/E-refinery
- Olindo Isabella – EEMCS/PV
- Linda Kamp – TPM sustainability coordinator
- Hubert Linssen – CRE sustainability coordinator
- Anne Medema - CRE
- Gilbert de Nijs – CRE
- Peter Palensky – EEMCS/Powergrids
- Sander Snelleman – CRE
- Phil Vardon – CEG
- Pedro Vergara Barrios – EEMCS
- Gillis de Wit - GreenTU



Energy System
Main proposals

General aims and principles

- To establish an entirely **sustainable energy system** on campus
- To develop the TU Delft campus as a **smart city** of its own
- To make the campus' energy system **smartly managed and controlled**

To be investigated

- Developing an **energy roadmap** (2025)
- Studying heat grid expansion to other **districts of Delft**
- Studying integration of TU Delft heat network into the **metropolitan region** (MRDH)
- Elaborating a **5th-generation heat/cold network** in the Kluyver area
- Studying energy-saving options with the **datacentres**
- Making an inventory of all **cold potentials** on campus
- Studying **heat-powered cooling**
- Exploring options of a **borehole thermal energy storage** (BTES) pilot on campus
- Exploring options of **wind turbines** on campus
- Exploring options of **CO_2 capture, storage and conversion to e-fuels** on campus
- Determining the potential for **green fuels, e-fuels and hydrogen** on campus
- Exploring options of a **thorium plant** test facility
- Extending the **24/7 project** to TGV and campus
- Developing a TU Delft **energy control room** set-up, with digital twins

Projects, pilots and actions

- Elaborating the case of **geothermal heat**, including TCO and carbon pricing
- Realising a **HT heat storage** that serves the campus
- Exploiting the NorthC **datacentre waste heat**
- **PV roll-out** on campus
- Electric mobility **charging points** expansion project
- **Charge/discharge pilot** for plug-in electric vehicles
- Rotterdamseweg **parking garage microgrid** pilot
- TU Delft **smart multi-commodity network** design and development
- Roll out of **measuring equipment and sensors**

The current energy system of TU Delft needs to change to keep up with the future demands, developments and regulations, including carbon neutrality. This chapter describes the optimal future energy system and looks into the challenges of the current system of TU Delft. Subsequently, specific projects and actions are mentioned to reach the goals.

12.01 Desired future system

In the near future, more than 50% of all energy used on campus – heat, cold and electricity – will be generated on campus. The Sankey diagram of figure 12.01 illustrates this new situation. To a great extent, on the campus, electricity is generated by PV systems, on roofs, facades, parking garages and in the urban environment. There is a portion of electricity that comes from hydrogen and synthetic methane generated from excess power in summer. There might even be wind turbines of TU Delft Campus South. The remaining electricity demand is bought from wind farms.

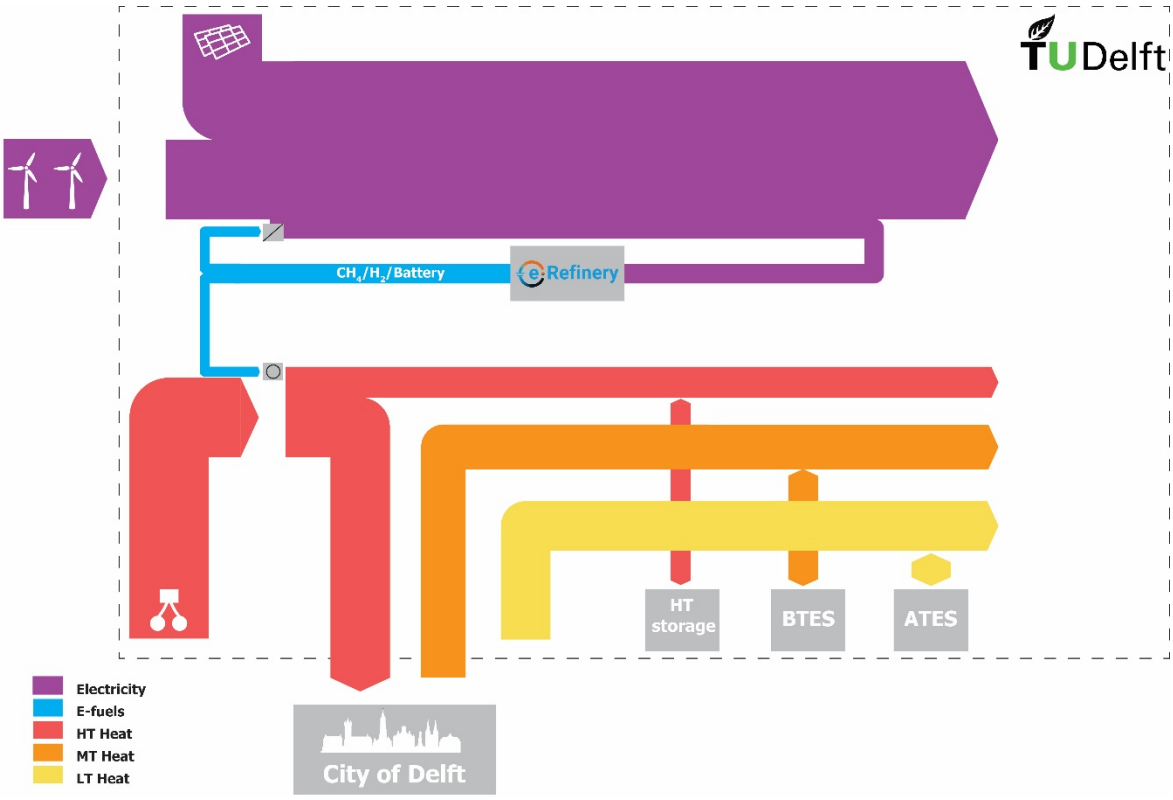


Figure 12.01: Sankey diagram of TU Delft's desired future energy system

The basis of TU Delft's heat demand is delivered by the geothermal heat system, which is linked to the heat network of the metropolitan region. Only a part of its high-temperature (HT) heat is used on campus itself; the greater part goes to other districts of Delft. The mid-temperature (MT) return temperature of the system is used by a greater number of buildings than HT heat. The largest share of buildings however uses low-temperature (LT)

heat from residual heat and environmental sources on campus, which are interconnected through peer-to-peer networks. HT, MT and LT heat[18] are seasonally stored on campus.

12.02 Energy system at present

The current energy system of the TU Delft campus can be subdivided into three parts: electricity, heat network, and individual gas boilers in several buildings; see figure 12.02.

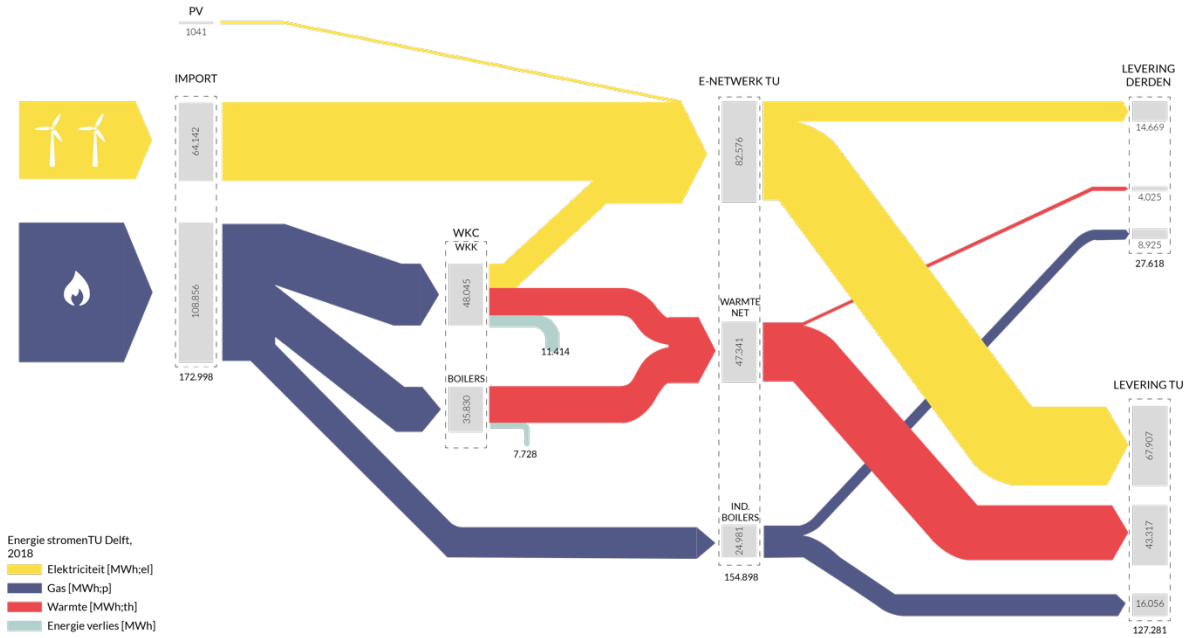


Figure 12.02: Sankey diagram of TU Delft's current energy system

Heat

There are multiple forms of heat: high temperature (HT), medium temperature (MT), and low temperature (LT). HT heat is above 65°C; it is often used in older buildings that are poorly insulated. MT heat is between 40-65°C; it can be the return temperature of a HT supply. LT heat means that the heat supply is 25-40°C; this can come from renewable heat sources as environmental heat, geothermal heat, solar thermal and waste heat. Furthermore, there is also ultra-low-temperature (ULT) heat, which delivers heat below 25°C, and HT cooling (10-15°C).

TU Delft's heat system

The heat system of the TU Delft campus consists of two main two parts. Firstly, there is the heat network of Campus North and Campus Centre (figure 12.03, left) fed by a cogeneration plant running on natural gas. This plant contains 3 gas boilers and 2 combined heat and

[18] HT heat: above 65°C; MT heat: 40-65°C; LT heat: 25-40°C; ultra-low temperature (ULT) heat: 15-25°C

power (CHP) boilers. The 2 CHP boilers are only active when the return temperature is lower than 85°C; this is more than 4500 hours a year [Blom & Dobbelsteen 2019].
Secondly, some buildings, especially on Campus South, are individually heated by LT heat from aquifer thermal energy storage (ATES) systems (figure 12.03, right). At the moment, TU Delft has 16 aquifer thermal energy storage systems, supplying LT heat and HT cold[19] to 17 buildings, using 32 wells in total.
In addition, some buildings have individual local gas boilers.

Figure 12.03: Map of TU Delft with buildings connected to HT heat network (left) and current ATES systems (right)

Heat for cooling
HT heat can also be used to generate cold (or more correctly put: to extract heat from a source), through adsorption cooling. Since due to climate change and well-insulated buildings, TU Delft might rather have too much heat than cold available in the near future, using heat for cooling is a good option.

[19] HT cold: 10-15°C

Cooling

The cooling energy currently required is mainly provided by air-conditioning, ATES systems, and free-cooling utilities on the roof of buildings. The research installations and rooms in the Stevin 2 Hall and part of the CEG building use a cooling plant that has been replaced to the basement of Stevin 2. In addition, air-handling units are placed on the roof to provide cooling.

We do not exactly know how much of TU Delft's electricity use is used for cooling. As stated, as a result of climate change, there will be an ever-greater cooling demand. Avoiding or reducing the need for mechanical cooling and using sustainable means to cool becomes important with all new buildings and renovation projects.

Electricity

Figure 12.02 shows that at present electricity is produced by a CHP plant and PV panels. The remaining electricity demand is supplemented with wind energy purchased from a wind farm of Eneco [Blom & Dobbelsteen 2019].

Challenges of the power grid

In order to tackle climate change, TU Delft must switch from fossil fuels to sustainable energy supplies. At the moment, due to the low price of electricity bought, there is no financial drive to invest in PV fields or wind turbines on campus. This is however expected change due to the increasing demand for renewable power. Moreover, the the demand for electricity will increase due to various developments:

- Electrification of transport
- Electrification of air-conditioning
- Increasing use of data and therefore datacentres

Sustainable generation of electricity, such as large-scale application of PV will put extra stress on the energy grid in the future and will require storage systems to cover the changeable production of solar and wind power. It is important to include this in the all plans from now onwards.

Carbon impact of the energy system

The SKAO CO_2 Prestatieladder manual indicates that the carbon impact of renewable Dutch electricity is 0 tonne of CO_2-eq. This includes wind energy purchased and self-generated energy with PV. The carbon impact of gas purchased by TU Delft is 20,743 tonnes of CO_2-eq [Tax 2021].

As a result, the main carbon emitted from energy use on the campus is coming from natural gas, used in the cogeneration plant and in several boilers. However, as explained in chapter 11, the university must invest in renewable energy to become independent and carbon neutral, e.g. by means of PV panels and geothermal heat.

Energy monitor

TU Delft's Energy Monitor keeps track of the energy use of the different buildings. At the moment CRE is working on a new – more detailed - monitoring system. Pulse, Echo, or new buildings on TU South should be used as a pilot to test this new detailed monitoring system.

Eventually, the university wants to be able to show the energy consumption of all buildings on the screen based on day-to-day measures.

Energy roadmap
In the next three years, low-hanging fruit will be actively plucked. Parallel to this, an energy roadmap will be developed by CRE that shows which other measures must be taken in order to meet the stated objective.

12.03 Approach to a sustainable energy system on campus

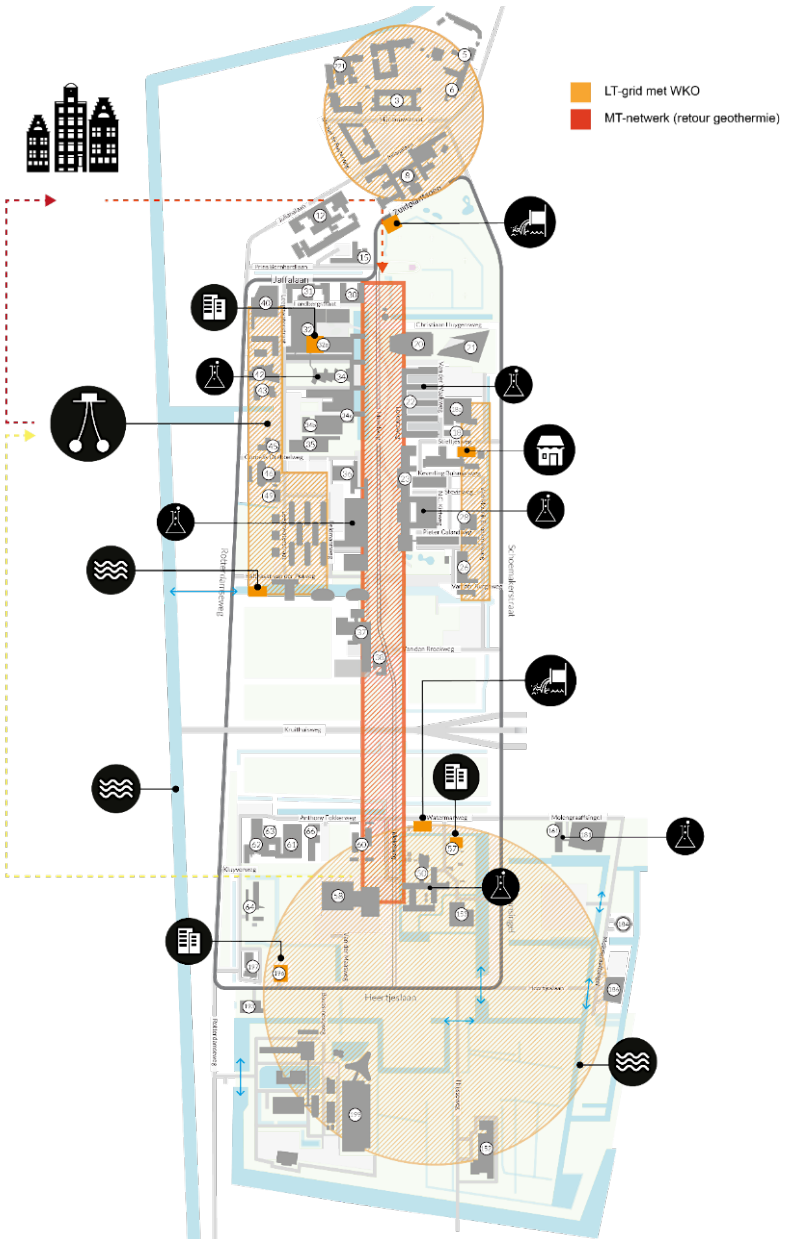


Figure 12.04: Proposed division of HT (red) and LT (yellow) networks at the TU Delft Campus

Sustainable heat

TU Delft should proceed with the plans for the geothermal well and use this source instead of gas in the CHP plant. In the first phase, the geothermal source can be used as sustainable heat supply to the buildings on the campus, and at the same time serve as a living lab. Figure 12.04 shows these HT and LT networks at the TU Delft Campus.

Carbon emissions from formation gas

Carbon emissions from a geothermal heating system can have multiple sources, related to formation gas, which is likely to be >95% methane:

- Direct emissions from volatile formation gas. Since gas can be captured, this emission must not be accepted.
- Indirect emissions, from TU Delft's own usage. Formation gas can be stored as backup energy for wintertime or for special applications. However, burning gas will cause carbon emissions. The CO_2 released from incineration can be captured and used for algae production, for e-fuels (see later), to be stored in the underground[20] or for food production on campus. These options do not reduce carbon emissions, only neutralise them.
- Indirect emissions from usage by others. Formation gas can be converted to Groningen quality type gas and injected into the municipal gas grid. Since it will then be used by others, carbon emissions will not be of TU Delft.

A HT ATES system for geothermal heat will allow TU Delft to reduce emissions significantly: it is estimated that CO_2 for heating will be reduced by more than 60%, the HT ATES system will reduce another 30% at least.

To be investigated: a system wider than just the campus

The supply temperature of the geothermal source is around 75°C (maximum 73°C after the heat exchanger), a bit lower than the current heat delivered, which means that, although limitedly, connected buildings must be renovated. In later phase, when most buildings of TU Delft have been renovated, the geothermal well (still delivering HT heat) could be used for corporation houses in Voorhof East or buildings in the inner city of Delft, see figure 12.05. The MT return temperature of about 55°C can then be used for TU Delft, which in due time will also have a lot of buildings using LT heat.

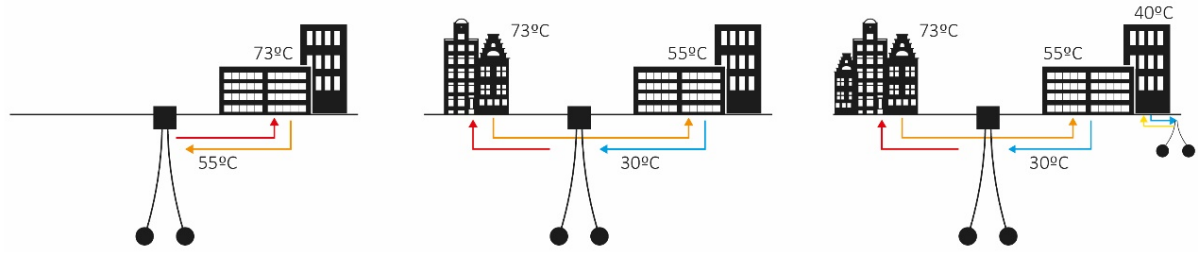


Figure 12.05: 3 phases of a heat network powered by the geothermal well (HT, MT, LT)

[20] Injecting CO_2 into the ground may have benefits: it makes the soil weakly acidic and thereby reduces scaling.

A high-temperature seasonal storage is required to store the excess/residual heat in summer or to drive heat-powered cooling. This HT ATES system can allow for utilisation of other sources of excess heat, e.g. produced from the sun with solar collectors and PVT panels (power-to-heat) and stored in the underground.
Using geothermal heat already reduces 60% of carbon emissions from heat production, including a HT ATES adds another 30% of reduction. Therefore, switching to a geothermal system is essential for large carbon reductions on the campus.

Smart exchange of heat and cold

TU Delft should use smart exchange, linked to seasonal storage, of heat and cold. Buildings with too much heat can then simultaneously supply buildings with a shortage and the other way around. This reduces the total energy demand as well as peaks and valleys in supply and demand. Seasonal differences cannot be completely covered, which requires seasonal storage. ATES is a well-known and proven technology to do this. By implementing this, a smart and sustainable exchange and storage system is created that matches the ambitions and activities within TU Delft. Working with supply based instead of demand based might be an interesting paradigm shift, focussed on the heating and cooling potential of sources on the campus and using intermediate storage to leverage differences.

Sustainable cooling

As described in the previous chapter, the New Stepped Strategy should be used during the design of buildings. The first step is to reduce the (cooling) demand by passive, smart & bioclimatic design. Examples of nature-based and passive solutions are shading, insulation, reflection, natural airflow, water, plants, earth, and thermal mass. Next to outside air, the water of the Schie canal, Zuidpolder pumping station, Rotterdamseweg drinking water pipe, and the sewage pumping stations at Watermanweg and Zuidplantsoen have a great cooling potential all together and can be combined with a cold storage. The Schie has a cooling potential of 4,000 MWh_{th} per year and the Zuidpolder pumping station even 10,000 MWh_{th} per year. In addition to passive solutions and aquathermal energy, absorption cooling is also a possibility in summer.

Sustainable electricity

In order to become CO_2 neutral in 2030, half of all the energy should be produced on the campus of TU Delft. This refers to heat and electricity. Electricity can be used for heat as well (‘power to heat’).

PV

TU Delft should also use PV on a larger scale to reach the sub-target of producing half of all energy on campus. PV should be applied on both roofs and facades to enlarge the energy production and to ensure an even production throughout the day. In renovation projects, building services should not be placed on the roofs to make sure this space can be used for PV. Beside this traditional use of PV, PV can also be used in skylights, integrated into roof

slates, cover parking garages and cycle paths, PV fields on empty lots, floating PV on water features, and acoustic PV screens along the Kruithuisweg.

To be investigated: wind
Wind could also be used as a sustainable energy source. However, the potential of wind turbines on campus is minimal because of the high building density and surrounding residential areas. In the past, research was done into the possibility of wind turbines. At the time, this was impossible. Research should show whether this is still the case or not**;** especially the south campus has space for wind turbines – it should be investigated if these cause undesired vibrations for the research facilities over there.

To be investigated: batteries
Batteries are needed for daily storage of renewable energy and grid stability (MWh), mobile electronic equipment (Wh), and electrical vehicles (kWh). Batteries are currently made of scarce materials and have a limited capacity. At present, research is done into Li-ion, Li-metal, Li-air, solid state (both inorganic and polymer based), Mg-ion, Na-ion, as well as aqueous batteries. In addition to batteries, a fuel cell could be used as electricity generator, using hydrogen as energy storage. The fuel cell combines hydrogen and oxygen to produce electricity, the by-products are water and heat. There are no emissions due to the fact that there is no combustion.

To be investigated: networks
On the one hand, the electricity system is decentralising through the generation of solar power, wind power etc., which results in a variable energy supply. On the other hand, as a result of new applications such as electric cars, consumer needs change. Consumers become producers themselves, which means that the network must also be able to handle two-way traffic. With a smart grid, TU Delft can enable the optimal alignment of supply and demand of electricity. Network sensors that monitor the levels and quality of tension, smart energy meters, and digitised electricity networks with smart algorithms are all examples of techniques that could support the smart grid[21].
The electricity grid can be stabilised by means of Battolyzers.

To be investigated: green fuels

Biofuels
According to Blom & Dobbelsteen [2019], the energy potential from biomass, wood-like and fermentable material, is relatively low within the limits of the campus. This can increase if TU Delft separates organic waste and convert it into biogas or another form of biofuel. Experiments should be done in the forms of Living Labs with production of other types of biofuels, such as from algae. Algae can be used to process waste (water) and at the same time produce energy (biodiesel) and absorb CO_2.

[21] https://www.tudelft.nl/en/tpm/research/projects/smart-grids

E-fuels
Another form of green fuels are electro fuels or e-fuels. E-fuels store electrical energy from renewable sources in a liquid or gas state. Butanol, biodiesel, and hydrogen are examples of e-fuels, possibly even distributed in a network. These are examples of downstream finishing of primary products. For instance, when CO_2 is produced and coupled to green hydrogen, everything can be made: from methane, via kerosene to waxes. A hydrocracker is needed here. Methane and methanol and CO_2 can be first target molecules.

ESP Lab
ESP Lab stands for Electrical Sustainable Power Laboratory. Scientists research the generation, transmission, distribution and use of electricity by households and companies. As university, we need to take decisions quickly and take tangible steps toward a sustainable energy system. A green and smart system is needed that allows everyone to connect their solar panel and that allows any vehicle to recharge without any problems. To establish such a system requires extra research, which is done in the ESP Lab. It focusses on four research fields: photovoltaics, e-mobility, DC systems and intelligent energy systems.

Digital twin
In addition to the previous research fields, ESP lab also works on developing a 'digital twin'. Research on the intersection between energy systems, digitalisation, and artificial intelligence requires access to the proper (simulation) infrastructure and data. New decision support systems, as well as self-learning algorithms, need to be integrated into the energy system to assess their performance. We can however not experiment with the real system. The solution is a digital twin; this is a virtual system that matches reality as closely as possible.

TU Delft digital twin platform
In agreement with the ESP Lab we propose to develop a digital twin platform of the TU Delft distribution network and the infrastructure needed to facilitate research and education, and then grow towards a broader virtual model, integrating other energy carriers (e.g. gas and hot water) that are also used on campus. With this platform, TU Delft will be internationally leading in the development of digital energy system models for real-time decision-making and planning, while the campus is established as a European pilot for research in digital energy projects. This project can become an enabler for other research studies and a base to secure funding.

12.04 Specific projects, pilots and actions

Research is needed into the seasonal and diurnal differences in demand and supply, per building or area, in order to get a better indication of shortages and surpluses and of the best fitting solutions and best options for energy storage.

HT heat

- HT heat from natural gas to HT/MT geothermal heat. The threshold is financial: a subsidy or extra investment money is needed to get it started.
- Expanding the heat network to the city of Delft; this also need to be made it feasible.
- There can be synergy with the heat network plans coming from the Rozenburg waste incineration. There is a strategic agenda running with the Ministry of EZK.
- (Experimental) HT heat storage is economically feasible, but research requires funding.
- Additional winter fuels: biogas, biodiesel, e-fuel from air-captured CO_2.

LT heat

- (Experimental) LT heat and HT cold networks in new developments and midlife renovations, linked to labs and datacentres.
- NorthC datacentre can supply the heat network to buildings at the Heertjeslaan; this may also be possible with the RID datacentre.
- Certain functions could be connected to the datacentre.
- ATES and BTES systems for seasonal storage; the ATES system could be combined with underground water storage (possible collaboration with a company called Field Factors).

Cooling

- Insight is needed in the current cooling demand.
- Cooling is the main problem, not heat. Options for cooling capacity: Schie canal and other water bodies, drinking water network, BTES system in the shallow underground (down to 150 m). We need to try to match in time (seasons) excess heat and excess cold and their demands.
- Cold network, or local solutions (closed circuit cooling), such as the new Physics faculty. To be determined: HT cooling only, or also LT cooling and ULT cooling (for cryogenic processes).

Electricity

- Maximisation of PV on campus, based on study of a team led by Olindo Isabella [Zhou et al. 2021]: lightweight modules on large flat roofs, EEMCS to be further elaborated, ESP Lab roof, Bouwcampus is priority. The PV study needs to be translated into a PV action plan and timeline for the campus.
- Network capacity: although the PV generation (and in the future, with other sources) will not go beyond consumption, a technical study is needed regarding network capabilities to handle reverse power flow.
- A study regarding voltage magnitude violation threshold is needed, as well as distribution transformer overloading capacity.
- (Experimental) wind turbines, large ones possibly on Campus South.
- (Experimental) electricity storage in batteries, hydrogen, e-fuels, for instance to convert formation gas into hydrogen → mineralising CO_2.
- (Experimental) thorium plant, with Jan Leen Kloosterman and in collaboration with NRG, Petten.
- (Experimental) two-way charging of electric vehicles (at parkings).

- TU campus as power plant, including smart management (measurements, control, storage).
- Detailed and updated network topology of the campus. This information can be used to develop a digital twin of the campus in our (IEPG) control room of the future.
- Real-time monitoring model (digital twin) of the campus in the control room of the future (Peter Palensky)

Living labs

- See experimental set-ups above.
- Brains for Buildings / Future Lab for Smart Building / Smart multi-commodity network (including measurements and data processing).
- The 24-7 project, also expanded to clusters, neighbourhoods and campus. Power to heat/cooling, run heat pump on a supply base rather than demand based.
- Firma van Buiten aquathermal energy living lab.
- Solar power, batteries and charging facilities.
- PV, microgrid and battery at the Rotterdamseweg parking garage: the entire 3mE area as test site with living labs.
- Hydrogen project with Bendiks Jan Boersma and Fokko Mulder (Battolyzer): electrolysers as grid stabilisers.
- CO_2 into geothermal well or HT heat storage, or as source for carbon in industry.
- E-refinery large-scale facility lab (100 kW), electro-bio conversion; this was requested, with a completely new regime for electric current.
- Data measurements, sensors, digital twins (connecting energy data and building management system data).
- Use networks on campus as scientific infrastructure (living lab) – 'include sustainability as a lump sum'.

Datacentres

- Energy savings in the datacentres themselves, energy efficiency of computers and servers, smart work schedules.
- Other forms of computing → more intelligent processing, nanocomputers.
- Making better use of residual energy → Feeding residual heat into the LT network via water-based cooling.

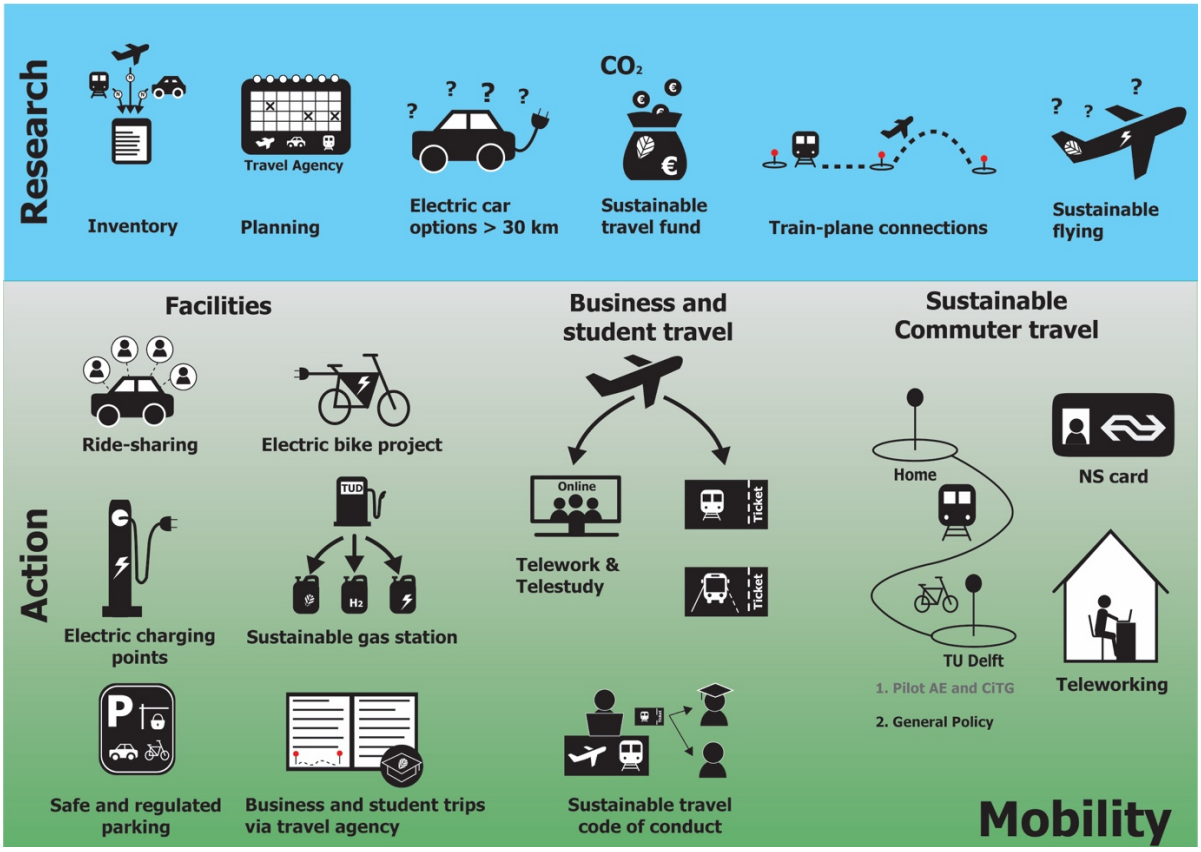
Other projects

- CO_2 capture from (exhaust or outside) air and mineralisation (carbonisation)
- DC network for stand-alone lampposts

13 Mobility

Team (in alphabetical order)

- Mignon van den Berg – IDE, mobility programme coordinator
- Stijn van Boxmeer – CEG executive secretary
- Lieke Brackel – TPM
- Andy van den Dobbelsteen – TU Delft sustainability coordinator
- Jessy van Eesteren – GreenTU
- Irene Fernandez Villegas – AE sustainability coordinator
- Deirdre van Gameren – TU Delft sustainability researcher
- Andrea Gammon – TPM
- Gerdien de Graaf - ESA
- Anke Hacquebord – ESA/International Office (ABE)
- Sascha Hoogendoorn-Lanser – I&IC
- Serge Hoogendoorn – CEG
- Denise Huizing - CRE
- Judith Jonkman – HR
- Arthur Koeman – HR
- Maaike Kraeger-Holland – ESA/International Office (CEG)
- Eline Lakerveld – HR
- Olivia Meng - GreenTU
- Rick Nelen – GreenTeam AE
- Ingeborg Oostlander-Çetin - CRE
- Cristina Riti – GreenTeam AE



Mobility

Main proposals

General aims and principles

- To **avoid and reduce** travel and make it sustainable
- To standardise **online and hybrid** sustainable conferences
- To have **fossil-free, emission-free** transport on campus by 2030
- To **prohibit** flying within the Netherlands and Belgium
- To include an internal **carbon tax** for travel

To be investigated

- Making an inventory of **student travel**
- Exploring options of **electric car** incentives for >30 km commuting
- Starting up international **train ride and bus planning** by travel agency
- Getting **student trips** planned via travel agent pilot
- Using **train-plane connections** for intermediate stops
- Initiating a TU Delft **sustainable travel fund**, financed from internal carbon taxes
- Exploring options for sustainable flying at Rotterdam-The Hague **Innovation Airport**
- Elaborating a **ride-sharing** pilot
- Designing an online **tool** or smart phone app

Projects, pilots and actions

- Writing a **sustainable mobility policy**
- Writing a clear **travel policy** for the tender to select a new travel agency
- Writing and communicating the sustainable travel **code of conduct**
- Elaborating **e-learning facilities** on campus
- Commencing the CEG, AE and ABE **business travel pilots**
- Developing a European **green exchange options** catalogue
- Prolonging the **electric bike project** for 10-30 km commuting to a larger audience
- Expanding the **NS card** project to all employees
- Regulating **car-parking**
- Expanding electric **charging points** on campus
- Designing comfortable and safe **bike parking facilities**
- Commencing the **mobility dashboard** project
- Showcasing the difference in carbon emissions per type of travel, with **infographics**
- **Mapping** travel destinations, travel modes, carbon emissions, travel time and costs
- Finishing the sustainable student travel **video** (GreenTU)
- Re-installing **employee sporting** on campus
- Upscaling the **health coach** programme

This chapter focusses on 3 different types of travel: commuter travel of staff and students, business travel (national and international), and international student travel. These 3 forms of travel all fall within scope 3, upstream and downstream.

13.01 Desired future situation

Commuter travel

Avoiding commuter travel
The best way to avoid carbon emissions due to travel is to avoid travel itself. The corona crisis demonstrated that working from home is possible for many, almost all activities. The near-future situation does not have to be as stringent as during the lock-down periods, but a certain part of working time can be executed from home; good teleworking facilities are essential. A good thing of the corona crisis is the social acceptance of working from home. A second aspect is the possibility to work at different times that better fit the private home situation, whereas the old situation was based on the rigid 9-to-5 scheme. It is important to make clear agreements about this so that both the employer and employee know what is expected from them and what the boundaries are.

Sustainable commuter travel
Staff and visitors of TU Delft come to the campus in a sustainable manner: on foot, by bike or e-bike, public transport, or fossil-free car. Employees of the TU Delft receive a NS travel card as stimulation to take the train.
Various studies in the Netherlands indicate that from 2030 onwards no new fossil fuel cars will be sold anymore and that by then at least 20% of the vehicle fleet will be electric. Eventually, all fossil-fuelled vehicles will be banned from the TU Delft Campus. By 2030, this will not be entirely the case yet but fossil cars will have to remain at parking facilities on the edges. To discourage parking, however, the university is using the carbon tax to calculate parking fees, which will logically be higher for fossil cars. In addition, parking spaces will only be used by students and employees that do not have a sustainable alternative.

International travel

Avoiding international travel
Another effect of the corona crisis is the growth and improvement of online meeting tools. Teams, Zoom, Webex, GoogleMeet, GoToMeeting…, all have taken off as tools for (inter)national meetings, while Skype (for Business) has actually become less popular. International conferences and project meetings will be online or at least hybrid by default, not just for safety reasons, but also for the inclusion of people who otherwise would not be able to travel, for instance, people from developing or emerging economies.

Sustainable travel
Regarding trips for projects or conferences, employees and students are conscious of their choice to travel or not. A code of conduct on sustainable travel decisions helps to guide this process: what are the basic requirements for acceptance of a foreign trip for various purposes? Providing good information to students and staff helps to take away unease for traveling with a different mode of transport. A sustainable travel map is in place to find the most sustainable means of travel in Europe. TU Delft supports employees with an EU train card and the possibility to hire an electric car abroad. Travelling outside Europe is only done when strictly needed, and then in the most sustainable (shortest) way.

Travel agency
For best insight into the environmental impact of travel, all travel movements for TU Delft activities are registered by both students and staff. In order to achieve this, all trips are booked through the travel agency. Without this registration, it is not possible to get a sustainable travel fund or to invoice travel costs via Digiforms. In that case, the student or employee will pay the trip themselves; exceptions to this rule are limited.
In contrast to the situation in the past, thanks to extra training and new tools, the travel agency now finds the most sustainable alternatives for travel, first looking at train and bus rides (and possibly boat trips) before flights.

TU Delft's internal carbon tax
When choosing a form of travel, a trade-off is made, taking into account travel cost, duration, and carbon emissions. By installing a carbon tax, environmental costs are included in the price automatically. This carbon tax is based on the carbon price: € 150/ton CO_2-eq. Non-sustainable travel options have become relatively expensive compared to sustainable ones. The carbon tax goes into the TU Delft Sustainability Fund, from which sustainable investments are financed, indirectly reducing carbon emissions at another point, and from which financial support can be given to relatively expensive sustainable trips, such as train rides across Europe for students. That way, a bonus-malus system is installed which makes unsustainable travel more expensive and sustainable travel cheaper.

External parties
The desired future situation outlined above also applies to external companies affiliated with TU Delft. The university has drawn up basic rules in cooperation with external companies, which they adhere to. The university facilitates the basic needs to adhere to these rules, such as sufficient electric charging stations.

13.02 Mobility at present

Environmental impact of various transport modes
The climate impact difference of various modes of transport is great, as figure 13.01 demonstrates. Flying is most impactful, but also travelling by car alone has serious implications when compared to bus or train rides.

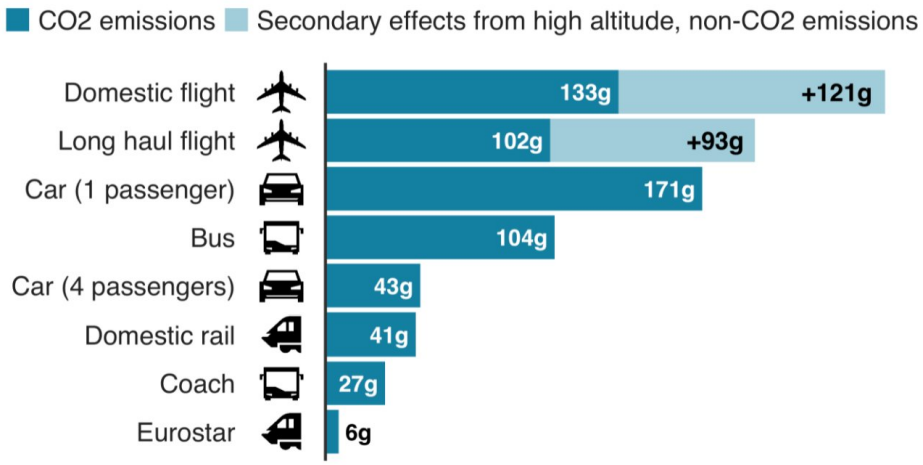


Figure 13.01: CO_2 and other greenhouse gas emissions from different modes of transport, per passenger per km travelled [BBC, source: BEIS/Defra Greenhouse Gas Conversion Factors 2019]; 'car' is an average diesel car

Figure 13.01 is based on the UK; in the Netherlands, as a result of the wind power procured by NS, travelling by domestic train is carbon neutral. The graph does not show the impact of electric cars, but even with an average energy mix in the electricity grid, these are expected to reduce emissions by a factor of 4, getting close to the emissions by a coach.
Regardless, the message is clear: if TU Delft takes climate action seriously, it will have to be sharp on the choice of travel mode, since mobility is one of the significant factors in its carbon emissions.

Commuter travel

Commuter travel by employees
In 2018, the total number of fte for employees was 5,421. Per fte, staff travels to and from the university 10 times a week, 44 weeks a year. Around 2,168 fte (40%) is living in Delft and the average distance per fte is 15.6 km (as the crow flies). Figure 13.02 shows the modality choice. It is assumed that all employees living in Delft and up to 6 km away travel on foot or by bicycle. For distances greater than 6 km, the average distance to the campus was taken [Blom & Dobbelsteen, 2019].
The total number of fte for employees is rising every year; in December 2019 it was 5,607 fte. This increase leads to more travel movements, and more emissions if no measures are taken. Table 13.01 shows that the carbon emission of employee commuter travel is 3,118 tons CO_2-eq [Tax, 2021].

Table 13.01: CO_2-eq emissions by staff due to public transport (OV) and cars (Voertuig) [Blom & Dobbelsteen 2019]

Woon- werkverkeer	Eenheid	Volume	Emissiefactor CO_2	2019 (ton)
OV	fte per postcodegebie	953	verschillend	281
Voertuig - fossiele brandstof	fte per postcodegebie	2.019	verschillend	2.837
Totaal	**ton**			**3.118**

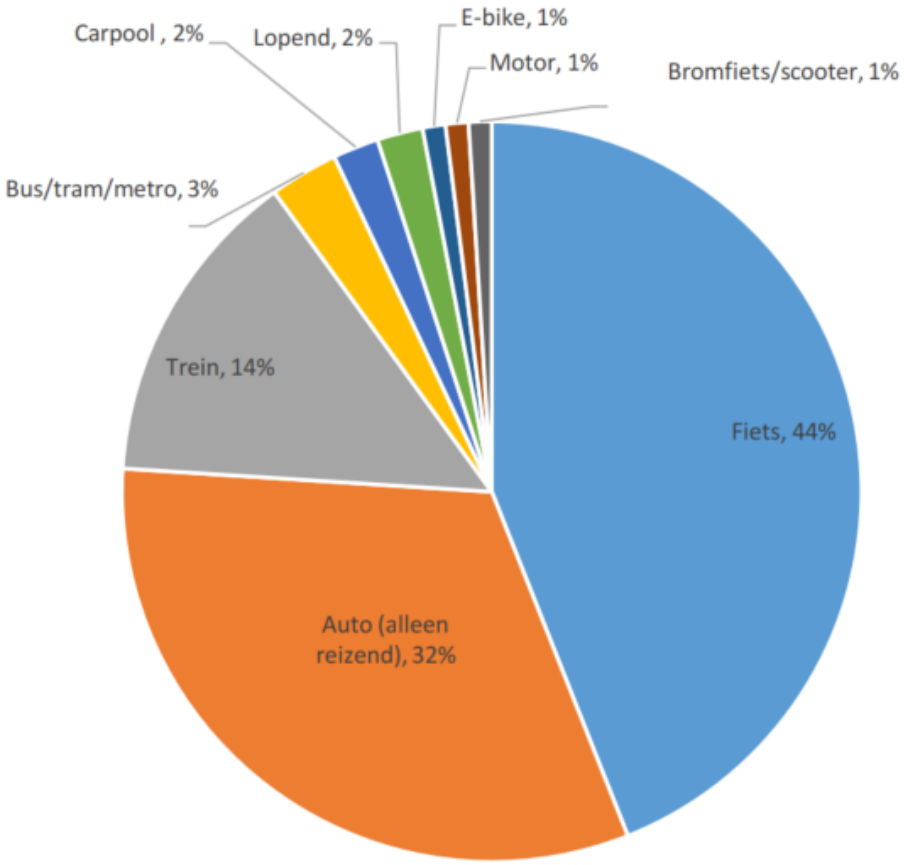


Figure 13.02: Modality choice TU-Employees [Klugt et al. 2018, in Blom & Dobbelsteen 2019]

Commuter travel by students

There is no information about the means of transport chosen by students. The only information available is the places where they live. In 2017, 54% of the students (13,720) lived in Delft; it can be assumed that the majority of this group travels by bicycle. 84% of the students live in South-Holland, including Delft; the same percentages are used for 2019. It is estimated that students outside Delft mainly use public transport. The average commuter distance is 16 km; outside Delft it is 34.5 km.

It is assumed that 2.3% of the students travel to TU Delft by car, based on various parking studies [Dijk-Koekkoek 2018]. Table 13.02 shows that the carbon emission of student commuter travel is 2,816 tonnes of CO_2-eq [Tax 2021].

Table 13.02: CO_2eq emissions due to commuter travel by students [Blom & Dobbelsteen 2019]

Gebruik van verkochte producten en diensten	Eenheid	Volume	Emissiefactor CO_2	2019 (ton)
Reisbewegingen studenten	aantal studenten	25.407	verschillend	2.816
Totaal	**ton**			**2.816**

International business travel

Next to commuter travel, employees of TU Delft also travel for work to clients, events, workshops, conferences, etc. Staff has to book their business flights via BCD travel, which keeps track of the booking of so-called travel segments. Table 7.03 shows that a distinction is made between air travel and travel by taxi and public transport. In the year 2019,

employees flew 29,388,256 km, which is 733 times around the world, and 307,499 km by taxi and public transport, which is 7.7 times around the world. It is likely that these numbers are even higher because not all trips were booked via BCD, but invoiced later. In 2017, 3.66 million euros were paid via digiforms to invoice trips abroad. Table 13.03 shows that the carbon emission of business travel in 2019 was 4,948 tonnes of CO_2-eq [Tax, 2021].

Table 13.03: CO_2eq emissions due to international travel by employees [Blom & Dobbelsteen 2019]

Dienstreizen vliegtuig	Eenheid	Volume	Emissiefactor CO2-eq	2019 (ton)
Regionaal	km	1.463.769	0,297	435
Europees	km	7.373.011	0,20	1.475
Intercontinentaal	km	20.551.476	0,147	3.021
Totaal	**ton**			**4930**

Dienstreizen medewerkers	Eenheid	Volume	Emissiefactor CO2-eq	2019 (ton)
OV	km	272.141	0,04	9,8
Taxi	km	35.358	0,22	7,8
Totaal	**ton**			**18**

Zakelijke dienstreizen totaal	**4.948**

Student travel

Next to daily commuting, students also travel for excursions, site visits, holidays with a student association, or for an exchange. There was no information about this when the most recent carbon accounting report was made, but at the moment this is under scrutiny. The first step is to make an accurate inventory of the number of trips made by students[22], which in the future will be better administrated if these trips are requested through TU Delft's travel agency.

Faculties have their own mobility fund to stimulate students to go on exchange. At the moment the further the trip, the more money students receive, promoting trips far away rather than close by. We propose that this system is changed into a fund for sustainable travel defined by the distance and means of travel, such as Utrecht University has.

Carbon impact

Commuter travel and business travel of staff both fall under scope 3, upstream. The total emissions of scope 3 upstream are 25,605 tonnes of CO_2-eq; 32% (8,066 tons CO_2-eq) originates from these travel movements. Considerable improvements can be made here. Commuter travel for students falls under scope 3, downstream. The total emissions of scope 3 downstream are 2,817 tonnes of CO_2-eq; 99% (2,817 tonnes of CO_2-eq) originates from commuter travel for students. As mentioned, there is no accurate figure for international student travel yet.

[22] An (insufficient) overview of student trips can be obtained from trips registered in OSIRIS (MyTUDelftApp)

13.03 Specific projects, pilots and actions

Labour conditions

In order to reduce the emissions caused by employees, TU Delft should make some changes in the labour conditions at TU Delft. The university should make its ambitions and drive clear during the employment interview so that new employees are aware of the common sustainability goal. During this conversation, it should be discussed how the employee wants to commute to the campus and how the university can facilitate them with green solutions. Possibilities in IKA and other arrangements should be discussed.
Figure 13.02 showed that 44% of the employees come by bike, which is a good starting point. However, 32% comes alone by car and only 2% uses carpooling. It is likely that the vast majority of this group lives too far away to cycle or walk to the campus. TU Delft should encourage and facilitate this group to use electric bikes or public transport, to share rides with colleagues, or to use an electric car. It is important to take away the worries to choose a different sustainable way of traveling.

Biking

Around 40% of the employees live in Delft. This group of people should mainly use the bike to go to work. To stimulate this, the university must make it attractive to use and buy a bicycle. Offering employees a lease bike is not a good option because employees cannot receive any other travel allowances, which makes it more expensive. It is also not possible to apply the old IKA arrangement, to buy a bike without tax, because there is no room in the work-related expense scheme (WKR). This was checked with PwC and Executive Board. More space is needed in the work-related expense scheme to make this possible.

Electric bikes

A large share of people using cars is living within 30 km from the campus, which makes electric bicycles (e-bikes) a suitable mode of transport. TU Delft should stimulate this group to use an e-bike, when a normal bike is not an option, instead of the car. Research is needed into tax possibilities, discounts, and IKA arrangements. It can be checked whether after a number of years, services can be added such as repairs, new battery, etc. A comparison must be made to find the most sustainable brand/model and to see which company fits within our circular procurement and contracting vision; see chapter 14.

Discount on bike purchases

Since November 2021, HR made arrangements with local bike shops in and around Delft for a 5% discount on the recommended price of a standard or electric bike, a free maintenance package, free maintenance at 3 months and a free loan bike during maintenance and repairs. We propose to make this a more generous arrangement in the coming years.

Bike-sharing

As the campus is working on regulating car parking there is a probability that someone has to park further away from their destination. To prepare for this, the university organised a free bike-sharing pilot. The bikes could be pick-up and dropped-of at all large car parks, at

the Aula, and at Coffee & Bikes. This pilot currently runs until 30th of April 2022. The municipality expects that the permit system for shared bicycles will be operational in the second quarter of 2022, when there will probably be more shared bike systems in Delft.

Public transport

Several incentives exist to stimulate employees to take the train, bus or other means of public transport instead of the car. In 2019, the mobility management team organised the 'Travel to campus the other way' pilot. A group of employees were given free use of public transport. 52% of the participants found it easy to use the train for at least three times a week; they were able to relax on the train. Moreover, 60% of these employees started to think more positively about public transport and believed that the train is a good alternative after this pilot.

Bespoke approach

Incentives can be installed for business trips and/or commuting purposes. Based on data of where employees live and travel from, we can differentiate between incentives for specific target groups. Not only financial benefit but also user comfort and easing administration are important factors for the instruments to be effective. Two concrete incentives to stimulate the use of public transport for business and commuting travel are listed below.

To be investigated further: NS business card

A selected group of employees already makes use of the NS Business Card for business trips, as part of a pilot that started in 2019 by ICT-FM. The processing of travel invoices (traditionally via invoices of the employee, which need to be checked and accompanied with travel ticket overviews) proves to be much cheaper when TU Delft has an automatic bill arrangement with NS. More research is needed into possible regulations to control the use of NS travel cards and to find out if everyone gets a personal card or a group card, per chair or department for example. We advise TU Delft to investigate the feasibility of an NS Business Card roll-out for all employees or academic staff at least, for the purpose of business trips.

To be investigated: NS discount card

Another option is to provide all employees with an NS discount card. Depending on the discount card the price varies from €5 ('dal voordeel') to €23 ('altijd voordeel'). These cards are much cheaper than the business card and with the 'altijd voordeel' card the employees will receive a 20% discount during peak hours and 40% discount during off-peak hours, weekends and public holidays. Another option is the 'traject vrij' card. With this card employees can travel for free on the route from home to work and receive a 40% discount on other routes. The price of this card depends on the length of the route. These discount cards could already be enough to motivate employees to take the train.

More research is needed into possible regulations to control the use of the NS cards and to find out if everyone gets a personal card or a group card, per chair or department for example.

To be investigated: cars

Ridesharing
Encouraging ridesharing is also a possibility. By connecting staff and students who travel similar trajectories, fewer parking spaces will be needed, less traffic will be on the road, and carbon emissions are reduced and shared.
There are several systems and tools on the market, which can help people with (almost) the same travel schedule and route to find each other. We recommend to set up a ridesharing pilot project to test this. This could entail the stimulation of carpooling and the development of an online tool or app.

Electric cars
When staff lives at a distance farther than 30 kilometres from TU Delft, using an electric bike is not a serious option. If public transport is not an option either, TU Delft can promote and support the use of electric cars, instead of fossil-fuelled cars. This converges with the ambition to make the campus fossil free by 2030. Options should be discussed during the interview of the employee.

Other arrangements

Home office facilities
Another measure that can be taken to reduce emissions from commuter travel is to offer staff proper facilities to work (partly) from home, as was widely done during the corona crisis. We recommend TU Delft to make arrangements with its employees about the possibility to work from home as a part of their appointment size.

Sports facilities and the Health Coach Programme
At present, arrangements for employees to do sports on campus are limited or unreasonably expensive. If we want to stimulate walking and cycling instead of taking the car, it is beneficial to both TU Delft and employees to become fitter (and healthier) by doing sports. It is also possible to follow the Health Coach Programme at TU Delft.

External parties
The university has to cooperate with external companies affiliated with TU Delft to become a sustainable campus. The university will enter into discussions with these companies to clarify its vision and ambition and to ensure that these goals are jointly achieved.

Clear insight
At present, people are not aware of the impact of their travel. Simple comparisons can be made to clarify this. An online tool or smart phone app could do the job, next to information meetings. The university and student exchange office could stimulate the use of apps like Trainline, GoEurope, and OMIO. Explaining it in understandable quantities will help. For example: taking a train instead of an airplane saves the energy of X many minutes of showering, or Y trees are needed to offset your carbon emission by plane or by train. This

can be illustrated by engaging images. Additional research is needed to find the best way to show this. The goal is to clarify someone's personal impact and to show that they are also the ones who can change this.
In addition, the university should work together with Bereikbaar Haaglanden en Rijnland; they developed a mobility scan which can initially be used as a baseline measurement. This tool can be used to personally advise people to take the most sustainable means for commuter travel.

Facilities on campus

Teleworking and E-Learning facilities
To reduce commuter travel from employees and students, the university must improve teleworking and e-learning facilities at the campus. Meeting and lecture rooms must be provided with cameras and other electronics that are needed to enable hybrid meetings and lectures, see ICTAID chapter.

Travel infrastructure
The TU Delft campus should be comfortable and safe for people moving around. At present, there are spots on the campus (for instance the west entrance of ABE and the crossing next to ESA), where during rush hour dangerous situations exist for both pedestrians and cyclists. We suggest that the infrastructure of the campus be improved so that employees and students can travel safely. The bus line is going to be replaced to prepare for the tram and to improve transport on the campus. In addition, other cycle routes will be initiated on the outer edges of the campus. In addition, a pilot has started to test the possibilities of an electric waterbus that sails between Deltares, L&R, 3ME, Nieuwe Haven and Delft station.

Facilities for e-bikes
Alongside the arrangement to stimulate electric biking among employees, we propose that the campus offers sufficient charging points and adequate and safe parking facilities for e-bikes. Repair facilities and air pumps will also stimulate the use of bikes and e-bikes. These facilities must be designed in a corporation with the Health, Safety & Environment (HSE) department due to fire hazards. At the moment, Denise Huizing is writing a project brief for electric charging points and bike parking.

Car parking
Eventually, all fossil transport will be banned from the TU Delft Campus. Special rules should be drawn up regarding parking. As a starter, TU Delft has frozen the number of parking spaces. The next step is to regulate parking. We recommend that parking spaces on campus are available to TU Delft staff, students, visitors, and employees from companies located at the campus during work days and that the citizens of Delft can use the parking spaces outside these hours. This ties in with the idea of Campus as a City, City as a Campus.
We propose that from 2022 onwards TU Delft implements a carbon tax for parking to discourage the use of fossil transport. In addition, another means to regulate sustainable commuter travel, parking rights can be made exclusive or primarily for employees who live

at a minimum distance from TU Delft (e.g. 30 km) or who have special rights (e.g. medical requirements or physical limitations), to discourage others from taking the car. This can include several free parking days, paid parking, and parking on request in special circumstances. We advise to investigate parking arrangements (or cards for public transport) further.

Charging points for electric cars
In order to stimulate the use of electric cars, we advise TU Delft to facilitate enough charging points. At present, there are far too few of these. As with electric bicycles, HSE must also be involved in this case to make sure the facilities comply to the fire safety rules. The Central Government Real Estate Agency has drawn up a document about this. In addition, research is also conducted into electric cars that are able to cool their own batteries in the event of a fire.

Facilities for external parties
The external companies, located on the campus, should also have proper facilities to park their (electric)-bikes and (electric)-cars. In addition, the mobility dashboard could be extended to these companies if relevant. In any case, the dashboard can be used to get information about mobility. The simple comparisons that are drawn up to show the impact of travel are made for the whole community, including the external companies. By facilitating the external companies and providing the needed information the step to use sustainable ways of travel will become smaller. Most of the external companies are located at Campus South. It is important to create a good connection between the campus and campus south and between campus south and Delft campus station. To stimulate sustainable means of travel the bike sharing pilot should include external companies.

Outdoor mobility dashboard
The team of Serge Hoogendoorn, professor of Smart Urban Mobility, developed the campus mobility dashboard (CMD). This is a digital twin of the TU Delft campus, which provides insight into crowding on campus, at bus stops, and other hotspots on the campus.

Mobility plan
In 2022, Campus Real Estate & Facility Management started working on a new mobility plan for the accessibility of Campus South. The companies there have indicated that they want to be involved in this process and that they consider the possibility of using fewer cars. CRE wants to investigate whether a 'mobility hub' can be set up at the tram stop at X and P Sports (behind the parking building next to The Green Village). The idea is to be able to offer last-mile solutions, aimed at better accessibility of the south. At the moment, the university is already looking into last-mile solutions at Delft Campus station.

Business travel

Hybrid events
To reduce the amount of business travel, hybrid conferences should become the standard. During corona, we learned that events and conferences can also be held online. On the one hand, this saves time, travel costs, and emissions but on the other hand, it lacks personal contact. By offering a hybrid event, everyone can consider whether it is necessary to travel to the location or whether it can also be done online.

We recommend to write a code of conduct for travel decisions, which can guide this process: what are the basic requirements for acceptance of a foreign trip?

To be investigated: travel agency

As shown in Table 07.03, the total carbon emission of business travel in 2019 was around five thousand tonnes of CO_2-eq and the registered distance flown was nearly thirty million kilometre [Tax, 2021]. The actual emissions and distance travelled are higher because not all trips were booked through the travel agency. For better control over travel and to enable carbon tax and subsidy arrangements, we recommend – in order to justify reimbursements – to make bookings via the travel agent mandatory.
The current contract with BCD has almost ended. A clear travel policy (including the code of conduct) should be written and used for the tender to select a new travel agency. This must be done in collaboration with experts: External Office, HR and the sustainability coordinator.

From air to green travel
At present, the travel agency only looks into air travel. This must change. We propose that the travel agency first looks at the most sustainable travel options before advising on flights, and that a carbon tax must be included. The travel agency should specialise in advising green travel; personal contact is preferable to discuss options. To help the travel agency, a guideline should be made to find the best way of travel for a certain country, city, or area. A list of cities can be made to be reached otherwise than by plane, because of alternatives that are better in travel time, costs, and especially CO_2 emissions.

Sustainable travel pilots

Currently, with close involvement of GreenTU, two pilot projects have started at the faculties of Aerospace Engineering (AE) and Civil Engineering & Geosciences (CEG). The faculty of Architecture and the Built Environment (ABE) is planning a pilot as well. During these pilots, new policies and rules are tested.

National flights
As a very obvious measure to reduce unnecessary emissions, business flights within the Netherlands and between the Netherlands and Belgium should be prohibited.

Faculty of Civil Engineering & Geosciences
The management team of CEG made the following statement: “We contribute to a more sustainable world by considering how we execute our business travel. If online participation is not an option, we consider more environmentally friendly travel options. For travel to one of 15 defined cities, or when the total travel time from TU Delft to the destination is less than 8 hours, the default is the use of the train. Travel abroad by car is done with an electrical vehicle. We comply or explain.”
This policy went into place on the 1st of August in 2021. The train is the default option for Bremen, Brussels, Cologne, Dortmund, Dusseldorf, Frankfurt, Freiburg, Hamburg, Hannover, Lille, London, Luxembourg, Paris, Stuttgart, and York (via Leeds). Special permission is required for travelling abroad by plane or with a fossil fuel car. Furthermore, employees are allowed to travel 1st class by train if the trip is longer than 30 min. The costs for this upgrade is paid by the project or via the department, if they are not project related. The faculty supports a similar policy for travelling abroad by train. It is the individual responsibility for a traveller to comply or explain.

Faculty of Aerospace Engineering
In autumn 2021, a mobility pilot was proposed at the faculty of Aerospace Engineering. The general rule will be that meetings should be attended online, and that when this is not possible the train is the default option for 16 destinations. In addition, the train must be taken when the trip is not taking 1.75 times more hours than flying. Furthermore, intercontinental flights should be discussed with the supervisors.

International PhDs and postdocs
Special attention must be given to international PhD candidates and postdocs. Some have complicated arrangements with their home country, which makes traveling for their study exceptional. This group should be supported to make it possible to use a sustainable way of traveling to their destination instead of the cheapest way. The university must be more lenient with this category.

Towards greener travel means

International train rides
Europe is rapidly expanding its fast-speed and night train connection, as a result of which international travel by rail is becoming ever easier. At present, TU Delft staff and students can already use easy night train connections for longer distances: for instance, the night train to Munich, Innsbruck, and Vienna has been back since December 2020. In the future, more of these connections will be available; we recommend keeping a sharp eye on the newest developments in European train connections. With only a few good international connections (to Germany or Brussels/Lille/Paris or Brussels/London), the Netherlands could also be much more on the ball of international train travel; perhaps TU Delft, or the VSNU could urge the Ministry of Infrastructure (with NS and KLM) to initiate new connections, for instance to Hamburg and Scandinavia.

The Interrail pass is developed to make train travel within Europe easier. It is a single pass which can be used for all European train networks for a set amount of travel days. We recommend TU Delft to adopt this new system.

International flights
Even if a distant destination is chosen, there are still some important decisions to be made. For example, it is better to book a direct flight than indirect flights, some airlines are more sustainable than others, some planes are more sustainable than others, and there is the possibility to offset carbon emissions.
More research is needed into carbon emissions related to the type of airplane and distance flown (local, continental and intercontinental). Other than the type of airline and airplane, people can also choose between economy vs business class. The CO_2 emissions of 1 person in economy class are lower than 1 person in business class because this person takes up less space, which means that the emissions can be spread over more people. Economy class should become the standard and business class can be requested in exceptional cases.

Train-plane connections
Perhaps the worst performance in CO_2-eq emitted occurs when a European or intercontinental flight includes one or even two intermediate stops. In that case, taking the train to the airport with the longest haul flight will help to significantly reduce carbon emissions. Next to Schiphol Airport, typical airport hubs (mainports) that serve many destinations are Paris-Charles de Gaulle, London Heathrow, Frankfurt, and München, all cities that can be reached by (fast-speed) train connection. We recommend to investigate these train-plane connections better and to make these defaults when required to make an in-between stop. On the way back, a similar principle can be used by default: flying to a mainport and taking the train back home, for which extra reimbursement can be arranged.

Travel protocols
Based on carbon emissions per passenger.kilometre, it would seem logical to set a limit for flying defined by travel distance, for instance, to forbid or strongly discourage flights shorter than 750 km and to prescribe the train or bus as alternative. But as it is, some destinations within that range are difficult to reach by train or bus, and other destinations farther than 750 km can be easily reached by train or bus. So the decisive indicator can best be travel time. Including pre- and post-transport, a comparison can be made between air, rail, and road transport, of travel time, costs, and carbon emissions. Assuming more effective working time on the train, we suggest that on an international trip, compared to flying, taking two extra hours when taking the train is acceptable.

Travel comparisons
The time and cost that it takes to travel from door to door should be used when comparing traveling options. This includes the trip from home to the train station or airport, boarding time, and the trip from the train or airport to the destination.
Some pre- or post-transport options will be more expensive or will take longer. The train has some advantages over flying: it is an easy and relaxed way of traveling; the time on the train

can be seen as effective working time, and it emits less carbon emissions. It also has some smaller advantages, such as the seat size, foot space, and the possibility to walk. A disadvantage in comparison with flying can be costs and travel time, but as GreenTU has found, this disadvantage is often perceived more negatively than true.
We propose to work on a system that compares travel time, costs, and carbon emissions for flights, trains, buses, and other alternatives when planning a trip. This pilot has already started.

Travel map
With all of this investigated well and updated regularly, a travel map was developed (figure 13.03), providing information of travel time and carbon emissions. It shows destinations in Europe that must be reached by train (green dots), destinations that are preferably reached by train (yellow dots), and destinations where air travel is accepted (red dots). This should be part of the communication strategy to staff.

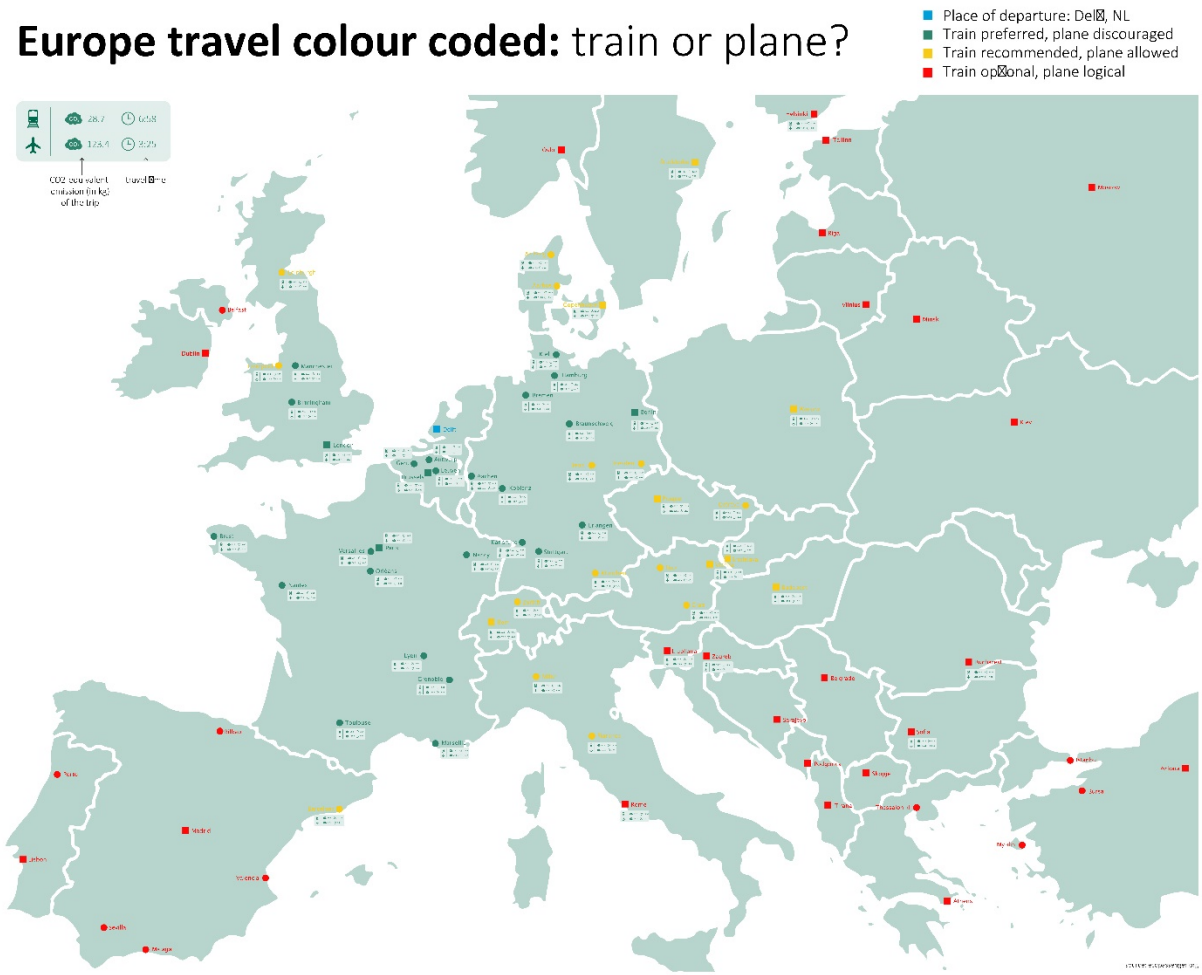


Figure 13.03: Draft travel map of Europe indicating preferred train travel connections (green), possible train connections (yellow) and destinations that require air travel (red)

Student Travel

There are 3 types of trips that a student can make, for a course (excursions, site visit, company visit, etc.), for holidays with a student association, and for exchange or internship. For each purpose, it must be checked whether the excursion, site visit or company visit is actually necessary and whether this can be done online. When it is necessary, a sustainable form of travel must be chosen, e.g. train or bus.

Travel agency

Just as with staff, it is proposed to have student trips booked by TU Delft's travel agency. This provides insight into its travel movements and the agency can help the students make a sustainable choice. As with staff requests, the carbon tax is included in the price and the agency looks into the most sustainable travel options before advising on flights. Also, financial support (to make a sustainable trip feasible) can only be arranged if the trip is registered through the travel agency.

Distant trips

Student association's trips often go to distant destinations. However, there are also interesting destinations closer to home, enabling a train ride. An advantage of taking the train is that students can bring large items with them, for example, their bike. A small disadvantage (mobility wise) of universities closer by is that it could be that friends and family will visit sooner and that hence more secondary carbon emissions are generated.

Travel choice support

In order to make responsible choices, student associations need to become aware of the emissions. We propose to make a document or tool (together with GreenTU and the travel agency) to help students make the right decisions. The GreenTeam of AE is working on a video to inform students on sustainability; mobility is one of the topics they will address. This will be relevant for all students, and possibly PhDs, postdocs, and staff. (International) Student associations may be involved, as well as the PhD board and councils.
Also for students, a travel map was made that shows the difference between airplane and train in time and emitted carbon; see figure 13.04.

Student exchange office

Students from TU Delft can go on an exchange during their bachelor's or master's curriculum. The student exchange office should help students with choosing the right university and the best means of transport. One way is by showing the student travel map on their website. We suggest that the exchange office stimulates exchanges with universities closer to home, so that students can take the train or bus. It can also highlight universities that focus and are ahead of the curve in the field of sustainability. Of course, intercontinental travel will remain but will have to be reduced for our carbon footprint.

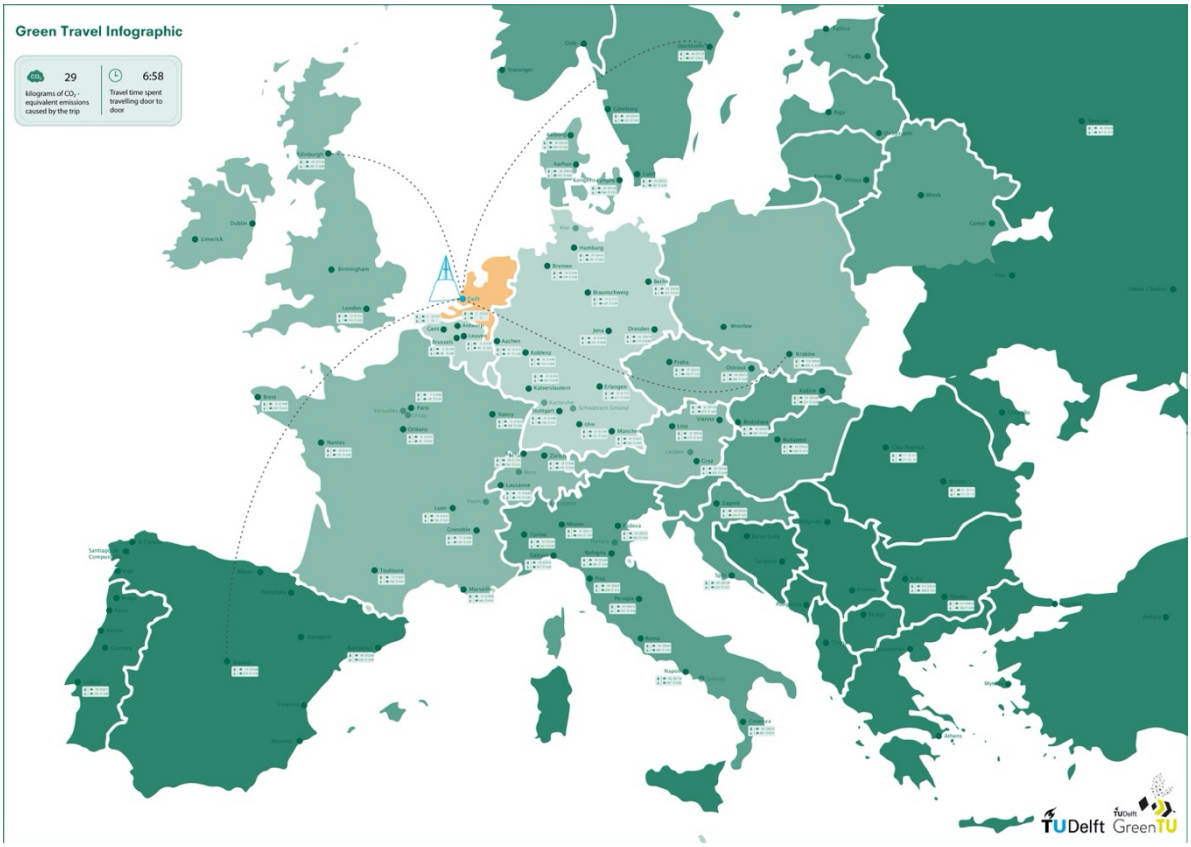


Figure 13.04: Green travel map for students, overview and detail [Green Travel (tudelft.nl)]

To be investigated: sustainable travel fund

Beside highlighting these universities, the exchange office can also help financially. For example, the University of Utrecht offers a green grant to students who take the train or bus to their European host university. We propose to arrange a sustainable travel fund at TU Delft, financed from the internal carbon tax imposed on business flights.

A Green Travel Student Grant was developed in collaboration with GreenTU and the student exchange office. This grant would offer financial support to TU Delft students travelling abroad by train or bus. The grant would provide them a reimbursement of a maximum of 185 euros in total, aiming at covering one full way ticket. This amount is based on the costs

for an interrail ticket that allows for travelling through all European countries for four days (the minimum number of days for a ticket). In this way, all Erasmus destinations could be reached by train, while the students are provided economic support.

Erasmus+ support
In the meantime an arrangement came into force with Erasmus+, which now offers 50 euros support to students, PhDs and staff travelling by sustainable means. Due to this arrangement, the Green Travel Student Grant was halted, but it remains to be studied whether TU Delft can still provide a top-up support for students, as € 50 may not be enough for them to take the most sustainable means of travel.

Studying from home
TU Delft must do research into the possibility of studying partly from home. Students could watch lectures from home which reduces the amount of student commuter travel. Of course, for other forms of education, e.g. design projects, this is not possible or desirable.

Other Means

Tools from external companies
Three companies already contacted the sustainability coordinator to offer help with improving the carbon footprint on mobility.

- PWC developed a dashboard where the employees of the university could see their own footprint focussing on mobility. They include the shadow price, CO_2 price, in this dashboard. That amount of saved money is put in a fund and used for sustainable alternatives, as suggested in this chapter. The money from this fund is used for direct offsetting, developing the tool, and other general high impact sustainable initiatives at PWC.
- Toogethr is the second company that contacted us. They developed three tools focussing on smart parking, ride sharing, and Toogethr cycles. This ridesharing app connects people with (almost) the same travel schedule and route to find each other; this will reduce the number of cars on the road. The parking app provides real-time insight into the parking location and optimises occupancy.
- The third company is Bereikbaar Haaglanden en Rijnland. Their mobility scan shows how much CO_2 can be saved by traveling differently and by working from home. By changing some buttons, TU Delft will be able to see the effect of adjusting their mobility policy in order to determine what is most efficient.

Other organisations that are looking into sustainable travel are erasmusbytrain.eu, Erasmus student network and Nuffix. In the coming period we will invite them to present themselves and look for possible collaboration.

Planning your own train trip
There are several websites and apps that support international travel by train. Examples are Trainline, NS International and Deutsche Bahn. An interesting and useful one is the Austrian

direkt.bahn.guru (figure 13.05), which shows the destinations that can be reached from any European station by direct trainlines.

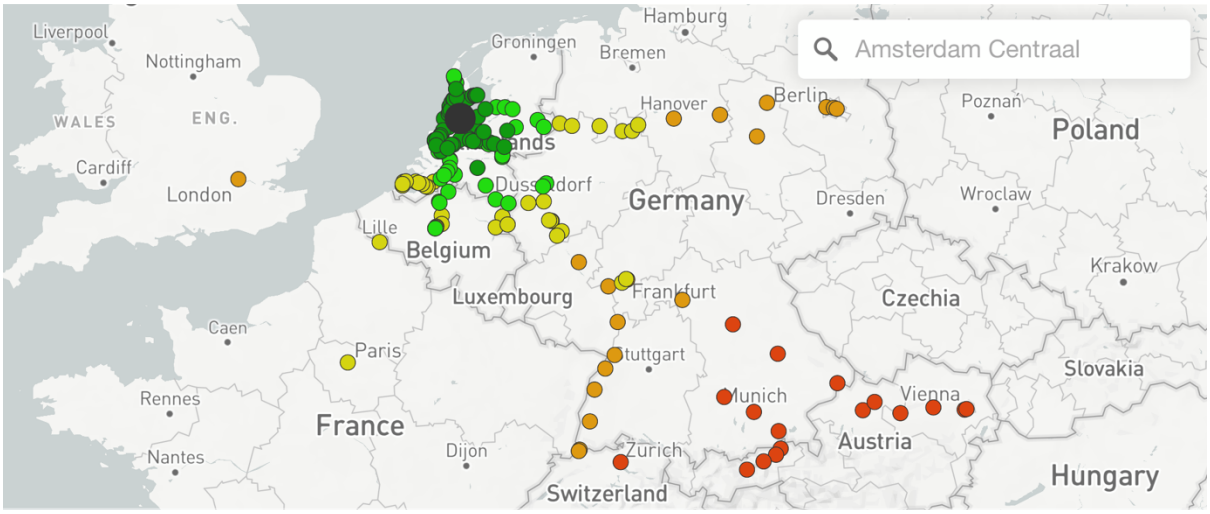
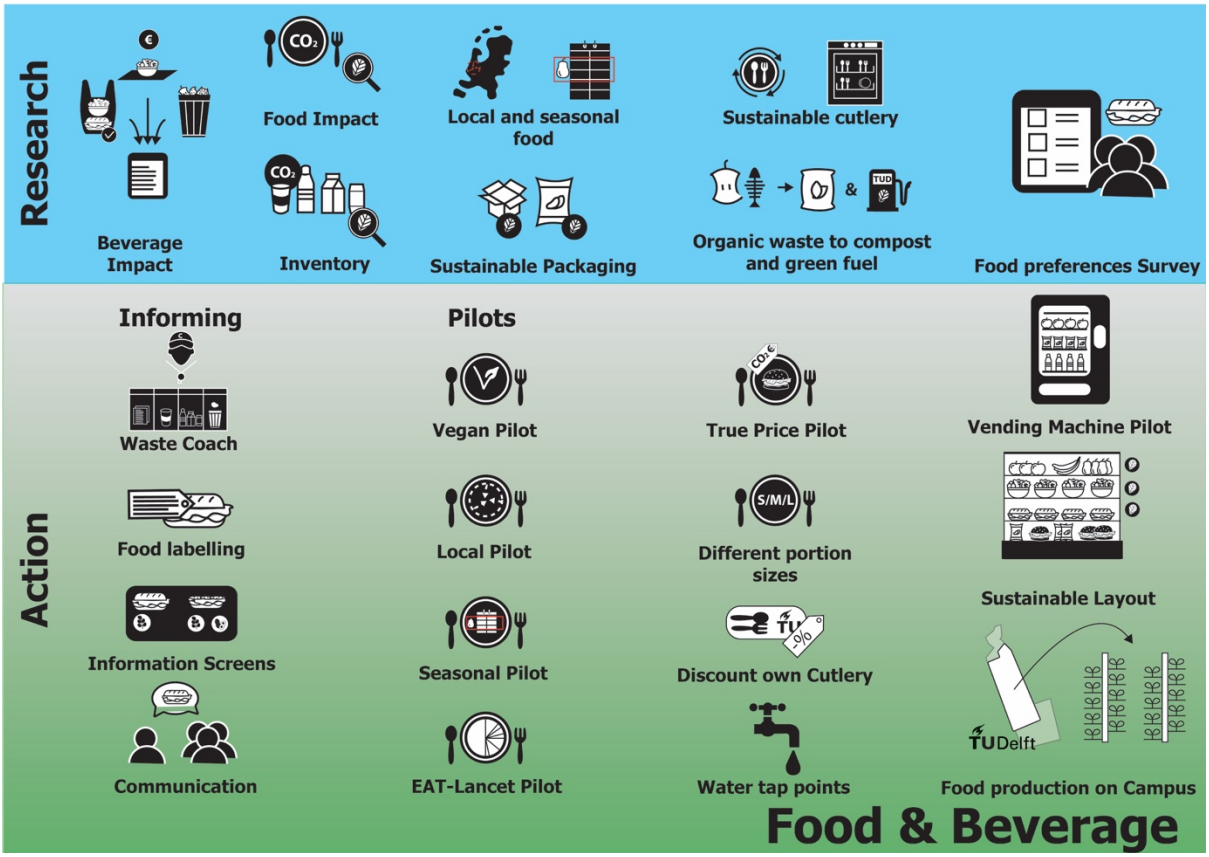


Figure 13.05: Map indicating the destinations that can be reached by direct trainlines departing from Amsterdam CS [source: direct.bahn.guru]

14 Food & Beverage

Team (in alphabetical order)

- Tess Blom – ABE
- Raymond Browne – ESA/X
- Nick ten Caat – ABE
- Andy van den Dobbelsteen – TU Delft sustainability coordinator
- Irene Fernandez Villegas - AE sustainability coordinator
- Deirdre van Gameren – TU Delft sustainability researcher
- Hannah Goss – IDE
- Pieter van de Graaf – ICT-FM, external
- Eva Gresnigt-Raam – ESA/X
- Andy Jenkins – ABE
- Olivia Meng - GreenTU
- Gerben Ouwens-Nooijen – F
- Rick Schifferstein - IDE, Food and Eating Design Lab
- Dave Seegers – CIRFOOD
- Mark Voorhaar – CIRFOOD
- Annelien Wehrmeijer – ICT-FM/Com
- Rosa Weinzierl – GreenTU



Food & Beverage
Main proposals

General aims and principles

- To offer **sustainable and healthy** food and beverage at TU Delft
- To offer a **wider range** of food on campus, involving cultural preferences
- To offer sustainable and **circular catering facilities** on campus
- To communicate the **content, origin and environmental impact** of food
- To **support the caterers** in preparing food consciously and helping customers
- To introduce personal **reusable cutlery, plates and cups**
- To solely work with **food suppliers** that subscribe to TU Delft's sustainability goals

To be investigated

- More accurately determining the **carbon impact** update of food and diets
- Making an inventory of food **bought, sold and wasted** in 2019-2021
- **Comparing** unseasonal local food versus seasonal food from afar
- Attuning the **price of food** with its environmental impact
- Determining the environmental impact of **beverage**
- Comparing disposable with reusable and with durable **cutlery and plates**
- Executing local **food preferences** survey on the campus
- Processing **organic waste** to produce compost or biogas
- Exploring **restaurant layout design pilots** for sustainable behaviour
- Exploring options of small, medium and large size **portions** in restaurants
- Exploring food production options with the **Hammen Farm**

Projects, pilots and actions

- Initiating a complete **food and food waste inventory** system
- Starting **sustainability scans** of restaurants and food trucks on campus
- Starting **restaurant pilots**: vegetarian, vegan, 100% organic, carbon pricing
- **Waste coach** pilot, to inform and help customers separate their waste
- Starting a **foodsharing** pilot
- Introducing sustainable **packaging** for transport, in vending machines and restaurants
- Introducing **discount** for people bringing their own durable cutlery
- Setting up a **sustainable Plates, Cups and Cutlery** design challenge
- Starting a **vending machines** pilot: offer, food waste reduction, carbon impact info
- Initiating **water tap points** instead of water tanks
- Starting **food labelling** pilots: content, origin, seasonality, carbon emissions, allergies
- Starting **information boards** in restaurants, coffee bars, near vending machines
- **Communicating** about sustainable food policy and food-related events and projects

In the assessment of the year 2018, food had the second-largest CO_2-eq share in the university's footprint, which means that there is a lot of room for improvement. Students and employees eat around 50% of their daily intake at the campus [Blom & Dobbelsteen 2019]. This chapter looks at the desired future situation and the current catering on campus and its environmental performance. Subsequently, a new policy is put forward and specific projects and based on this, actions are drawn up.

14.01 Desired future food system

In the near future, the TU Delft Campus will have a sustainable and healthy catering system, in which where plant-based food forms the basis and animal products are seen as extras. The CO_2 price is included in the price of the products, which means that vegan products have become cheaper and animal-based products more expensive.
The university only works together with suppliers that commit to our sustainability goals for food and beverage. The caterer offers local, seasonal, and organic food and sustainable, healthy beverages. The food supply is attuned to the wishes and the cultural background of the TU Delft community, which differs per location.
In order to stimulate costumers to make a sustainable choice, CO_2-eq emissions, origin of the product and other environmental information can be seen on products, in restaurants, and near coffee and vending machines. That way, labelling is used to nudge people. The restaurants, bars, and machines are also designed in a way that stimulates costumers to make a sustainable choice. No packaging is used during the whole process and the costumers bring their own plates, cutlery and cups to reduce waste.
The university also actively stimulates pilot projects and living labs related to food. Together with X and researchers, several living labs have been set up to test if the university can produce food on the campus sustainably and in synergy with other processes on campus.
The university actively communicates about food-related research and events. This was possible due to the fact that the new vision on catering has been set up in such a way that specific wishes and needs can be considered per location and that sustainability is integrated in the entire process, from purchasing, through use to waste treatment.

14.02 Current situation

Carbon impact of food

There are great differences in the carbon equivalent emissions of food, as figure 14.02 from Our World in Data demonstrates [Poore & Nemecek 2018][23]. The values presented in this graph are based on global averages; for the Netherlands the values deviate to some extent, mostly due to our country's intensive agricultural system and short travel distances.

[23] Values that apply in NL can be downloaded here: https://www.rivm.nl/voedsel-en-voeding/duurzaam-voedsel/database-milieubelasting-voedingsmiddelen

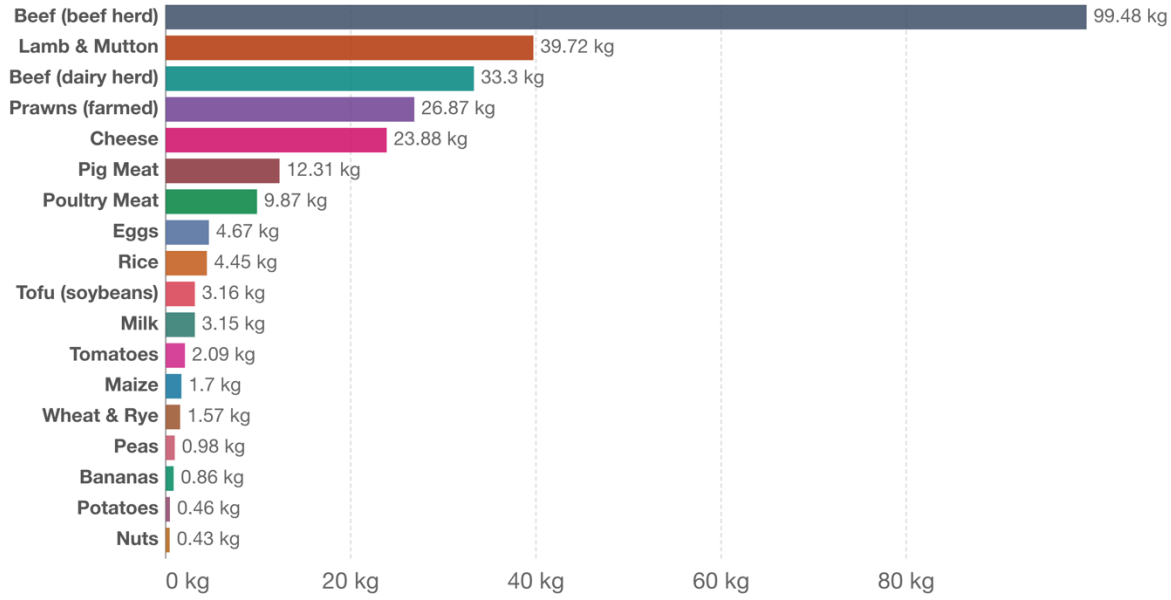


Figure 14.02: Greenhouse gas emissions per kilogram of food product, in kg of CO2-eq per kg of product [Our World in Data, source: Poore & Nemecek 2018]]

Key in the transition to a more sustainable food system lies in the protein transition, from sources that are carbon intensive, mostly animal based, to ones that have a smaller impact on climate change. Figure 14.03 shows the carbon impact of food as purchased in Dutch supermarkets. Fish is missing. The message is clear: stay away from animal protein (also cheese) if you want to seriously reduce your carbon footprint. Eggs and especially insects are the exceptions.

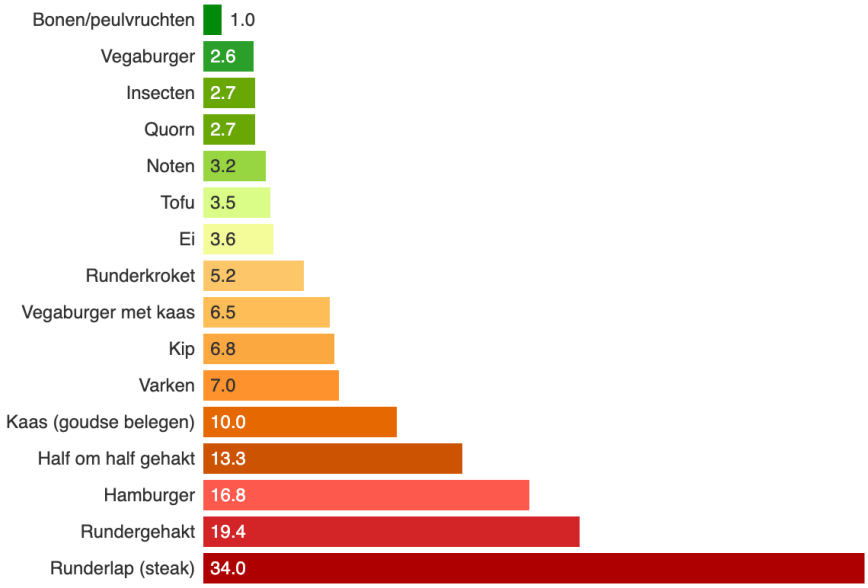


Figure 14.03: Carbon emissions of protein-rich food, in kg of CO_2-eq per kg of product [Milieucentraal 2021, based on Blonk Consultants 2017]

When Blom & Dobbelsteen [2019] analysed the carbon footprint of food at the TU Delft campus, they used the results of a study by Andy van den Dobbelsteen some years ago, involving a lot of sources when the impact of food was not registered well yet (as is done now by RIVM). The results of this study led to the graph of figure 14.04, for which the background information can be found in the Appendix. This figure and its sources were published in a scientific book [Roggema 2021].

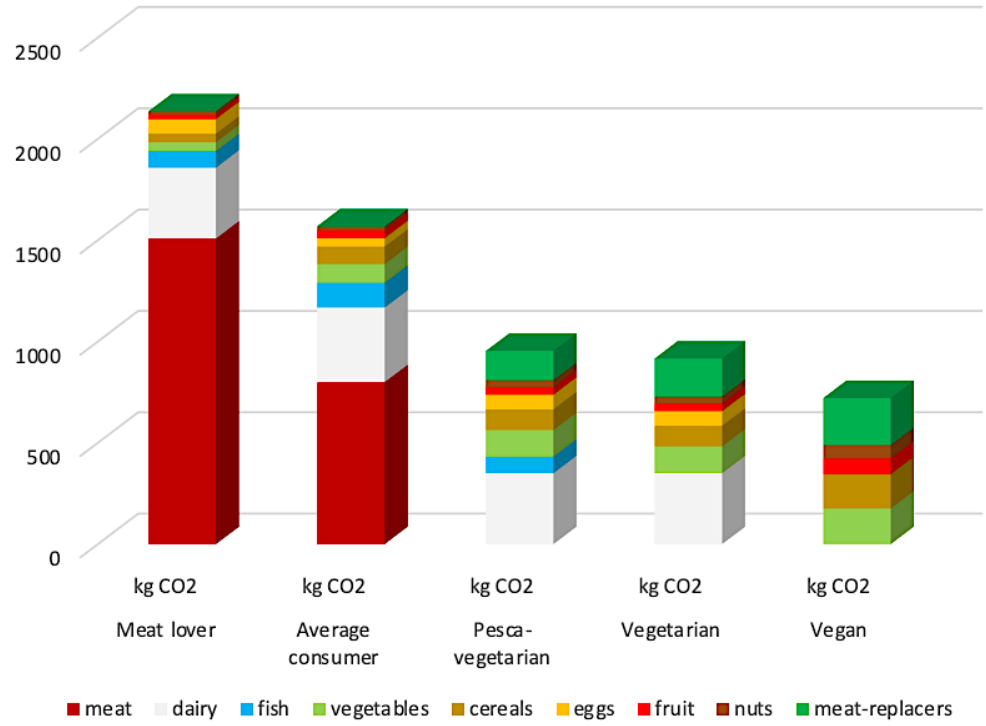


Figure 14.04: Carbon emissions of food diets
[based on: Milieucentraal 2016; Environmental Working Group 2017; Blonk Consultants 2017; WUR 2017; Doornewaard et al. 2017; CBS 2017; EUMOFA 2017; Eurostat 2017; Productschap Pluimvee and Eieren 2013; GfK 2006; Voedingscentrum 2017; Vegetariersbond 2017; Rossum 2016; Bartels et al. 2009]

Catering on campus at present

At present, catering on campus is based on 4 levels and each level has its own type of food offer (figure 14.01).

- Floor level: vending machines, hot beverage machines, and unmanned catering facilities
- Building level: faculty corner, salad bar, and sandwich corner
- Service area: marketplace and food trucks
- Campus-wide: high-end catering, mini-super, and baker

People can also order food during an event or meeting. This can be done from CIRFOOD, X or another external company.

The previous vision on catering was written in 2015. At the moment, a team is working on a new vision with people from facility management and procurement. The sustainability coordination also part of this team and they ensure that sustainability is included.

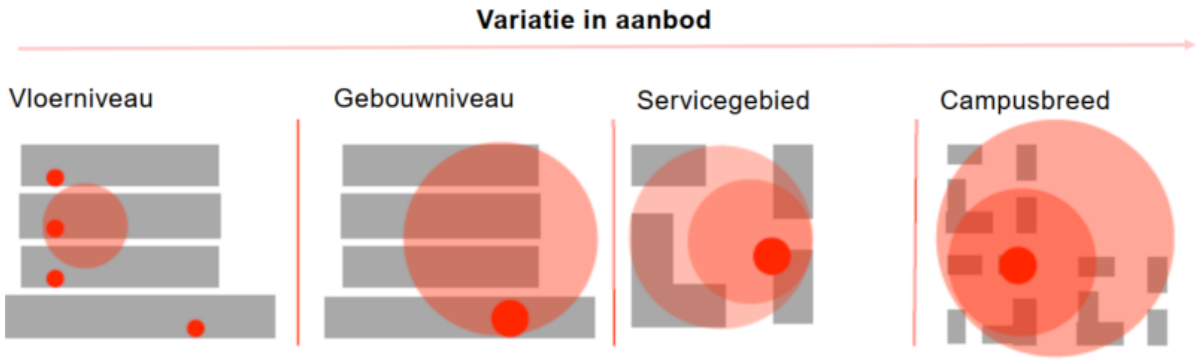


Figure 14.01: Catering levels on campus

Environmental performance of TU Delft

In 2019 [Blom & Dobbelsteen 2019], TU Delft's carbon emissions were established at 13,800 tCO_2-eq, based on figures of an average Dutch diet and assuming half of the average daily consumption on campus during working and studying days.
It is important to calculate the carbon footprint of food, specifically for TU Delft, to know the starting-point of the university and detect the areas for improvement. The database of RIVM should be used and combined with information from the caterer. Together with the caterer, the university should work towards an inventory of quantities of food, drinks and waste[24]. This inventory must be supplemented with information about the origin of the product. With this information a sustainability scan must be made of every type of restaurant.
Research from Vellinga et al. [2019] shows that plant-based food such as vegetables (5%), fruits (3%), nuts (2%) and legumes (0.2) emit far less GHG emissions than meat (33%), which contributes the most, followed by diary (14%) and non-alcoholic beverages (9%).

Environmental impact of food diets in the Netherlands

The average daily diet in the Netherlands was associated with 5.0 ± 2.0 kg CO_2-equivalents of greenhouse gas (GHG) emissions and 0.14 ± 0.08 m^3 of blue water use. Meat, dairy and non-alcoholic beverages contributed most to GHG emissions, and non-alcoholic beverages, fruits and meat to blue water use. More healthy diets were associated with a lower GHG emission and higher blue water use.

Share in GHG emissions
For the total population, main contributing food groups to total GHG emissions were: meat (33%); dairy (14%, of which more than half, 8%, are dairy drinks) and non-alcoholic beverages (9%). Plant-based foods, such as vegetables (5%), fruits (3%), nuts (2%), and legumes (0.2%) contributed less to daily GHG emissions

[24] Perhaps this can be extracted from the product ordering software, perhaps after signing a confidentiality form or blacking out sensitive information, e.g purchase prices.

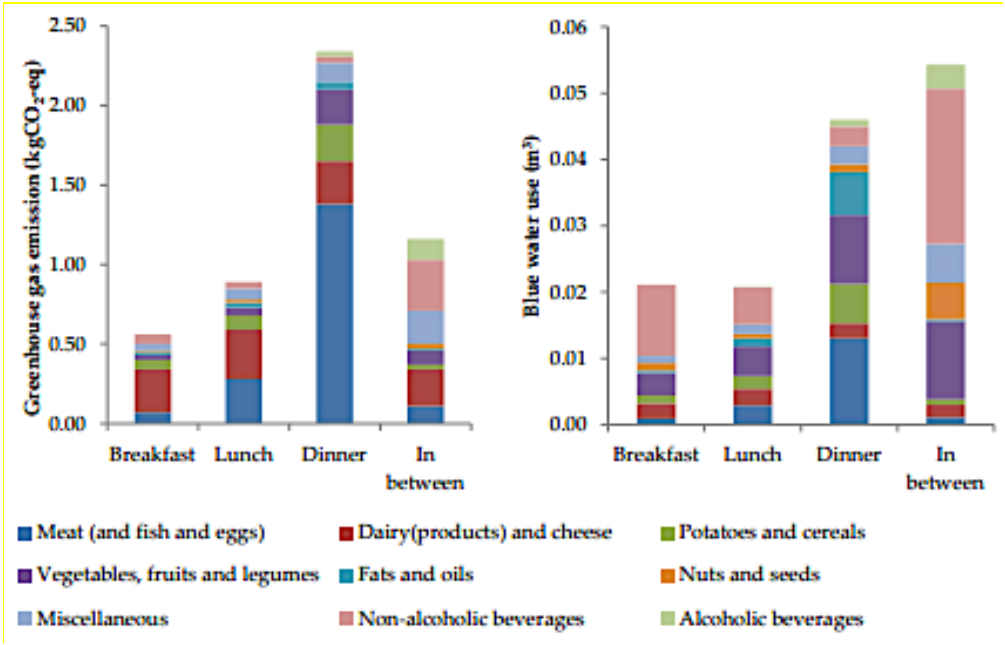


Figure 14.03: Carbon emissions of different meals (https://www.mdpi.com/2071-1050/11/21/6027)

Non-alcoholic beverages (31%) and fruits (14%) mainly determined daily blue water use. Meat contributed 11% to daily water use, remaining animal-based foods contributed less, for instance dairy (4%) and cheese (2%). Of the beverages, fruit- and vegetable juices (13%) and coffee and tea (12%) consumption were associated with the highest use of blue water.

Blue water use

The blue water use per person for the average diet of the Dutch adult population aged 19-79 years as calculated in this study was 160 l/day (= 57 m^3/year) for men and 153 l/day (= 56 m^3/year) for women. Non-alcoholic beverages were the most important contributor to water use for the diet of men as well as women. Fruits were the second most important contributor to water use for the diet of women (particularly oranges, tangerines, strawberries and bananas), and the third most important for men. Meat was the second most important contributor for men (particularly chicken fillet and beef meat) and the third for women. About one third of the blue water use for the Dutch diet takes place in countries where 30 to 70 times less available water remaining per area than the world average.

[http://www.sciencepublishinggroup.com/journal/paperinfo?journalid=540&doi=10.11648/j.wjfst.20210501.13]

Coffee

A lot of water is needed for the processing of coffee beans. Coffee producing countries are often countries that already struggle with water scarcity and access to clean water. The university should look into sustainable coffee brands that make organic, Fair Trade, Shade-Grown (i.e. bird-friendly) coffee. It is also a question whether the university should provide free coffee to employees (and not to students).

The university uses energy-efficient coffee machines from Maas International, which have LED lighting, a power-saving mode and a standby mode. The coffee machines also use certified coffee. In addition, 99.14% of the vending machine from Maas International can be recycled or reused and an arrangement is made that for every litre of water from the vending machine a litre of clean drinking water is donated to a developing country.

14.03 Policy for sustainable food & beverage

Reversing the order

To stimulate customers to choose and eat sustainable food we want to propose plant-based food as the basis and animal products for example meat, fish, and cheese as extras. If the customer would like more toppings with their salad, sandwich, or any other dish they need to pay accordingly. In practice, this will mean that vega(n) products will be cheaper and animal products more expensive. The maximum carbon fee will be determined together with the caterer, which could be based on the carbon emission price.

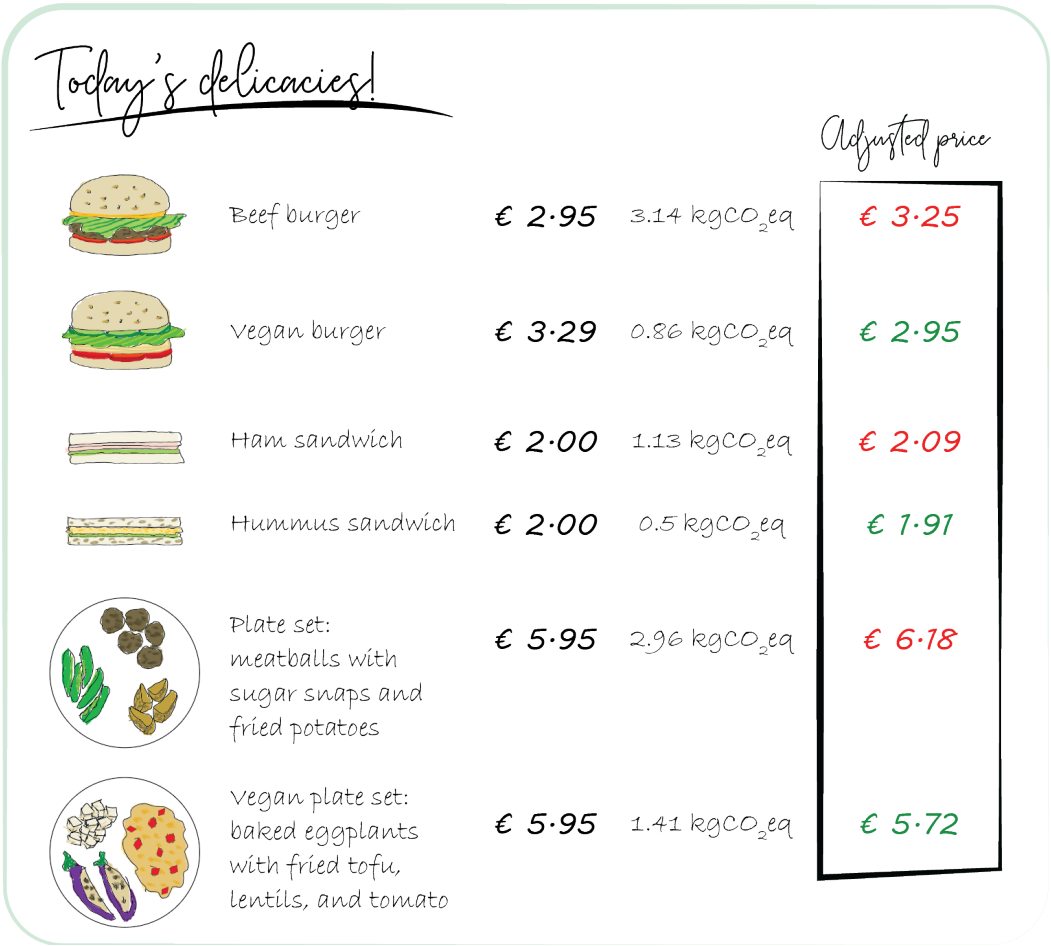


Figure 14.04: Example of a bonus-malus system based on carbon emissions

Figure 14.04 gives a possible example how the price of food can be influenced when including the carbon emission differences (based on real carbon figures).

Information & communication

There should be information available for the customers about the GHG/CO_2-eq emissions and origin of the product. In order to get insight into this, it is important to know if the product is local, seasonal, organic, vegetarian, or vegan. Most customers are unaware of the carbon impact of their food and beverage and do not know what the cause is of this higher or lower impact. That is why the product itself, with stickers or labels, and the canteen, with information boards and screens, should show this information, next to allergy information. Customers should be able to see the carbon impact of the products they are comparing, including the relation with the price of the product. This is already done and tested in a restaurant of Chalmers University. By making the climate impact of food visible they lowered the GHG-emissions for lunch by 25%[25].
The layout of the restaurant should be designed in such a way that the information is visible and that it stimulates sustainable behaviour. Catering staff must be trained on sustainable and healthy food. This way they can cook and prepare food offered consciously and help customers with questions and point them in the right direction. People with allergies are more likely to look at a label than people without allergies. Research should be done into the effectiveness of (carbon) labelling of food. If the current design of labels is not effective research must be done into new designs.

Principles of sustainability

Locality

TU Delft should work preferably with local products. This will save energy for transport ('food miles') and (refrigerated or frozen) storage. Local food also often means less use of packaging and preservatives, because it arrives quicker at the customer, less food waste, and less reduction of nutritional quality. This must be done in collaboration with the caterer. The caterer should include local (organic) farms into their supply chain, e.g. the Bieslandse hoeve.
Furthermore, TU Delft can create a living lab that focusses on producing food sustainably on campus. The fresh food produced can then be offered directly at the campus. Examples of such living labs are greenhouses on roofs or facades or vertical farming with an energy purpose for a building or the energy system on campus.

Seasonality: unseasonal local versus seasonal from afar

One could have a discussion on providing unseasonal food (food that would naturally not be available in the respective season) from local suppliers, such as horticulture in the Westland, which in wintertime uses a lot of (fossil) energy, or to import seasonal food from afar, such as from southern Europe in the intermediate seasons and from the southern hemisphere in winter. This needs to be studied further, because although zero km is considered as a major

[25] https://www.chalmers.se/en/news/Pages/Carbon-label-2016.aspx

advantage to reduce carbon emissions, Delden et al. (2021) state that their contribution is overestimated, as transportation has a relatively small contribution to the carbon footprint of most products. Avestisyan et al. (2013) state that diverting to the consumption of local goods only reduces the global emissions when undertaken in regions with relatively low emissions.

Organic food
No chemical pesticides are used in the cultivation of organic food and no genetic modification is allowed for food with an organic certificate. Organic food can be grown under natural circumstances but also in artificial environments, such as greenhouses and vertical farms. The latter two means of producing food are more energy-intensive, but they can also deliver greater quantities and higher quality, being under controlled conditions. At the moment, in the Sky High project (with TU Delft involved), a study is conducted on the environmental impact of various means of food production. TU Delft can base its decisions on the forthcoming results thereof.

The previous three criteria regarded general principles TU Delft should adhere to. Of course there will be unsustainable organically grown food (e.g. from the other side of the world), as there will be sustainable non-organic food (locally produced in an environmentally friendly manner), but this is about the case when two similar products are either organic or not.

Animal friendly
Less than 1% of the 450 million animals annually produced in Dutch farming are organic and have a free-range system. The better life label is introduced to improve the welfare of the other 99%. The Dutch Society for the Protection of Animals (SPA) implemented the 3-stars system; the more stars, the more animal-friendly the product. One star means that animal welfare is given sufficient attention, there is more space than on common farms and they have play materials. With two stars there is plenty of attention given to animal welfare and animals can go outside. Three stars means that the animal welfare is good and that they get as much freedom as possible [Beterleven Dierenbescherming, 2020]. The university does not buy products where animal welfare has not been taken into account. In the vein of the star system, the product must have at least 2 stars.

Healthy beverages
At present, a lot of the drinks offered in the vending machines, in restaurants, or with catering of special events are not sustainable nor healthy. A more conscientious policy here is welcomed: more natural, organic drinks from suppliers that produce them sustainably, with less refined sugars or artificial sweeteners, and no artificial colorants or preservatives. This needs to be studied further.

Sustainable plates and cutlery
There are two possibilities to reduce the current one-off cutlery waste stream.

Take your own
The first option is that the customers have to pay for their (sustainable/durable) cutlery the first time and then they can reuse it with every meal. The customer will receive a small discount by bringing their own cutlery with each meal. This can be the durable cutlery purchased at the first visit or cutlery from home. By doing this, the current one-off cutlery waste stream will be avoided. In addition, the university could place mobile cutlery and plates wash stations so that employees and students can clean or rinse them.

Reusable cups
TU Delft is already stimulating its students and employees to bring reusable cups and bottles from home for their hot beverages and water. By bringing their own cups, customers will receive a small discount of 5 cents. In an ideal situation, the university would not offer cups at all. People would have to get used to this, but eventually it would become the new normal.

Durable plates and cutlery
The second option is that the restaurants will have dishwashers and serve food on ceramic (or perhaps wooden or bamboo) plates and provide metal cutlery. After the costumer has finished eating, the plates and cutlery will be handed in. Apart from cutting down on waste this will also elevate the perception of food. To make sure that the plates and cutlery are returned after the mail a small deposit is paid. The disadvantage, as seen with LCA studies in the past, can be that dishwashing durable plates and cutlery (of more environmentally damaging materials) is more harmful than using disposal biobased materials.
New LCA research is needed into the most sustainable option at present.

Preventing food waste
Food waste can be roughly divided into three parts, the food itself, packing material, and tableware, such as cutlery, cups, and plates.

Vending machines
It is likely that a small amount of purchased food becomes waste at the vending machines because these are small snacks. However, the food and drinks from the vending machines are always packed, which leads to waste. Research should be done into other types of sustainable packaging material. The products in the vending machine often expire, the chance of this can be reduced by reducing the supply of one product in the vending machine, making the vending machines smaller, or placing fewer vending machines per building and encouraging people to walk a few meters further, which is good for their health.

Packaging materials
A general rule should be to avoid unnecessary packing materials. When possible, food products as fresh vegetables and fruit should not be transported in packing material. The same applies to the food that is offered in the restaurants: these are often wrapped in plastic. Research must show whether and how this is possible. Clear agreements must be

made between TU Delft and the caterer and the caterer's suppliers. Some buildings still have plastic water tanks, these should be removed and replaced with water tap points. A cold water tap point is included in the vending machines of Maas International, this needs to be communicated better to the community.

S-M-L portions
In order to prevent food waste, food in the restaurants and buffets must be presented on smaller plates, and smaller plates should be offered at the buffet. This prevents people from taking an unnecessary amount of food. In addition, the caterer should offer small, medium and large portions for small and big eaters.

Waste coach
In addition, a waste coach can be appointed to help customers separate their waste and inform the employees and students. The food that is still edible but that (due to certain rules) cannot be used anymore in the restaurant should be offered to students or employees. By doing this the university will prevent food waste, reduce its footprint, and support its community at the same time. F

Banqueting
ood waste cannot only be found in restaurants but also when people order catering on campus, for an event, masterclass, meeting, etc. This is called banqueting. During the commissioning of the catering, supply and demand must be properly coordinated, taking allergies and personal diets into account. However, it is logical that the caterer wants to ensure that there is enough food, which inevitably leads to food waste. However, this is not necessarily waste: prepared sandwiches can also be offered that same day to the students.

Composting
The remaining food waste, organic waste, can be turned into compost. The compost can be used as fertilizer on the campus or used in a pilot project about farming on the campus or at the farm at X. The organic waste can also be turned into biogas, by means of fermentation. Another important aspect is creating awareness about the impact of food and using sustainable cutlery, see headings 'Information & communication' and 'Sustainable Cutlery'.

14.04 Specific projects, pilots and actions

EAT-Lancet
A scientifically sound basis for a healthy and more sustainable diet is the EAT-Lancet menu. This menu is based on the question: "How can we provide all 10 billion people with a healthy diet in 2050 and stay within the carrying capacity of 1 planet?" Therefore, TU Delft will base its average offer of food on campus on the EAT-Lancet menu, meaning that there will be a much larger share of plant-based food and much less animal-based (but not entirely omitted).

Restaurants

At TU Delft, catering should offer healthy, local, seasonal, organic, animal-friendly food. The university should stimulate and help its caterers and restaurants to become sustainable and economically viable. Plant-based food must become the basis in restaurants and animal products should be seen as extras, to stimulate customers to eat more sustainably. An action can be organised to introduce vegetarian food to meat lovers by giving it away for free. Next to that, labels on food, and information boards and screens in restaurants are needed to make customers aware of the carbon impact of food. The layout of the restaurant should be designed in such a way that the information is visible and that it stimulates sustainable behaviour.

Restaurant of Architecture and the Built Environment

The restaurant of ABE already acts as a pilot project to offer a fully vegetarian (and vegan) menu (figure 14.05). It was opened as such in May 2021 and this announcement of caused quite some turmoil in the media, social media especially, in terms of critique from the meat industry and people outside TU Delft on the one side and strong support and calls for others to follow suit on the other side. Regardless, the vegetarian restaurant has been monitored since its opening and can be called a success: the vegetarian and vegan food offered is appreciated by its customers, students and staff alike.

Figure 14.05: The vegetarian restaurant of Architecture and the Built Environment, shortly after re-opening

Faculty Club
Since 1st of September 2021, the university opened the Faculty Club. This is a place where someone can bring their colleagues and business or academic relations for consultations, confidential talks or just a delicious lunch or dinner. Jeremiah Teeling, the former cook of the kind and queen of the Netherlands, is running this restaurant. The menu consists of only vegetarian dishes. The formal opening of the faculty club will be planned for 2022. This moment should be used to promote the sustainable food approach.
This can be combined with vegetarian food and/or local food market, including products from for example Bieslandhoeve, and from the Westland and Oostland.

Catering for events
It is important to properly coordinate supply and demand, know which allergies there are and what kind of dietary requirements before ordering. As with the restaurant, caterers should mainly offer local, seasonal and organic food when possible and sustainable drinks. The food that is not eaten but still edible should be offered to students and the remaining organic food can be used to create compost or biogas. Also, the food that is served during receptions in for example the Aula should be vegan/vegetarian by default. The caterer already serves bottles filled with tap water during lunch instead of bottled water.

Food trucks
The university should only select companies that subscribe to our sustainability goals for food and beverages. They should use local, seasonal and organic products when possible and offer more plant-based meals and less meat-based meals. The policy set in place on pricing and waste prevention for restaurants, catering, and vending machines should also apply to the food trucks.

Living lab projects together with X
X TU Delft is focussing on stimulating and facilitating the personal development of young people studying at TU Delft. Sustainability, nature, climate, health, food and lifestyle are serious issues for this group. X focuses on these issues in its programme, including the restaurant and catering of X. This organisation would like to collaborate with researchers at TU Delft to set up multiple living labs that are related to food production. They are interested in testing vertical farming in, on or attached to their building. This might be combined with the Sky High project at ABE, running with Andy Jenkins and Tess Blom. X would like to develop a student community and field lab at the Hammen farm related to nature and food (technology). Furthermore, X looks into the possibility to keep animals. By setting up these living labs, X would like to make their restaurant fully self-providing by using these innovative food production technologies. An inventory of types and quantities of food purchased will be needed then.

Vending machines
The main problem with vending machines is packaging, everything in a vending machine is wrapped. Research should be done into sustainable alternatives. The university must stimulate and help MAAS International to become sustainable. Maas is already offering

vegan milk for coffee. If Maas offered more sustainable products, they would sell less, which would lead to food waste. A pilot project should be set up to find out the best option to reduce the amount of expired food, to reduce the food supply in the machine, smaller machines, or fewer machines per building (and stimulate people to walk). Another pilot project should focus on a different selection of food, to find out what the customers want. This can be different per faculty or university services.
At the moment ICT-FM is working on a tender for True Pricing with coffee. The university is already stimulating students and employees to bring their own cups by giving a small discount. Now the next step should be made, offering no cups at all. Some buildings still have plastic water tanks or sell water bottles, these should be removed and replaced with water tap points.

To be investigated: other matters

Other cultural preferences
Currently, the food supply is not attuned to the cultural background of the TU Delft community. A cold sandwich will do as lunch in the Dutch culture, but many other cultures prefer a warm lunch and the majority of another culture can even be vegetarian or vegan. The university should investigate the possibilities to change the offer at other restaurants. A survey about preferred diets and food wishes can be conducted per location.

True Pricing
A potentially effective measure is implementing a carbon tax correction in the price of food. Then it will still be possible to eat animal products but customers have to pay accordingly. Implementing this CO_2 bonus-malus system should become a pilot project at AE. The first steps for this have been made.

Smaller portions
In order to prevent food waste in the restaurant itself, the restaurant should use smaller plates, offer small, medium and large portions of each dish, and appoint a waste coach.

Food packaging
When possible, the caterer should not use packaging for unpacked products when this is unnecessary during transport. The same applies to the fresh food that is offered in the restaurant itself. This needs to be studied further.

Bring your own cutlery
Customers should receive a small discount when they bring their own durable cutlery and help the university reduce its single-use waste stream. T

Sustainable beverages
Next to offering more sustainable food, TU Delft and its restaurants should offer sustainable beverages. Most beverages come into plastic bottles or aluminium cans. Research must be done into sustainable drinks and packaging.

Food waste
At the moment, food waste generated in the restaurants of TU Delft is 3%. The food that is still edible but that cannot be sold anymore should go to the students or to charity. The food waste remaining, i.e. organic waste, can be turned into compost or biogas. Research is needed into the most viable option. In both cases, pilot projects can be connected to this.

Food & Eating Design Lab (Student projects)
Rick Schifferstein, associate professor of Food Design at the Faculty of Industrial Design Engineering, is lab director of the Food & Eating Design Lab, coordinator of the MSc elective course Food and Eating Design, and supervisor of research projects, graduation projects, and PhD projects related to food products. He conducts research into food design in relation with sustainability, together with students, PhDs, researchers and stakeholders. The university should stimulate this research and use it to become sustainable on the topic of food.

Projects
Some interesting projects that have finished or are still going on: insects as food, use packaging to nudge people into a certain direction, food waste, and cross-cultural food-saving practices. At the moment, three students are researching a topic related to sustainable food & beverage. One student, a Team NL student, is doing research into the transition to a vegan diet focussing on athletes. Another student is focussing on food production across the TU Delft campus and the third student is conducting research into disposable cutlery. It is important to connect such sustainability topics to students.
Another design project or challenge that the university should organise is the KeepCutlery design challenge/Sustainable portable cutlery, plates and cups, design challenge. The winning idea should be used at the university, as a pilot at least. At the moment a durable cutlery set can already be bought at all restaurants.

Information & activation
Information should be available for customers about the CO_2-eq emissions and origin of the product: is it local, seasonal, organic, vegetarian or vegan? This should be done on or near the product itself, with stickers or labels, in restaurants, coffee bars and vending machines, with information boards and screens. Catering staff must be trained on sustainable and healthy food so that they can help customers with questions and point them in the right direction.

Events
Next to information about the food itself, TU Delft should also communicate about sustainable food and food-related events and projects. Annual events that the university

should communicate about, for instance, are the Week without Meat, the first week of March, and Animal Day, 4th of October. As during the meatless week, no animal products should be served on the 4th of October.

Thematic names
The university can also use catchy names, especially on daily platforms such as Instagram and Twitter, to promote certain topics weekly. Examples of these daily returning topics could be: Sustainable Sunday, Meatless Monday, Wasteless Wednesday, Fridays for Future. Meatless Monday and the Week without Meat could even become Meatless March, historically interesting since this also was a Christian month of fasting.

Exposition
To stimulate sustainable behaviour the university could organise an exposition in the TU library hall or use the freezones therefor. These areas can for example be used for a *borderline-ethical* wake-up showcase to spark dialogue. An example of such a wake-up showcase was held in the Amsterdamse Theaterschool. A chicken was on display and students could vote in a poll whether the chicken should be slaughtered to make a chicken soup or not. This experiment was done to start up the conversation on animal-based food.

Discussions

As of May 1st, 2021, the restaurant of the Faculty of Architecture and the Built Environment has switched to a completely vegetarian offer. This led to a discussion between supporters and opponents in the national press and social media. The commotion surrounding the reopening of the restaurant is not an isolated incident: it is a reflection of a broader discussion in the Netherlands, in the EU and worldwide.

Global challenges
As a result of the nitrogen crisis, the role and position of farmers in Dutch society have become an emphatic part of the social debate over the past two years. Global feed and meat flows are regarded as worrying even by European retailers in relation to deforestation in Brazil. Abuses surrounding the production and slaughter of animals have also led to public reactions. This, while farmers in the Netherlands are under great pressure to produce efficiently, within increasingly strict environmental conditions.

Sustainable food system
Although carbon and nitrogen reduction in food seems to point to a reduction of animal proteins in the human diet, there are several, possibly conflicting, paths to a sustainable food system, in the Netherlands, Europe and worldwide. There are many scenarios, from business as usual to a completely plant-based diet.

Food Symposium
The broad context and issues surrounding the transition to a sustainable food system must be mapped out and research questions must be articulated based on correct figures. That is why TU Delft, in collaboration with the LDE Centre for Sustainability, went into dialogue

with stakeholders from the plant and animal food chains during a symposium on the transition to a sustainable food system. This symposium was held a year after the opening of the vegetarian restaurant of ABE.

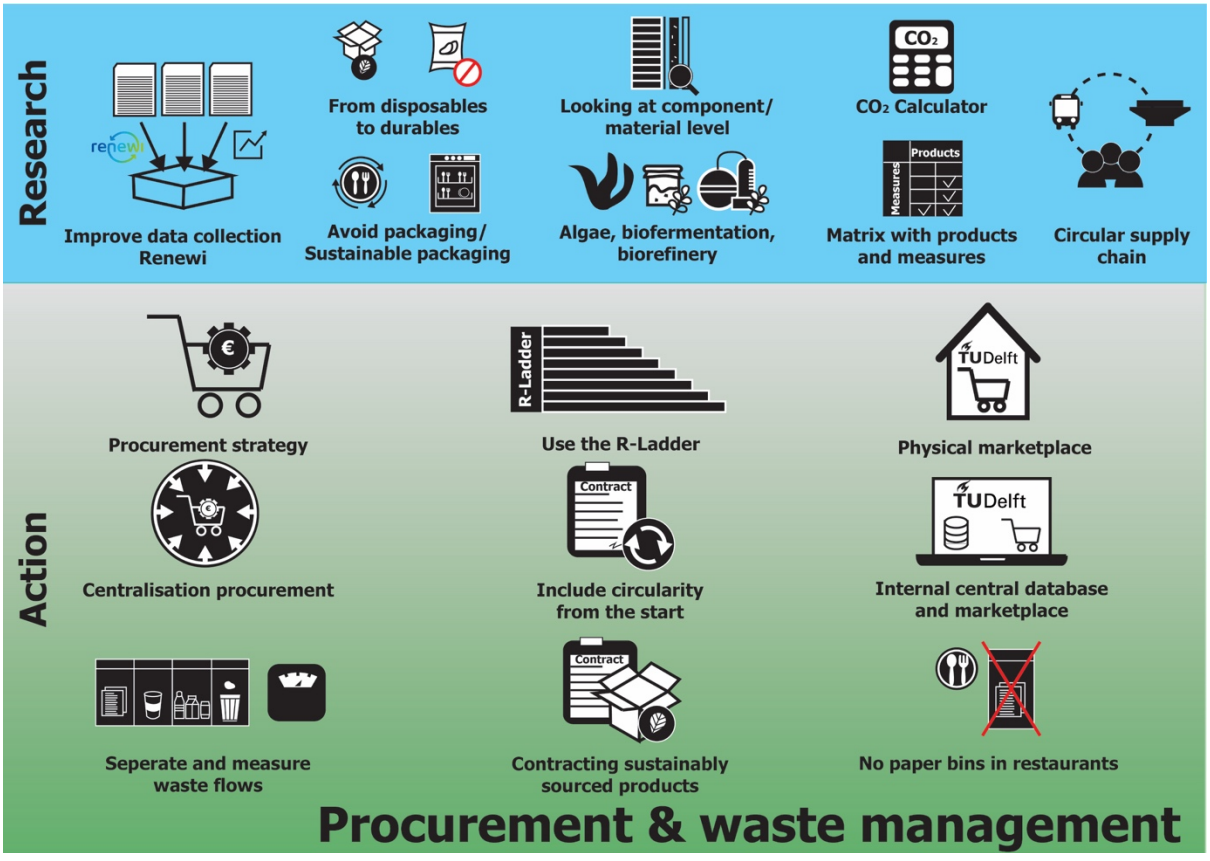
External support

Two companies contacted TU Delft to help create a sustainable and healthy catering system. Greendish offered to create an impact report of all the restaurants on campus. After extensive measurements, this report will state how sustainable and healthy the food supply on campus is. This would be beneficial for the university.
Also Studenten voor Morgen reached out to us. They work together with True Animal Protein Price Coalition (TAPP) which is a non-profit foundation. Their focus is on fair prices and taxes to make the production and consumption of meat and dairy more sustainable. At the moment we are looking if we can start a pilot project with them at AE.

15 Procurement & Waste Management

Team (in alphabetical order)

- Kornelis Blok – TPM
- Andy van den Dobbelsteen – TU Delft sustainability coordinator
- Michiel Faber – ICT-FM, Logistics & Environment
- Deirdre van Gameren – TU Delft sustainability researcher
- Caroline Gasten – GreenTU
- Heleen Geerligs - CRE
- Bob Geldermans – CRE/ABE
- Yumiko Henneberry – IDE sustainability coordinator
- Linda Kamp – TPM sustainability coordinator
- Ivo Leite – ICT-FM
- Ivan Ligardo Herrera - TPM
- Olivia Meng – GreenTU
- Jaga Schreiber – SD
- Mees Walhof – F
- Rosa Weinzierl – GreenTU



Procurement & Waste Management
Main proposals

General aims and principles

- To become **circular** in procurement and waste management
- To include a **carbon price** in bidding, assessments and evaluations
- To create **awareness** about circularity and waste management and in all daily actions

To be investigated

- Improving of data collection of **Renewi**
- Exploring the avoidance of **packaging** or sustainable packaging when needed
- Exploring options of shifting from disposables to **durables**
- Studying the possibility of **algae, bio-fermentation** or biorefinery
- Investigating making the entire **supply chain** circular
- Investigating products at the **component and material** level
- Developing a **matrix** with products on one side and measures on the other side
- Developing a system to calculate **carbon emissions** for all categories

Projects, pilots and actions

- Supporting Finance with including sustainability in the **procurement strategy**
- Developing an **Internal Central Database** and Internal Central Marketplace
- Determining a place for a **physical central marketplace**
- Including circularity **from the start**, in the tender and contracts
- Getting suppliers and the university to use the **r-ladder**
- **Centralising** procurement of all products
- Contracting **sustainably sourced products**
- **Separating waste flows** in all parts of the campus
- **Stopping paper bins** in restaurants
- **Measuring** all waste collected at Renewi

The university and its community need products to work and fulfil their daily activities. Furthermore, waste is produced by everyone visiting the campus. This chapter looks into the desired future situation of procurement and waste management on the campus and the current situation. Subsequently, a new policy is proposed supplemented with specific projects, pilots and actions.

15.01 Desired future situation

In the near future, TU Delft should have an effective circular procurement and waste management strategy. Circularity is immediately included from the start, in tenders and in contracts. Suppliers take their products back when they do not meet the requirements anymore. Circular waste management is used for all the products that cannot be taken back by the supplier and for the products that were purchased before circular contracts were set up. The r-ladder is used to reduce the amount of waste and to make sure all steps are taken before the materials and components in the products become waste.
The CO_2-price is embedded into the price of the products and services and suppliers deliver information about embedded carbon. By making use of circular contracts, the amount of waste produced at TU Delft is reduced. Other steps to reduce waste are: avoidance of packaging and use of sustainable alternatives, when possible, use of durable goods, etc. Control has been established over products in the use phase. To get grip on this, TU Delft developed an Internal Central Database (ICD) and Internal Central Marketplace (ICM). These databases enable complete knowledge of what TU Delft has, where it can be found, and in what condition it is. By combining this system with a centralised procurement system, it has become possible to exchange products between faculties and services, which reduces new purchases and waste. Together with suppliers, Renewi and the entire community, the university has its procurement and waste management under control.

15.02 Procurement and waste management at present

Procurement

Procurement includes many different products and services. The main product groups are discussed here.

- Food and beverage
- Furniture and other hardware
- Office supplies and expenses
- Labs and equipment
- Services

Food and beverage

The university buys food and drinks for its students, employees, and visitors. This theme includes vending machines, hot beverage machines, unmanned catering facilities, faculty

corner, salad bar, sandwich corner, marketplace, on-location catering, and food trucks. Food & beverage was discussed in Chapter 14.

Furniture and other hardware
Furniture can be found in each building on the campus. The faculties and services are responsible for their furniture and use them solely in their own building. It is unclear which and how much furniture is in which building.

Office supplies and expenses
Office supplies are traditional office items as pens, staplers, paper clips, printer ink cartridges, etc. It also includes products like paper towels, bathroom tissues, and plastic utensils. Printer ink/cartridges and printing paper is under contract management with the ICT department (central purchasing). All other office supplies within FM (decentralised purchasing).
Office expenses are for example website services, computer software, domain names, computers, laptops, printers, office phone systems, internet fees, etc.

Labs and equipment
There are several laboratories at TU Delft, each with special needs to be able to carry out their research. Some examples of basic lab equipment are pipette, test tube (rack), beaker, flask, syringe, thermometer, stethoscope, scale, magnifier, level, barometer, etc.

Services
Services are also purchased: an agreement has been established between TU Delft and service providers. Maintenance services, consultants, accountants, legal services, and flex work forces are all examples of this.

Carbon impact
For the year 2019, Herth and Blok [2021] studied the direct and indirect carbon emissions of TU Delft. They made 18 categories, 10 of which fall under the procurement theme: Administration, Consultancy and Auditing, Equipment, ICT, Facility Services, Finance and Tax, Other, Real Estate and Construction, Research Expenses and Consumables, Administration, Consultancy & Auditing, Paper Products, and Transportation and Travel. The total carbon emission of these groups turned out to be 68,661 tCO_2eq, which is 64% of the total footprint, see figure 15.01.
The surface area and wedges correspond to the various contributions of the current CO_2 footprint. The goal is that the surface area of the circle becomes smaller and smaller, which means that less waste is produced. Over time, the wedges will change in proportion to the contribution of that wedge at that time. Figure 15.02 shows a possible example of the total carbon emissions of TU Delft in 2025 (percentages became smaller), and figure 15.03 shows the possible emissions in 2030 (almost all to 0%).

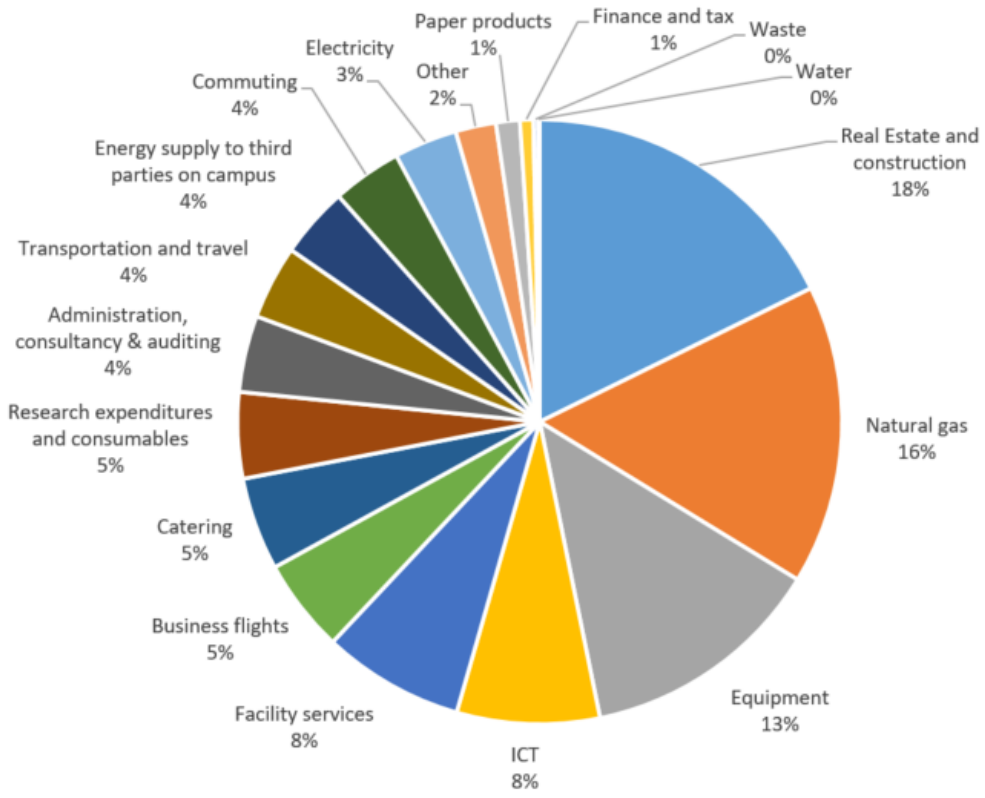


Figure 15.01: Division of carbon emissions of TU Delft by emission source[26] [Herth & Blok, 2021]

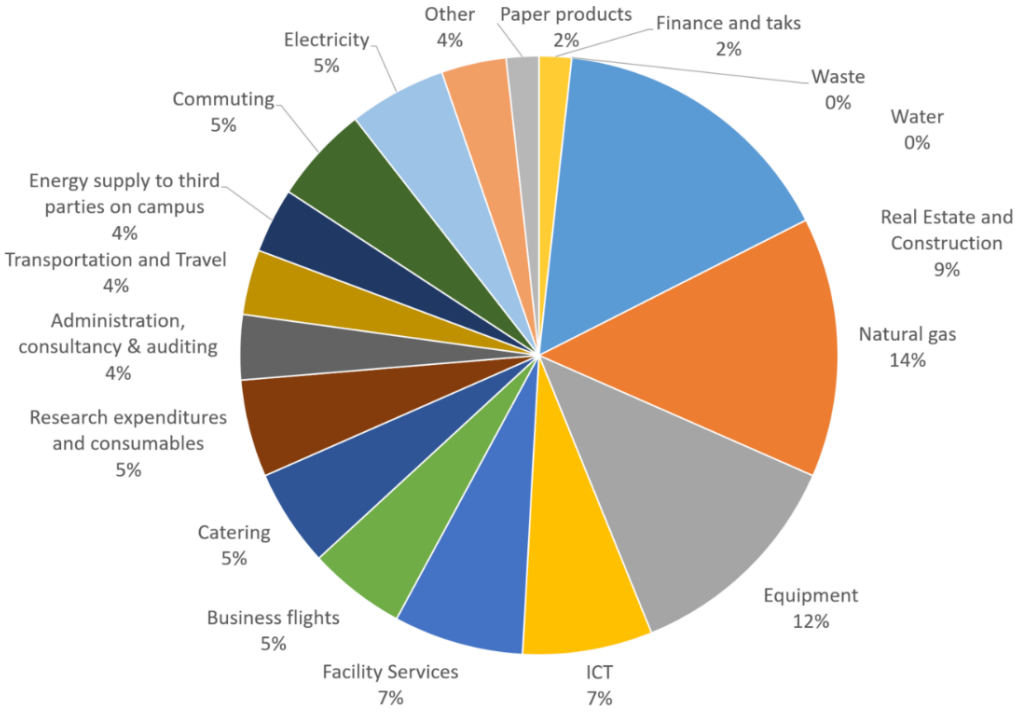


Figure 15.02: Possible total carbon emission division of TU Delft by emission source, 2025

[26] Electricity has a carbon emission due to the embodied carbon of wind turbines

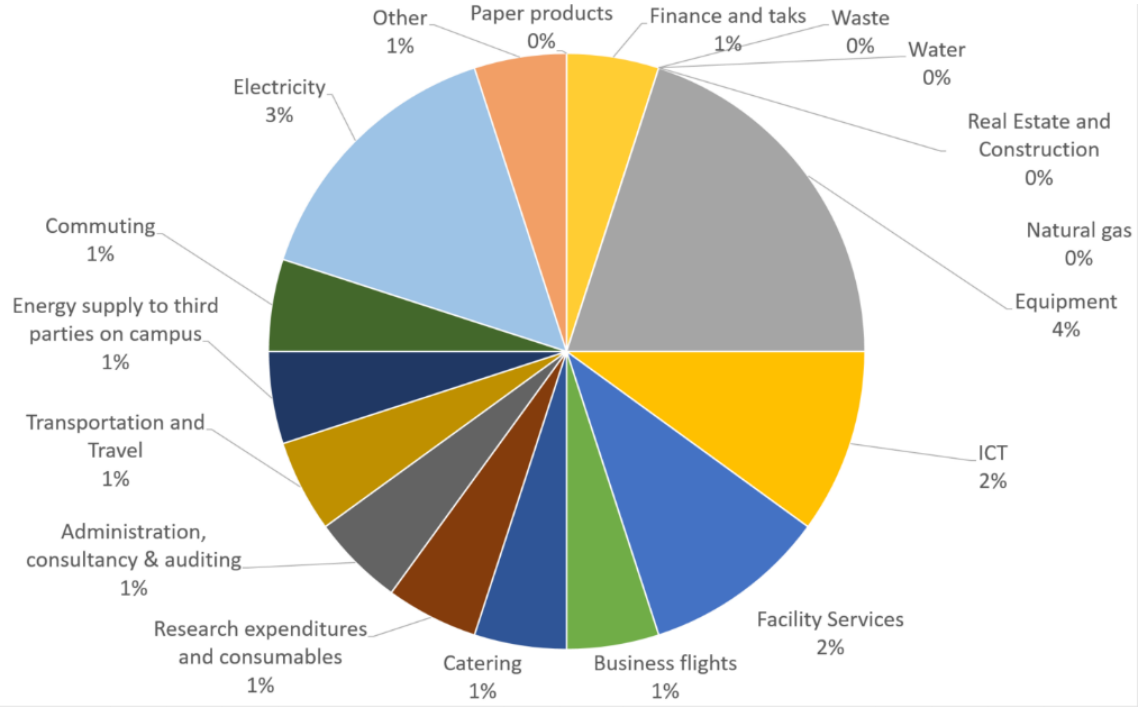


Figure 15.03: Example of possible total carbon emission division of TU Delft by emission source, 2030

In October 2021, a postdoc was appointed for three years, who is going to look into our direct and indirect emissions and who will make a new overview of 2021. In addition, he will make a tool so that the university can calculate its footprint by refreshing the database.

Waste production on campus

In the year 2018, TU Delft produced 2,788,757 kg of waste, see figure 15.04 [Renewi 2019]. This is 514 kg per fte and 92.6 kg per person. Almost half of the waste is currently residual waste (47%), which goes to the waste incineration plant in Rozenburg. Separate collection of the waste streams takes hardly place. The current vegetable and green fraction (VGF) consists almost entirely of green waste (pruning waste, maintenance of landscaping). Swill (biomass from catering) is only collected separately at X and the Aula [Blom & Dobbelsteen 2019]. Another waste stream that is collected separately is old iron. In 2020, there was a waste separation pilot focussing on the separation of paper, PMD, coffee cups, and residual waste at ABE and the Aula.

Carbon impact

The Finance division has been calculating the university's carbon footprint annually since 2019, according to the method of the 'CO_2-prestatieladder'. This method follows the international Greenhouse Gas Protocol. Waste is also included and falls under scope 3, upstream. Calculation of carbon emissions is based on the waste report from Renewi, which contained the amount of waste collected from the TU Delft campus in 2019. The carbon impact of waste is 3,242 tonne of CO_2-eq and the carbon impact of radioactive waste is 18

tonne of CO_2-eq; see table 15.01. 45% of the waste produced in 2019 was residual waste; this is 2% less than the previous year. The table shows that the green waste category has the largest share of emissions, followed by residual waste. The emissions released during transportation are not yet included.

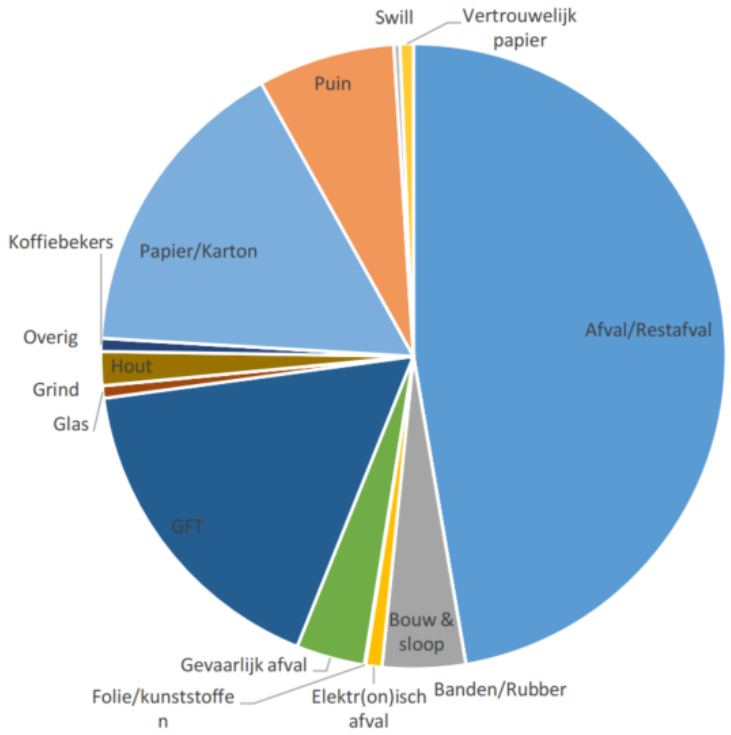


Figure 15.04: Distribution of waste materials at TU Delft campus [Renewi 2019]

Table 15.01: Emissions from waste [source EF: Tax, 2021]

Afval operatie	Eenheid	Volume	Emissiefactor CO_2	2019 (ton)
Bouw & sloop	kg	137.870	1,00	138
Afval / restafval	kg	950.856	1,00	951
Banden en rubber	kg	151	3,18	0
Elektronisch afval	kg	17.630	2,70	48
Swill	kg	11.474	4,25	49
Groenafval	kg	367.370	4,25	1.561
Papier / karton	kg	261.652	1,10	288
Glas	kg	23.330	0,85	20
Gevaarlijk afval	kg	81.676	1,00	82
Hout	kg	48.850	0,63	31
Koffiebekers	kg	20.916	1,10	23
Kunststoffen / folie	kg	604	1,74	1
Puin	kg	193.890	0,18	35
Vertrouwelijk papier	kg	14.541	1,10	16
Transport afval	liter		3,23	-
Totaal	**ton**			**3.242**

Kernafval	Eenheid	Volume	Emissiefactor CO_2	2019 (ton)
Radioactief afval	stuks	1	18.000	18
Totaal	**ton**			**18**

15.03 New policy

Procurement

R-hierarchy
TU Delft and its suppliers must apply the R-hierarchy. The most important steps are refusing, reducing the demand and reusing the residual flows (the top of the ladder), see figure 15.05. When using the R-ladder, one must not only look at the product as a whole, but also at the elements it is made of. Perhaps only a small element must be repaired or replaced instead of the whole product. A workgroup might be started to get the R-ladder better implemented.

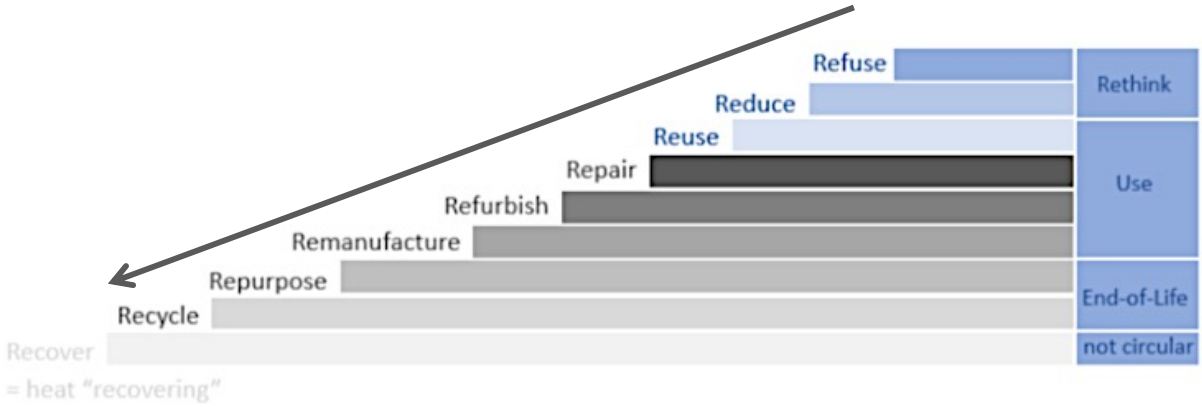


Figure 15.05: R-ladder
[PBL: https://www.rvo.nl/onderwerpen/duurzaam-ondernemen/circulaire-economie/r-ladder]

The entire supply chain
Circular procurement is about making the entire supply chain circular, processing circularity with contracted (preferred) suppliers, and it is about new contracts, in which circularity should be a key element. In order to secure the circular potential of a product or service, partners from the entire supply chain – and reverse supply chain – must be on board. Purchasing criteria must be streamlined with management, use, and the moment of disposal/waste.

Circular procurement
When new materials or products are required (so purchasing cannot be avoided or reduced, see R-Ladder below), only sustainably sourced products are contracted. These are products that do not have any damaging properties or negative externalities. These products are circular by design and come from a transparent supply chain. When products are purchased, they should be sourced in a geographically hierarchical manner, from local to regional to global, always taking transport miles into account. Also, aspects such as embodied energy and social impact are taken into account.

Sustainable procurement manager
The university appointed a sustainability programme manager within CRE&FM. This is one of the first steps to circular and sustainable procurement. This person is also the beacon for questions regarding this topic. At the moment, within TU Delft, the purchasing party is responsible and the Procurement department has an advisory role. This needs to change. A new code of conduct must be made for procurement.

Circular contracting policy
Circularity must be included immediately from the start when drawing up contracts with suppliers. TU Delft must explore and implement other ownership models where applicable, such as leasing [Ellen, 2020]**.** In that case, the supplier or producer remains responsible for the product and takes it back if the product no longer meets the requirements.

Structural measures
Some problems deeper in the system need to be tackled. For instance, contracts for furniture and other goods need to be attuned better with desires of employees and workplaces. And longer service lives of furniture and equipment should be translated into financial accountancy (regarding deprecation periods). Top-down commissioning is essential: Executive Board, deans and directors should set this in motion.

To be investigated: implementing carbon pricing
Usually, a supplier is chosen because they can offer the product or service the cheapest. This is often not the most sustainable option. Unsustainable products will be comparatively more expensive than sustainable products. That is why the CO_2 price of the product should be incorporated into the general price of the product or service. This way a fair comparison can be made. The university should already request for CO_2 data in the tender. This must be communicated to suppliers and the procurement department and tools must be selected and implemented to realise this.
In the ideal case, the university should not calculate their own carbon emissions of procurement. The supplier should be able to supply this information with the product or service. The supplier knows exactly which materials are used (circularity), how much carbon is emitted during production and transport (the footprint). The university actively searches for a supplier that is also looking for ways to make their organisation more sustainable as well and is willing to research this together.

15.04 Specific projects, pilots and actions

Circular Procurement
As said, procurement should be become completely circular and societally responsible. This can be achieved by purchasing circular products (made of biobased materials or fully reusable components) or by contracting with circular deliverers, who lease their products or ensure to take them back for reprocessing. The question of ownership therefore is essential. Regardless, the usage of goods on the TU Delft Campus should be made more efficient.

Furniture and equipment
At the moment, furniture and lab equipment are procured by faculties separately; they are not exchanged between faculties and services and it is not clear how much and what kind a faculty or service has. TU Delft should centralise the procurement of all products. If all of this is registered in a central administration system there will be no need to purchase equipment required for a short period of time.
In a pilot at the faculty of 3mE in 2019, a technical employee made an inventory of all products and materials stored within the Material Sciences department [Ellen, 2020]**.** For the new educational building of Echo, ICT-FM made a static inventory of everything stored in the basement of almost all faculties. The next step is to add more levels of detail to the stock: how old is it, how many years can it still be used, etc. This should be made visible, so others can order the equipment.

Internal Central Database (ICD)
Therefore, in order to become circular, control is needed over the input, use, and output phase of products and resources. An Internal Central Database (ICD) must be created as inventory of current input and output, aimed at sustaining circular product and material flows. The first step is measuring the input: all purchased goods must be registered in this system. By doing this, the use and condition of products and materials will become clear. This will prevent products from being purchased unnecessarily and gives the opportunity to lend out special objects such as lab equipment and furniture within the faculty or with other faculties and services within TU Delft. A benchmark might be useful to define targets for both TU Delft and commissioners.

Internal Central Marketplace (ICM)
Everything has a residual value; by creating an Internal Central Marketplace (ICM) connected to the ICD, the university is setting one step into the direction of circular procurement. The marketplace can be made accessible both online and on campus, for the storage and distribution of products. Such an ICM should be arranged and be made available for people off-campus. That way, when the university does not need a product anymore it could sell this to students, employees, or citizens of Delft, and give the product a second life. Furniture could, for example, be bought by Duwo for student accommodations.

TopDesk, the current product registration system, could be designed in such a way that it is clear which furniture is present in which room. This system could be used as the ICD and ICM, but this must be investigated further.

Storage and repair
Facilities are required for storage and exchange of furniture and equipment; this can be established on campus or in collaboration with an organisation as Rataplan. A ‘Repair Café’, a facility to repair broken goods, could be established in the canal zone; this could be informal and perhaps arranged with Extinction Rebellion.

Supplier portal
Mees Walhof and Kornelis Blok are setting up a supplier portal. This portal is connected with the research of Annika Herth, who looked into the direct and indirect carbon emissions of the TU Delft, including procurement. This supplier portal should be used as tool during the purchasing of goods. By using this portal, scope 3 is simultaneously registered and insight is given in the residual flows, enabling TU Delft to help suppliers reduce their footprint and employees to make sustainable choices during procurement. This platform can provide TU Delft with a lot of data and help other organisations with sustainable procurement. This must be tested in a pilot project, for instant focussed on one faculty.

Becoming paperless
Even in these electronic and digital times, TU Delft still uses a lot of paper, which – even if this paper is from sustainably sourced trees – implies a low-graded use of a material such as wood. Using fully recycled paper is better but reducing the need of paper completely is probably best, unless this would lead to a great increase in energy consumption for electronic applications. Further study is needed in how far TU Delft can become entirely or partly paperless, and what would be the savings in carbon emissions.
At the Vrije Universiteit (Amsterdam), no paper is used anymore for brochures and mailings to prospected students. Apparently, this has saved a considerable amount of carbon emissions.

Proposal
The ideas described above are summarised in a proposal, written by GreenTU and Mees Walhof. In this proposal, the current problems are identified, and concrete action points are given. Furthermore, the financial aspects of transitioning into another system are taken into account, as well as long-term goals. The first action points include appointing at least one responsible person, updating the current inventory and interviewing relevant parties, such as deans, facility managers and department chairs. This needs to be arranged through the Procurement department of Finance.

To be investigated: circular waste management

In order to reduce the amount of waste produced, the university should use less consumable and disposable products. This is the first step of the R-ladder to prevent the production of waste. For unavoidable waste, close collaboration with Renewi is needed to collect all data, and to find out how waste management of TU Delft can be improved. Renewi already collects (some) data; it is important to critically examine the data structure and improve this with researchers. When there is a clear insight into what type of waste is thrown away, in what amount and how it is processed, a plan can be established. Gom is the cleaning company that executes these waste scans.
An important step is to check if ‘waste’ that is thrown away is actually waste or that it can be repaired, refurbished, remanufactured, repurposed, recycled, or recovered. Avoidance is better, of course, by better informing staff and students. First, the low-hanging fruit and the high potential flows must be approached, but also the complex tasks must be tackled according to a plan.

Agreements about packaging
Where possible, TU Delft should avoid packaging. Nowadays, almost all products are delivered in (plastic) packaging. This is not always necessary. Clear agreements must be made about this with the supplier. Reusable or renewable packaging should be used, when it is not possible to eliminate the packaging. Research should be done into the possibility of using sustainable packaging material.

Sustainable goods
TU Delft should also use sustainable goods. Nowadays, there are many sustainable alternatives for products. These products are, for example, biobased, made from recycled material, or can easily be recycled themselves. The ICD will give an overview of all products purchased by TU Delft and from which company. Based on this, it can be checked whether this product is already sustainable; if not, a sustainable alternative must be sought. For example, agreements can be made with the supplier of (printing) paper. Instead of standard paper, sustainable paper should be used as standard in the printers. Other types of papers can only be used on request. The next step would be the paperless office. Both options – recycled paper and the paperless office – should be tested through a pilot.

Durable goods
Another easy step is to replace disposables with durable goods, e.g. cutlery and cups. This is helped by the fact that the use of single-use plastic has been prohibited since 1 July 2021. As mentioned in the Food & Beverage chapter, paper cups should not be offered any more and a design challenge on sustainable carry-on solutions including plates, cutlery and a cup must be set up to avoid plastics and disposables. This design challenges should be used to change the attitude and behaviour regarding disposables.

Stickers on bins
This is a project by GreenTU currently in the initiation phase. A pilot will take place in the faculty of Architecture and the Built Environment and the Aula of TU Delft, with the help of Arjan van de Groep and with Dave Seegers from CIRFOOD. The idea is to put stickers on waste bins in canteens and restaurants that correlate with the generated waste. The next idea is to also provide this for the other waste separation bins on campus from the pilot.

Waste separation
If agreements have been made with the supplier, products can be returned to the supplier when it does not meet TU Delft's requirements anymore. It is important to separate waste flows; otherwise, it is impossible to reuse or recycle the products or raw materials. This applies to both products and food.
The separation of waste can be done by installing Multi Waste Containers. A waste separation pilot focussing on the separation of paper, PMD, coffee cups, and residual waste is currently running at the faculty of Architecture and the Built Environment (ABE) and the Aula. This pilot should be evaluated quickly and – when deemed successful – expanded to other faculties and supporting divisions on campus.

Paper bins should not be placed in canteens to prevent greasy paper plates from going in this bin. In addition, special stickers should be made that correlate to the waste generated in that area. Another important aspect is to look at the duration of waste bin filling and the prevention of pests, mice, and fruit flies.
E-waste (electronic waste) is another important waste stream. This waste stream is classified as hazardous waste, which means that it can potentially become a threat to public health or the environment. This waste stream is discussed in Chapter 16, ICT, AI & Data Management.

Cleaning waste reduction
GreenTU and GOM will collaborate to involve students in setting up a few business cases, bringing new ideas on how to make the cleaning on campus more sustainable. The three cases are about:

- Reducing the use of plastic trash bags
- Reducing the use of tap water for cleaning windows
- Reducing stray litter around the campus, which takes up valuable time of cleaners
- Reducing residual waste

These business cases are planned to take place in the form of interactive events, most likely first in spring 2022.

Selection and temporary storage
At present, a lot of waste is disposed that might still be reprocessed. When the product no longer meets the requirements, it must be examined[27] whether the product can be reused, repaired, refurbished, or remanufactured. It is important to look at the possibility to reuse the raw materials instead of only looking at the product as a whole. If this is not the case the product should be repurposed or recycled within TU Delft. Therefore, TU Delft should have people in its organisation – most logically with Logistiek & Milieu – or hired from specialised companies who determine whether waste actually is waste or source for reuse on campus. In order to facilitate this, a temporary storage is needed before a final selection into waste fragments. Considering there is 'hidden vacancy' on campus, this storage should not be a problem. Reusable goods might be returned to the original suppliers or offered on Marktplaats or other second-hand trading places.

Algae
TU Delft should also look into the possibility of using algae, bio-fermentation, and biorefinery**.** Algae can be used to process waste (water) and at the same time produce energy (biodiesel) and absorb CO_2. Fermentation can be used to make compost, which can be used for the green on the campus. To ensure that waste separation happens, students and employees must become aware of this and change their behaviour. Special information sessions, events, and other activities must be held. For example, cleaners must be instructed how to handle the waste so that the streams remain separate.

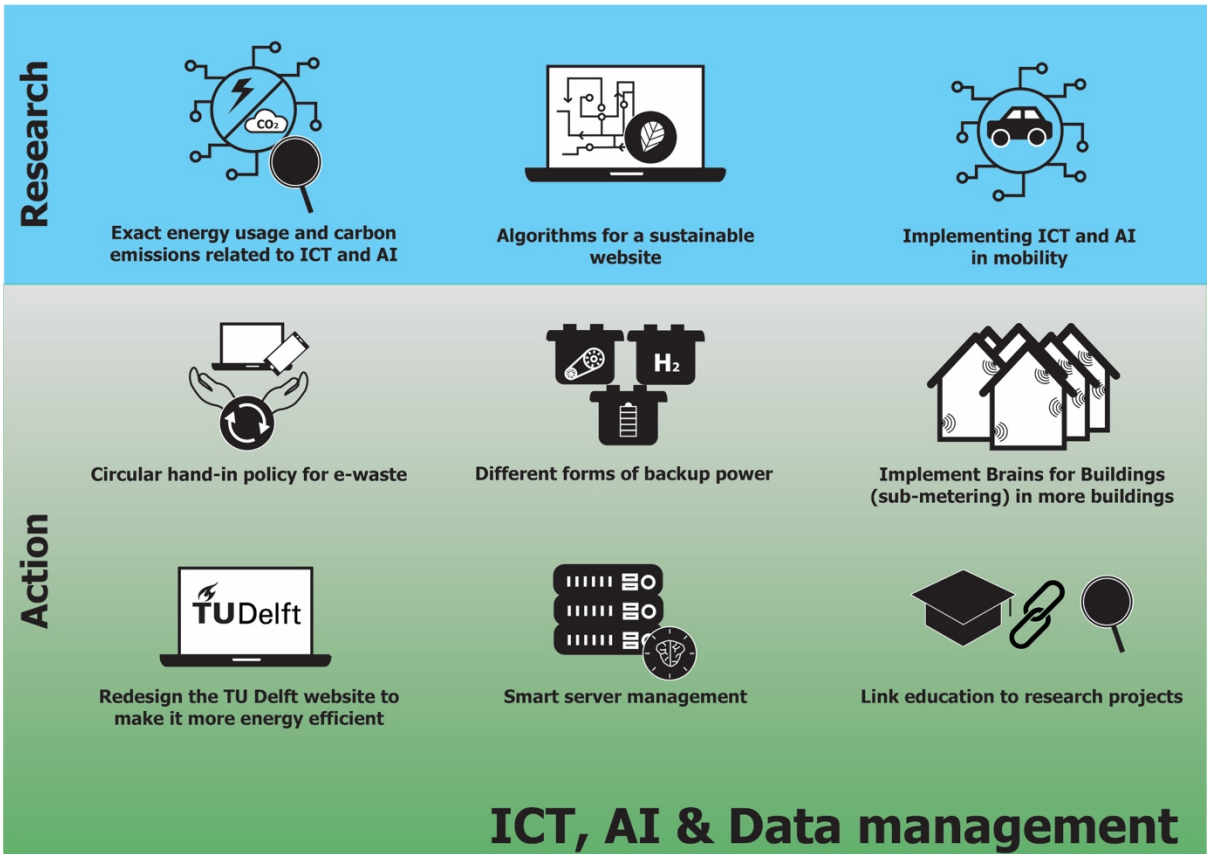
[27] Who determines when something resides under which step of the R ladder? For instance: person A thinks something is waste and person B (after revitalisation) still sees new life.

Because the area in TU South is being newly developed, there is a good opportunity to test possibilities here.

16 IT, AI & Data Management

Team (in alphabetical order)

- Abel van Beest – GreenTU
- Lolke Boonstra – ICT
- Andy van den Dobbelsteen – TU Delft sustainability coordinator
- Han Derkx – Director ICT-FM
- Arie van Deursen – EEMCS
- Aaron Ding – TPM
- Deirdre van Gameren – TU Delft sustainability researcher
- Olivia Meng - GreenTU
- Luis Miranda da Cruz – EEMCS
- Abhigyan Singh – IDE
- Annelien Wehrmeijer – ICT-FM/Com
- Julie Zonneveld – Com



IT, AI & Data Management
Main proposals

General aims and principles

- To use IT and AI smartly to **measure carbon emissions**
- To use IT and AI smartly to **make processes more energy-efficient**
- To use IT and AI smartly to **measure data** from living labs and pilot projects
- To **keep track** of the amount and type of (big) data stored
- To focus on the **quality of data**, smart data, not on requiring all data
- To use and design **energy-efficient codes** and software
- To educate **conscious programmers** using energy-efficient codes and software
- To manage **servers and data centres** sustainably

To be investigated

- Determining the exact **energy usage and carbon emissions** from the use of IT and AI
- Creating algorithms for a **sustainable website**
- Implementing ICT and AI in **mobility**
- Studying different forms of **backup power**: flywheel utilities, hydrogen, batteries
- Redesigning the **TU Delft website** to make it more user-friendly and sustainable

Projects, pilots and actions

- Implementing the **Brains for Buildings** programme in more buildings (sub-metering).
- **Linking education** to research projects
- Installing smart **server management**
- Creating a **circular hand-in policy** for e-waste

Everyone who works or studies at TU Delft uses Information Technology, Artificial Intelligence, and Data Management (ITAID) in one way or another. This use will likely be more intensive in the future. ITAID can be used as an enabler of making products and services smarter and more energy efficient, but it also uses a lot of energy itself. This chapter looks into the desired future situation, the IT and data management at present, and proposes specific projects, pilots, and actions together with a general approach.

16.01 Desired future situation

In the near future, the campus should work as a smart city. The university is using the new techniques around ICT, Internet of Things (IoT), AI, and DM to make processes more energy-efficient. Each time, an assessment is made whether the process will be more energy efficient with the use of these techniques or whether these techniques themselves cost more energy.
The university is applying ICTAID in an energy-efficient way, using AI critically, monitoring e-consumptions and making improvements. The university also keeps track of the amount and what kind of (big) data is stored and makes sure that it is not filled with useless data. Data acquisition through monitoring is well attuned to what is needed. It is not about storing and generating all the data but about the quality of the data, smart data.
ICT and AI are essential in measuring the data from all the living labs on campus. These are all new projects the university is learning from. It is also essential for circular resource management. It will help the university get control over flows on campus. A flow model has been made after an inventory of all the resource flows.
In addition to using energy-efficient codes and software, the university also focuses on educating and deploying conscious programmers who make energy-efficient codes and software. Energy related to electricity and heat, is saved by efficient programming and computation.

16.02 IT, AI and data management at present

IT on the campus: current facilities
First-line services involving IT are done by the service desk at each faculty. For other requests and questions, people can go to the self-service portal. There is also the Student IT Desk, where students can ask substantive questions about the software their working with. For teacher support, there is the teaching and learning services helpdesk at Academic Services as part of the Student Services building next to the Teaching Lab (brightspacesupport.tudelft.nl).

TU Delft website
According to the website carbon calculator, the TU Delft website is among the 4% energetically worst performing websites. Besides, the website is unpractical after decades of adjustments; the same applies to sub-websites such as Collegerama, Talent Services.

Energy and carbon impact

The energy consumption of the 33 buildings of the Delft University of Technology is measured every month, divided into gas consumption, heat supply, and electricity use. There is little information on the exact energy usage and carbon emissions by the use of ICT and AI. This should be investigated in more detail. At the moment buildings are monitored, but not in so much detail that we can distinguish between different sources of electricity use. More submetering and sensors are being installed with the Brains for Buildings programme. BNS data are being coupled to energy data. More detailed metering is needed for insight and to see the impact of measures taken (and the return of investment). Revenues are now going to CRE&FM. There is a different arrangement between buildings in general and datacentres.

IT and AI can also be used for more efficient and smart use of energy, and it is being utilised in this way already. The new educational building in TU Delft Campus South is going to get a smart metering system.

Datacentres

The differences in energy use per square metre are great when looking at figure 16.02, which includes all buildings monitored in 2018. The energy consumption of buildings 32dc, 36EKL, and 47 are far above average. Building 32dc and building 47 are datacentres and building 36 is the Else Kooi lab. It can be seen that these datacentres and labs are energy-guzzling. At the moment, the quality of the data is a problem to make optimal use of AI. The university should not collect all data, but it needs to define which data is needed and what to do with it.

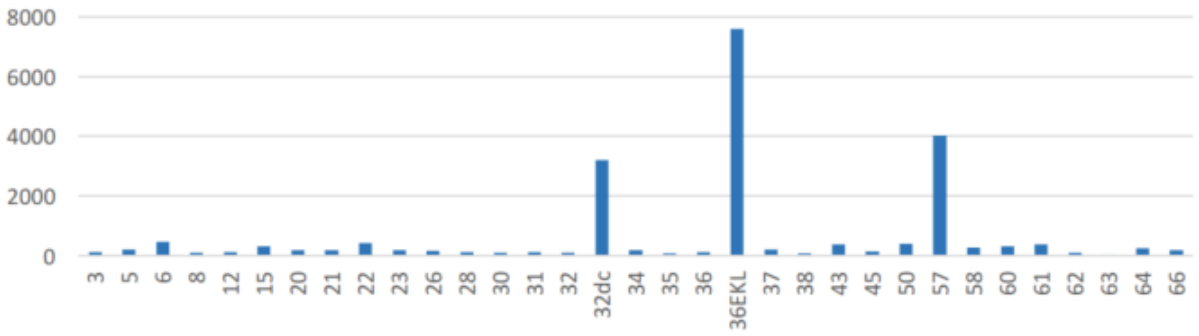


Figure 16.01: Energy use per m^2 of the buildings on campus, including data centres and labs

The datacentres and EEMCS building have backup generators that run on diesel. These backup generators are tested every month. One of these backup generators is now being replaced, powered by biofuel. A flywheel was also possible but due to the costs and innovative character, it was not chosen by CRE&FM. According to research by SURF, a flywheel would be the most innovative and effective source for backup. TU Delft should experiment with other forms of backup power: flywheel utilities, hydrogen, batteries, etc.

16.03 General approach

Reducing the impact of ITAID
TU Delft should reduce the negative impact of ITAID and make the processes more energy efficient. When ITAID is used, the total energy demand for the process should be reduced, including the energy cost for the process itself. The usefulness of ITAID should also be increased. To realise this, the university needs sufficient measuring tools, and storage to run the algorithms.

Carbon measurements
ITAID is not only used to make processes more energy efficient it can also be used to measure carbon emissions and visualising the carbon footprint of TU Delft. Once this information is known, ITAID can be used to reduce these emissions. The information can also be used to compare our footprint with other universities and learn from each other.

Telework
The IT and AI facilities need to be improved for (digital) education and working from home, especially after Covid-19. Beside using these techniques for education, TU Delft should also link research projects to student projects.

Energy-efficient programming
TU Delft should educate and deploy conscientious programmers who make energy-efficient codes and software. Beside teaching the students in this field to become sustainable programmers, students and staff need to become aware of the relation between daily actions in their behaviour and resulting energy usage and carbon emissions. Only then, staff and students can understand the importance of their daily behaviour and see that it is them who can make a change.

16.04 Specific projects, pilots and actions

To be investigated: reducing the negative influence of ITAID

Efficient computing
TU Delft should only develop and use energy-efficient codes and software. Besides, the university should educate and deploy conscientious programmers who make energy-efficient codes and software. Education on sustainable software engineering is getting started next year: the Sustainable Software Engineering course (CS4415) is starting in the academic year 2021/2022.

Reprogramming the TU Delft websites
The website of TU Delft should be made more user-friendly, sustainable, and show that we care about sustainability with real action projects besides just showing the energy and

carbon impact. A start is made with the TU Delft sustainability website[28] itself. However, research should be done into how to create a sustainable website and what makes the website sustainable. At the moment, rules are formulated to help and educate editors regarding how to change or adapt a website with for example a minimum and maximum MB for images.

Datacentres
The energy use and carbon emissions of datacentres must be reduced. Three important points where gains can still be made are in computation processing, server management, and waste heat usage. There is much to gain in high-performance computing (HPC), 30% of power use could be reduced when energy-efficient coding is used and by not running the server at full speed; this also results in less production of heat. The HPC is currently cooled in the old-fashioned way, which makes it impossible to reuse waste heat within 5 years. It is not possible to connect the HPC to the present heating system because that one runs at high temperatures. Campus South will however get a LT network. The NorthC datacentre should be used as test-site for waste heat usage. The RID datacentre is less suited for this. In addition, there are plans to make more use of the Cloud instead of the two datacentres at IDE and RID. This will also reduce the energy used by TU Delft.

Servers
Finally, TU Delft should manage its servers, because there are several ghost servers. Researchers forget that they have a server running for them. To tackle this problem the university could send a reminder, connect a fee to it, and show the carbon footprint of the server running to the specific researcher. The following website provides a tool to estimate the carbon footprint of processes https://mlco2.github.io/impact/. The infrastructure of the datacentres is old. The sustainability constraints should be there when the discussion starts about replacing this infrastructure. This team is keeping a close eye on it. In addition, a new digital board is being installed, climate and sustainability will be an important topic to discuss with this board.

Deep learning
The democratisation of AI across all divisions, despite the undoubted benefits, also entails larger carbon footprints. Deep learning is a form of machine learning which is a huge energy consumer. Hence, TU Delft puts research effort into energy savings in AI, sustainable edge AI and trustworthy AI in the project of Aaron Ding.

Electronic equipment
New employees receive a computer from TU Delft and in some cases also a phone. The university should investigate the market and include sustainable products in their offer as well. At the moment, for example, employees can choose a Fairphone, but a lot of people are not aware of the positive impact they make when they choose a Fairphone over an iPhone, for example. As they probably know the iPhone, it is likely that they will go for that

[28] www.sustainability.tudelft.nl

option. In 2022, the ICTAID team will be setting up a campaign to create awareness about this. In the end, the best option is of course not to offer a work phone at all but provide a dual sim or eSim. At the moment, CRE&FM is working on a new management system so that employees can use their own equipment in a safe way.

E-waste
Old computers and other forms of e-waste are now trashed or forgotten at the employee's home. There is a hand-in policy but most of the employees are not aware of this. In 2022, the ITAID team will organise a spring-cleaning event to create more awareness about this policy. This will include extra collecting points where employees can hand in their old electronic equipment. It is important that employees hand in their old equipment because it could contain sensitive data. The university collaborates with Digital Education in African Networks (DEAN). DEAN focuses on the realisation of enabling and supporting environment for education institutes that offer relevant tools, content, training and a support structure. The returned devices result in money that is used to help DEAN with their goal.

Impact of ICTAID interventions
When new inventions or breakthroughs are made in this field, the advantages, disadvantages, effects on energy, materials, CO_2, and money have to be weighed. This project must start after a proper inventory of the current impact of ICTAID is made.

Carbon compensation by Ecosia
By initiative of GreenTU, Ecosia has been installed as the standard search engine. This search engine plants 1 tree for each 40 search assignments. Ecosia takes biodiversity into account when planting trees.

Using IT, AI and digitisation to become smarter and more sustainable

Hybrid and virtual conferences
The university should use knowledge about ITAID to become more sustainable. Hybrid conferences should be the norm so that people can join in real life and online. A blueprint should be designed for this. At the moment, a team is working on the hybrid Ecocity World Summit/SASBE2021 conference. This could be a good pilot case.

Monitoring (data acquisition) and smart building management systems
A project should be set up to gain more insight into energy use and carbon emissions by ITAID. Detailed monitoring is needed so that a distinction can be made between different sources of electricity use and to see the impact of measures taken (and the return of investment). More submetering and sensors are being installed with the Brains for Buildings programme, where BMS data are being coupled to energy data. As mentioned in the monitoring chapter, the university should expand the Brains for Buildings programme for submetering in other buildings.

Teleworking and E-Learning facilities
TU Delft should provide employees with the opportunity to improve their home office so that they can work (partly) from home. Also, the meeting rooms at TU Delft should be provided with cameras and other electronics that are needed to enable hybrid meetings. TU Delft should offer enough facilities, recording studios and techniques – such as facilitated by the New Media Centre (NMC) – to give hybrid lectures, so that students can work (partly) from home.
In addition, it is important to create awareness about the energy use of electronic equipment. Tutors often leave zoom/teams meetings running during the break, which is unnecessary.

IT and AI for mobility
TU Delft must do more research into implementing IT and AI into mobility topic. This can be used for road infrastructure, e.g. lamp posts, traffic lights, but also for regulating parking, and electric charging planning (incl. safety).

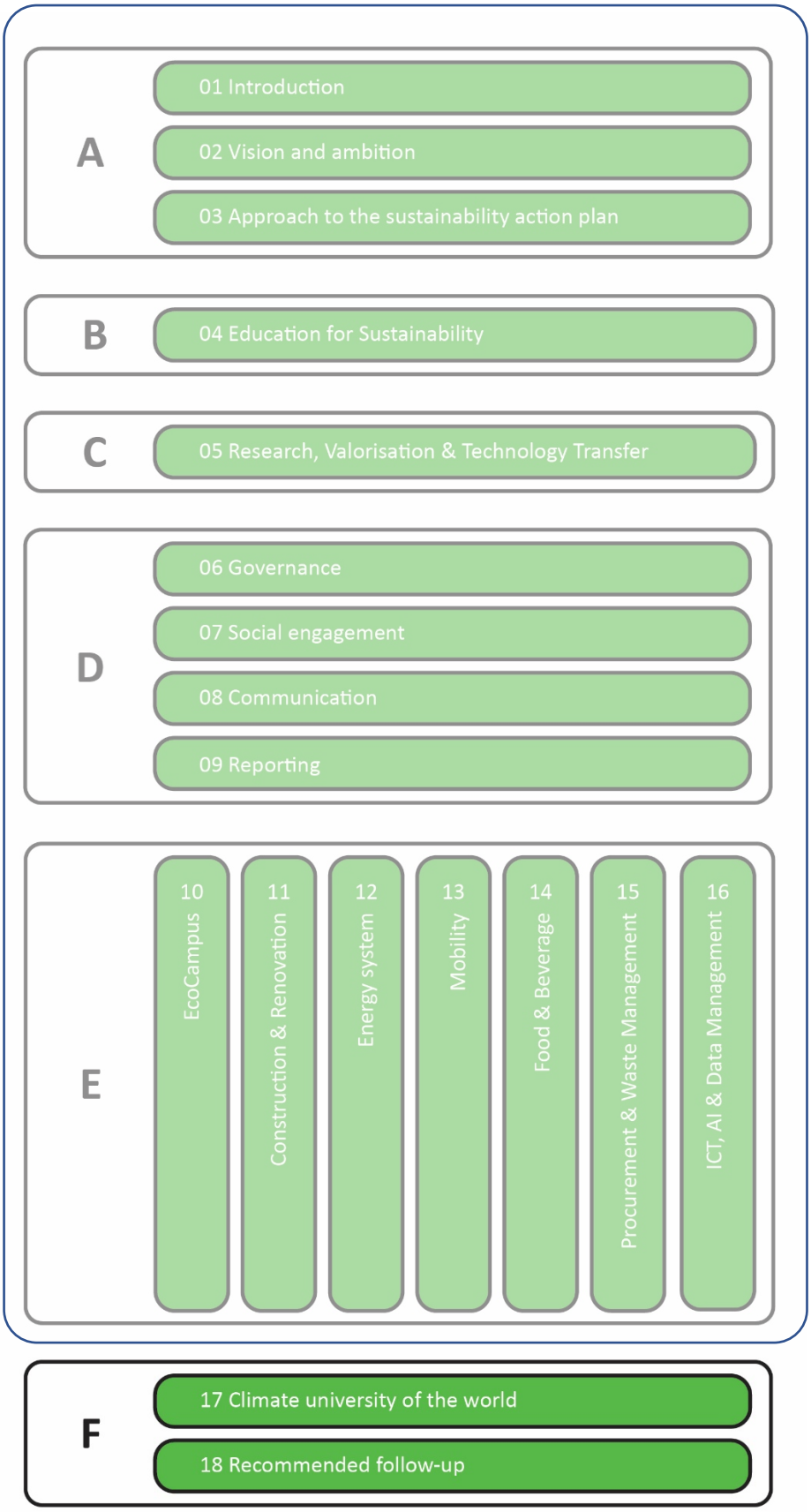
Repair, don't replace
Computers and laptops should be repaired, when possible, rather than handing them in and replacing them with a new one. A deal should be made with a computer company.

Living Labs
At present, the following living labs are ongoing
- A current running field lab is Do IoT, which implies research in the field of the Internet of Things (IoT).
- The Delft AI Lab for Sustainable Energy Systems investigates how new AI-based methods can contribute to managing (dynamic) energy systems.
- Gaming for Sustainability (Infrarium) is making people more aware of their behaviour and impact.
- The APROPOS project – Energy saving computing investigates how much impact new types of computing will have on energy and carbon.

TU Delft

PART F

ACTION!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17 Climate University of the World

TU Delft's Rector Magnificus, Tim van der Hagen, expressed his wish to make TU Delft the world's climate university. Considering the vision, ambitions and expertise present on the campus, this should be an attainable goal. If we want it, we will be able to do it.
This report is meant to kickstart sustainability and climate action on the campus. If you have read it until here, you have seen it is full of recommendations. They are all important, but some are essential to the success of making TU Delft the climate university we want it to be.

17.01 Most important interventions

This report started with the identification of TU Delft's main sustainability goals: becoming carbon neutral, circular, climate adaptive and contributing to quality of life, for humans and nature, in addition to testing these on campus in living labs. All of these need to be strived for, but perhaps the most urgent and concrete key performance indicator is carbon neutrality by 2030, in all assets and activities on and from the campus.
With that in mind, TU Delft needs to take some serious steps before 2030, most of which start this year, 2022. Effectiveness is key.

Effectiveness

Effectiveness is different from efficiency in that it is related to attaining a certain objective rather than improving the processes and products that be. In that sense, it fits the proposed method of backcasting better: where do we want to be in 2030, and how are we going to get there fastest.
Effective are measures that have a great improvement potential, as well as measures that can be applied to a large share of the system considered. For example: regardless of the means and costs, if the greatest energy-consuming building on the campus, the Else Kooi Lab, will be made 80% more efficient, that will be much more effective than making the Bouwpub building energy neutral. And also effective, related to scale: if we find a way to ban paper coffee cups, this will have an enormous impact on the campus, more than introducing one entirely sustainable espresso bar.
The most effective measures are the ones that both have a great improvement potential and relate to all places on the campus. An example might be the use of technical equipment: computers are used all across the campus and the carbon impact is huge (16,000 tons of CO_2-eq in 2018, according to Herth & Blok [2021]). Arranging circular contracts with the suppliers of our computers, forcing them to repair, reuse and recycle materials will have an enormous impact, not just for TU Delft, but all over the world.

In the text following, we will discuss the most effective reductions in carbon emissions.

Sustainable procurement: as soon as possible

For approximately half of the emissions – as demonstrated by Herth & Blok [2021] – TU Delft is dependent on the environmental quality of the products (stationary, equipment, furniture, …) and services (hired externals) it procures. So, from now on, all items bought should stand the test of sustainability, circularity in particular. Since most things are purchased at the faculty, department, section or even chair level, the importance must seep through in all layers of the organisation. Raising awareness therefore is an important first step. In addition, we strongly advise arranging all procurement centrally.

Furthermore, getting the full supply chain of products sustainable is simply paramount. The university cannot do this on its own, but we can motivate or enforce suppliers and partners to get it accomplished together. Agreements with partners that we have a contract with and circular contracting with new ones therefore need to be fully focused on our climate and sustainability goals. We cannot afford to lose time and bind ourselves to suboptimal contracts; everything from now on needs to be in compliance with TU Delft's sustainability goals.

Energy: geothermal energy, renovations and super-sustainable new builds

The use of fossil fuels – natural gas especially – presents the second largest source of carbon emissions. Therefore, just like the rest of the Netherlands, we have to become independent from natural gas; however, we need to get there faster than the rest of the country. This is an opportunity for TU Delft to lead the way in not only reducing our carbon footprint in an absolute sense, but also in helping to remove bottlenecks and barriers that still stand in the way of making society more sustainable. To make this happen, there are a few unmistakable necessities.

Geothermal heat

First and foremost, TU Delft will have to get the geothermal well operative as new source of high-temperature (HT) heat for the campus' district heating system. Geothermal heat will then replace hot water coming from the cogeneration plant, currently powered by natural gas.
In case of geothermal heat, many buildings may still be renovated after 2030 and gradually shift to mid-temperature supply, the return flow of the network, which by that time supplies its HT heat to other parts of the city of Delft. So, this source of heat is preferred as solution for a quick energy transition.

Or all-electric?

Without the geothermal well installed, getting to zero carbon will become virtually impossible. It would imply that TU Delft must shift to a system based on electricity, even in the case of a hydrogen network, because in the near future, this hydrogen would have to be produced with redundant renewable power.
A more logical alternative to geothermal heat would be a low-temperature (LT) network fed by various sources and boosted by heat pumps. This will most probably be a more expensive solution than geothermal heat. Moreover, all buildings on campus would have to be LT

ready, hence well-insulated and energy efficient. This is a good solution anyway, but to establish this before 2030 will be a difficult challenge.

Energy renovation
An absolute no-regret measure for any heat system is the renovation or transformation of existing buildings on the campus, to make these more energy efficient, or even energy neutral. We propose to tackle those buildings first that have the highest energy use per square metre. Think of building 22 (Applied Physics), 23 (Civil Engineering & Geosciences), 34 (Mechanical, Maritime and Materials Engineering), 36 (Electrical Engineering, Mathematics and Computer Sciences, the highrise and Else Kooi Lab), 50 (Reactor Institute Delft) and 58 (Applied Sciences). See figure 17.02.

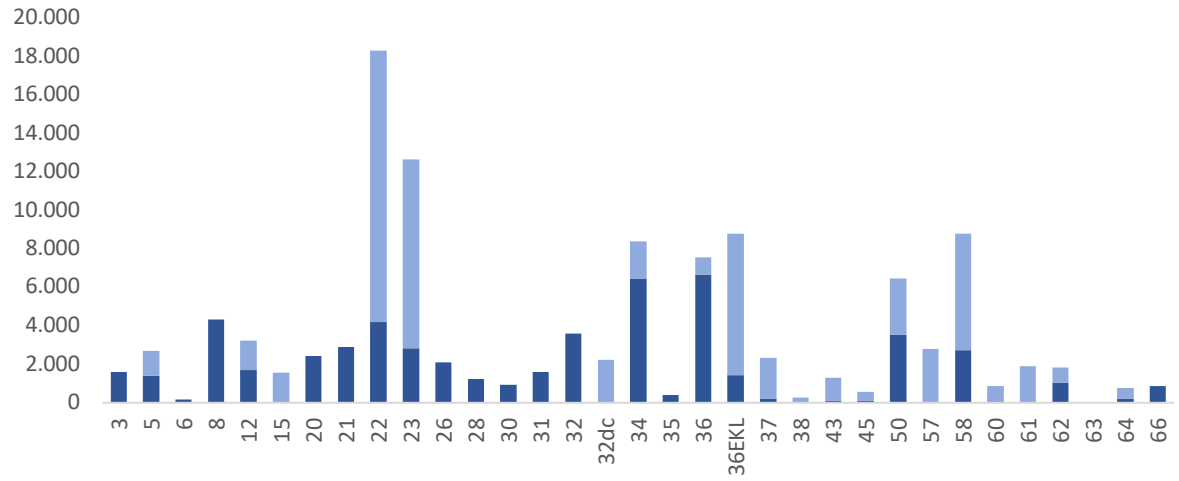

Figure 17.02: The total energy use of the buildings monitored in 2018 [emonitor.tudelft.nl]; dark blue indicates educational spaces and offices; light blue are research functions and labs

PV roll-out on campus
Apart from the renovation of the buildings mentioned, based on the study done by the faculties of Electrical Engineering, Mathematics & Computer Sciences (EEMCS) and Architecture and the Built Environment (ABE), the execution of the photovoltaics (PV) roll-out on campus needs to start as soon as possible. Important to understand: this will not reduce carbon emissions as currently calculated (since wind energy is considered carbon neutral), but it is important to align with the goal to produce at least 50% of the energy used on the campus; and when the contract with Eneco ends, more self-dependency is recommended.

Kluyver area as exemplar of TU Delft's sustainable ambitions
In order to give a boost to the new policy of TU Delft and to be taken seriously, the Kluyver area needs to become everything that we currently envision as the qualities to strive for: energy positive, circular, climate adaptive and nature inclusive. One may think that going for all four of these qualities is too much, but that is like an architect refusing to think about the

structural strength and stiffness of their building, or about the choice of material, or colour. Sustainability is a necessity just like those aspects.

Food & beverage: continue to improve the sustainability of food

The first clear action taken on the campus, visible to all, was the introduction of the vegetarian restaurant at ABE. Ignoring the extreme reactions by some parties with stakes in the meat industry, the community at the faculty was very positive about the decision by the dean, thanks to the great quality of food offered as alternative to what used to be prepared in the past. CIRFOOD and the people at TU Delft concerned with catering have done a great job to demonstrate that sustainable food can be delicious. The vegetarian restaurant of the Faculty Club underlines this.

To be continued: other restaurants

And now it is important to extend the policy of sustainable food to other restaurants, food trucks and distribution points. Sustainable does not necessarily mean vegetarian or vegan, but certainly local, seasonal, organic, animal-friendly, more plant- and less animal-based. As demonstrated, the impact of this shift is a reduction by at least half of the number 3 emitter of CO_2 equivalents. Also, sustainable behaviour can be promoted by changing the prices of food, dependent on its carbon impact.

Mobility: make the campus fossil free, and travel sustainably

Various cities such as Amsterdam are headed towards being fully fossil free by 2030, and TU Delft should do the same.

Non-fossil commuter travel

The chapter focussing on mobility presented many means to promote and stimulate non-fossil transport towards the campus, by bike, electric bike, public transport, or electric cars. At present, the campus' parking space still is too much focused on traditional cars, which is a shame. A quick transition is needed to significantly reduce the CO_2-equivalent emissions and fine dust particles on the campus and its surroundings. Facilities for bikes and electric vehicles should be extended significantly.

Sustainable business and student travel

As discussed, avoidance of travel – regarding commuter and study travel, but especially international business and student travel – is the most important step to reduce emissions of mobility. 2020 and 2021 have demonstrated this: a low figure of emissions was shown due to the corona crisis. It is paramount not to slide back to old habits and travel as intensely as TU Delft used to do before 2020. Telecommunication and teleconferencing facilities have now become so good that international meetings (e.g. for research projects) or lectures do not necessarily have to be done onsite, requiring travel.
Of course, a part of the activities typically done from universities requires travel (student exchange, conferences, design workshops, special ceremonies, etc.) and this will pick up again after the corona restrictions have been alleviated. Nonetheless, the policy from then

onwards should be different: avoid travelling, reduce travelling, plan travelling smartly, use the most sustainable mode of transport.
Trains, not planes, unless there are no reasonable options.

Code of conduct for travel
Travel guidelines will help students and staff make sustainable decisions. We propose to introduce a code of conduct for travel, which must be distributed among the entire TU Delft community.

Internal carbon tax
Another measure proposed by the Mobility team is the introduction of an internal carbon tax to compensate for emissions from flying (and other forms of climate-influencing travel). This internal carbon tax, as explained in chapter 06, should be equivalent to 150 €/tonne of CO_2-equivalent and it should be transferred to a fund that will be used for sustainable projects, pilots and actions, and for sustainable student travel across Europe (compensating for rail travel prices). The exact arrangement of TU Delft's internal carbon tax will be elaborated in the coming period.

ICT: reduce processing energy and use AI to improve campus operations

There are two ways that the impact of ICT (and AI and data management) can be improved: reduced emissions in terms of the energy currently used, e.g. by better programming, and utilising ICT and AI better to make the campus smarter, more energy efficient and circular. The second aim seems to be in contrast with the first, but it should not be done thoughtless: it is not about gathering as much data as possible, but being effective in it, for the use of many data has led to the stark increase of energy used by datacentres, server rooms and individual computers.

Compensation: green the campus and compensate CO_2 annually

As much as we want it, not all carbon emissions will be avoided by 2030. This is simply due to the fact that even sustainable solutions still emit carbon. Think of vegan food: it by far releases the smallest amount of carbon emissions, but it is not zero. The same applies to certain products that require virgin materials. And there will still be some non-emissionless flying going on in 2030. Therefore, also at TU Delft, a certain fraction of present-day's emissions will have to be compensated for.
A part of carbon sequestration can be established on the campus, by extending the amount of carbon-absorbing green. Regarding the large surfaces of stony, metal, bituminous origin, a lot can be done, also in combination with PV.
Estimating that by 2030, 10,000 tonnes of CO_2-eq will still have to be compensated, we propose to invest the equivalent of 1,000 tonnes of CO_2-eq each year in tree plantation, starting 2022. By the end of 2030, this will have produced a forest sequestering 9,000 tons (which is approximately 10% of the emissions of the 2020 reference). The costs of this compensation are limited (the current price of less than 20 €/tonne is lower than the market price of carbon certificates) but it helps to get to zero carbon, whilst also investing in projects on campus.

17.02 Timeline for action

Table 17.01 shows the proposed reduction of carbon emissions between 2020 (the reference year) and 2030, taking into account that the first years were strongly influenced by corona, therefore expecting an increase in emissions in the year 2022.

Table 17.01: Proposed carbon emission reduction goals for TU Delft until target year 2030

TU Delft Carbon Timeline											
year	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
source	base										carbon neutral
energy	**22102**	**19000**	**18000**	**17000**	**16000**	**8000**	**6000**	**4000**	**2000**	**1000**	**0**
electricity	0	0	0	0	0	0	0	0	0	0	0
natural gas	19739	19000	18000	17000	16000	8000	6000	4000	2000	1000	0
own operations	363										
energy to third parties on campus											
energy home office (estimated +10%)	2000										
mobility	**2503**	**6800**	**6100**	**5400**	**4700**	**4000**	**3300**	**2600**	**1900**	**1200**	**500**
commuter travel	1230	2800	2500	2200	1900	1600	1300	1000	700	400	100
fuels on campus	27										
business travel	1246	4000	3600	3200	2800	2400	2000	1600	1200	800	400
transportation & travel											
flights											
food	**13652**	**14000**	**13000**	**12000**	**11000**	**10000**	**9000**	**8000**	**7000**	**6000**	**5000**
food on campus	3652	14000	13000	12000	11000	10000	9000	8000	7000	6000	5000
food at home (estimated +10000)	10000										
resources	**32528**	**57200**	**51500**	**45900**	**40200**	**34500**	**28800**	**23100**	**17400**	**11700**	**6000**
resources purchased											
real estate & construction	9700	20000	18000	16000	14000	12000	10000	8000	6000	4000	2000
equipment	7100	12000	10800	9600	8400	7200	6000	4800	3600	2400	1200
ICT	4200	8000	7200	6400	5600	4800	4000	3200	2400	1600	800
facility services	4100	8000	7200	6400	5600	4800	4000	3200	2400	1600	800
research expenses & consumables	2500	5000	4500	4000	3500	3000	2500	2000	1500	1000	500
paper products	700	1200	1100	1000	900	800	700	600	500	400	300
distribution											
water consumption on campus	50										
waste	1978	3000	2700	2500	2200	1900	1600	1300	1000	700	400
resources at home (estimated +1000)	1000										
other	1200										
services	**2600**	**2800**	**2500**	**2200**	**1900**	**1600**	**1300**	**1000**	**700**	**400**	**100**
services		2800	2500	2200	1900	1600	1300	1000	700	400	100
administration, consulting & auditing	2200										
finance & tax	400										
carbon uptake	**-300**	**-1400**	**-2500**	**-3600**	**-4700**	**-5800**	**-6900**	**-8000**	**-9100**	**-10250**	**-11500**
green on campus	-300	-400	-500	-600	-700	-800	-900	-1000	-1100	-1250	-1500
green elsewhere	0	-1000	-2000	-3000	-4000	-5000	-6000	-7000	-8000	-9000	-10000
total	**70485**	**95600**	**86100**	**76700**	**67200**	**50700**	**40200**	**29700**	**19200**	**9650**	**0**
employees (fte)	6042	6000	6100	6200	6300	6400	6500	6600	6700	6800	6900
students	26960	27500	28000	28500	29000	29500	30000	30500	31000	31500	32000
total	**33002**	**33500**	**34100**	**34700**	**35300**	**35900**	**36500**	**37100**	**37700**	**38300**	**38900**
CO2/fte	**2,136**	**2,854**	**2,525**	**2,210**	**1,904**	**1,412**	**1,101**	**0,801**	**0,509**	**0,252**	**0,000**
		81,3%	60,4%	40,4%	20,9%	-10,3%	-30,0%	-49,1%	-67,6%	-84,0%	-100,0%

Apart from energy, for which the introduction of geothermal well enables a significant reduction of gas in 2025, most emitters of CO_2 are proposed to be gradually decreasing, in some cases leaving a small remaining emission that cannot be solved by TU Delft itself. For those emissions in 2030, carbon compensation is necessary, and as said, this is proposed to

be built up from 2021 onwards, by buying the equivalent of 1,000 tonnes of carbon emissions as forest plantation, as proposed in the previous section.
Table 17.01 is illustrated by figure 17.03. Annual values are proposed targets. It is more probable that on certain themes a stark decrease of emissions can be reached at once, by a new sustainable contract, or after one of the energy-inefficient buildings has been renovated, or that the decrease should go faster at the beginning (preferred indeed) and slows down in the end, but the gradual reduction leaves space for faster and slower developments. In this graph, 2021 was assumed to have the same emission as 2020, due to Covid-19.
The exact annual target can be determined and adjusted precisely in the coming years.

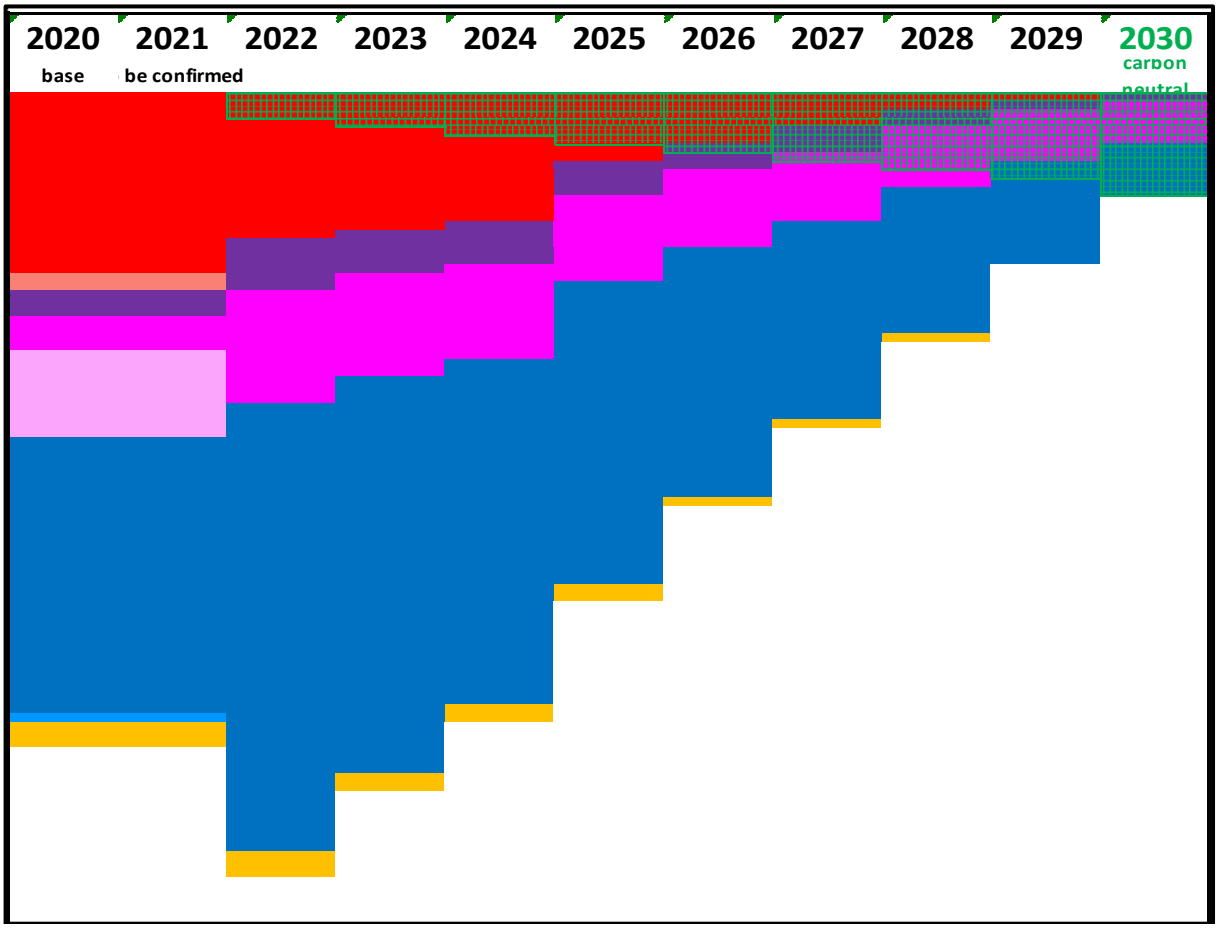

Figure 17.03: Carbon emission reduction towards the year 2030, graphically

17.03 It has already started

It might seem rash to start emission reductions already in the year of this publication, but TU Delft is not starting from zero (reductions). Independent from corona, we had already set in motion various projects that help to reduce carbon emissions and this will be seen more clearly when the effects of the pandemic have gradually vanished.

Table 17.02: Sustainability projects on the TU Delft Campus that have already started

Ongoing projects per theme
EcoCampus
Heat square @ TGV (Rainroad, Bluebloqs, Nature-Inclusive Shed)
Water street @TGV
50-litre house
Polder roof @ CEG
Climate arboretum @ ABE
Planting flower mixtures to attract insects
ECOCampus 2.0 course @ ABE
Construction & Renovation
Metabolic study of EEMCS high rise
Kluyver Area ambition document by Copper8
Energy-producing educational building ECHO
Circularity Roadmap
Rotterdamseweg parking garage construction
Brains for Buildings
Energy Systems
Roll-out of PV on roofs and facades of existing buildings
Geothermal well: final investment decision and preparation for realisation
Preparations for facilitating a heat pump centre in the vicinity of the geothermal well
Project development of a high-temperature aquifer energy storage
Adjustments to heat distribution in buildings, preparing for sustainable heat sources
E-refinery
Mobility
Electric bike pilot
NS business card pilot
Business travel pilot @ AE & CEG
Outdoor mobility dashboard
Food & Beverage
Vegetarian restaurant @ ABE
Vegetarian Faculty Club
Discount when bringing own cups
Procurement & Waste Management
Waste separation pilot at ABE and Aula
ICT, AI & Digitisation
Brains for Buildings
Ecosia as standard search engine
Facilities to work from home

Table 17.02 lists the most important projects that already started before 2022 to improve TU Delft's carbon performance. It just goes to show that change is already happening and that we should see the results thereof in the coming years. This is ever more so when the actions proposed in this report (the most effective ones mentioned in section 17.02) are executed. Let's do it.

18 Recommended Follow-Ups

Faculty and supporting division action plans
Faculties and supporting divisions have been asked to make their own sustainability action plans, based on this report before you. The respective deans and local sustainability coordinators will be responsible for them, in attunement with TU Delft's sustainability coordinator. Also, these plans need to be translated into planning schemes and financial consequences.

Continue with the theme teams
As TU Delft sustainability coordination, we propose to continue with the teams that have worked on the various themes discussed in this report. Most people involved have expressed interest to remain involved, new students and staff have joined and together they will elaborate the plans in detail, including time planning and financial schemes.

Elaborate the projects, pilots and actions proposed
As already said, the proposals made in this report need to be elaborated in more detail, connected to a time plan and to a financial scheme (when applicable). We propose to do this with the theme teams, including students and academic and supporting staff, and to prepare – together with Strategic Development – BVMs for interventions that require approval by the Executive Board.

Finish the education report
At the moment of writing, GreenTU is finishing an education report that analyses the various educational programmes at TU Delft and how these can be enhanced to include urgent themes of sustainability better. This will be done with our support and with the active involvement of the Pro Vice Rector for Joint Educational Affairs. The report is due to be finished in spring 2022, shortly after this sustainability report.

Start research on identified topics
As presented in almost every chapter of this report, there are aspects or elements of plans that require further investigation. This will be done in the coming period, or a research scheme will be set up for the coming years, together with the theme teams.
A different category refers to the monitoring of projects, pilots and actions already ongoing. To measure and learn from these projects is of great importance for future success.

Get things started in the year 2022
In normal cases, implementing change in an existing system or situation would encounter a lot of opposition, but the corona crisis has created a window of opportunity to introduce a lot of sustainability measures in a period when students and staff return after almost two years of (partial) exclusion from the campus. The new policy therefore can be best put into place at the beginning of the new year.

We do not expect a lot of opposition to the measures: the start of the vegetarian restaurant at the faculty of Architecture and the Built Environment and the Faculty Club demonstrate that the TU Delft community supports these initiatives so long as they are well prepared and if they mean better quality than beforehand.
Moreover, the elaborate round of presentations and discussions held in autumn 2021 disseminated the plans for sustainability among the TU Delft community (and outside), which created a lot of support, generated a lot of input for improvements as well as additional ideas and proposals that go beyond the original ideas presented in the draft version of this report (of June 2021).

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TU Delft

Appendices

Appendix A: The value of a tonne of carbon

We propose to start using an internal carbon tax at TU Delft, at the value of € 150 per tonne of CO_2-equivalent. This is explained here.

First of all, it is important to have a carbon price that is not too low to compensate for the societal costs of climate change and environmental damages. TU Delft could adopt the market price of carbon, but then this level would vary day by day.

As seen in chapter 02, the EU Emission Trading System (ETS) market price of one tonne of CO_2-equivalent is on the rise after years of a stable level far too low (figure 02.01). It currently exceeds € 70/tonne and a further increase is expected, but it may also drop due to unforeseen circumstances. The ETS value is not related to the actual expense of climate change.

In his study for the UN, Jochen Wermuth came to a value of $ 140/tonne of CO_2-eq (€ 130 at that time), constituted half of direct climate effects and half of indirect effects. Sweden was the first country to adopt this carbon price.

In its report, the World Bank Group [2020] presented a slightly lower value: $ 119/tonne.
The Planbureau voor de Leefomgeving (PBL) [Koelemeijer et al. 2019] came to a range of € 90-165/tonne around 2030 (median: € 127.50). The Nederlandse Emissieauthoriteit (NEa) expects a value very close to that average, € 125/tonne [NEa 2020].
PricewaterhouseCoopers (PwC) uses a value of € 100/tonne, but this was chosen arbitrarily as an easy value; their peers apply a range of € 50-145/tonne.
All in all, a value of € 125-130/tonne of CO_2-eq seems to be supported by various sources.

The values mentioned do not ensure sufficiency for climate change mitigation. In order to demonstrate the urgency and to compensate for damage done in the past, a price higher than € 130/tonne is recommended. Therefore, in deliberation with the sustainability working commission around professor Kornelis Blok, it was decided to go for € 150/tonne of CO_2-eq.

Appendix B: Analysis of sustainability in education

GreenTU, devoted to integrated sustainability into education, research and university operations, conducted research into the current status of sustainability in the various curricula. This is a summary thereof.

Bachelor (BSc) programmes

TU Delft offers 16 bachelor (BSc) programmes, which are given at the eight faculties. The education report forthcoming has an inventory of the different faculties at TU Delft with their bachelor programmes, learning trajectories and courses. It can be seen that few of the bachelor programmes at present implement sustainability as a main or underlying topic in their curriculum. For the bachelor of Architecture, Urbanism and Building Sciences, sustainability and use of energy, water and material play a role in various technical courses and design assignments. The final assignment in the 6th semester even is to design a sustainable, energy-neutral building. At the faculties of Aerospace Engineering and Mechanical, Maritime and Materials Engineering (3mE), the relation to the bachelor and sustainability is mentioned on the web page. However, at 3mE sustainability is an explicit element of the project line in the first year. So it is not always clear if the topic of sustainability comes back in the courses itself. None of the bachelors show the direct relation of their bachelor programme with sustainability, which can be improved.

Minors

During their study, bachelor students can choose between 4 types of minors: a minor from TU Delft, a self-composed minor, an internship minor, and a minor abroad. Students can choose between 42 minors from TU Delft. The education report will mention which minors can be followed at which faculty. It can be seen that every faculty offers at least one minor that has a relation to sustainability. However, only 10 out of 42 minors incorporated sustainability into the minor, and 6 out of 42 minors are connected to sustainability but sustainability is not explicitly taught. Students can also choose minors from Leiden and Rotterdam, amongst which are several minors on sustainability, and there are special minors developed by the three universities together. Currently, an LDE-minor on sustainability is developed.

Master (MSc) programmes

TU Delft offers 35 master (MSc) programmes, which consist of 49 MSc tracks. Some masters incorporate the topic of sustainability into their courses. The education report shows all the masters and their relation to sustainability. Sometimes the topic of sustainability is integrated in the course; sometimes there is a relation with sustainability but not explicitly mentioned or taught. Sustainability is at least mentioned in half of the master programmes. However, only 15 out of 49 master programmes and only 5 out of 35 masters integrate sustainability in one way or another. This means that there is a lot of space for improvement.

Honours programme

Bachelor and master students who perform above average can apply for the honours programme. There are special faculty programmes and Interfaculty courses. At the moment there are no special sustainability-oriented assignments for honours students. A new development in the honours programme is the 15EC specialisation. It is planned to offer a specialisation on sustainability in the near future.

Doctorates (PhD programme)

Someone with a master's degree at a renowned university can apply for a PhD position (Doctor of Philosophy) at TU Delft. At TU Delft there is a broad range of research areas, spread across the eight faculties. Sustainability can be a topic of the PhD trajectory, and it is so in ever more cases. The TU Delft Graduate School guides PhD candidates during their project and offers Doctoral Education, which teaches methodological skills, practical skills and courses of content. As heard from PhD candidates themselves, too few courses are offered that deal with sustainability or climate action. It would be good if PhD candidates were asked to add a paragraph to their thesis to address which UN sustainable development goals are served by their research.

Professional doctorates (PDEng)

A PDEng is a practically oriented professional doctorate in engineering, sometimes called design traineeships. TU Delft offers 5 PDEng programmes, of which two are connected to sustainability. The education report shows the faculties with a post-master or a PDEng programme.

Post-master programmes

Post-master programmes can be followed by people with a master's degree and/or 5 years of relevant working experience. TU Delft offers 5 post-master programmes, in the area of 3mE Architecture and the Built Environment (ABE) and Technology Policy & Management (TPM). Sustainability is a topic in three of these programmes.

Online education

In addition to the education given at the campus, TU Delft also offers Open & Online Education, in the form of MOOCs (Massive Open Online Courses), open courseware, ProfEds, and online education at a distance. The TU Delft Global Engagement Framework 2018-2024 states that TU Delft wants to develop an open and online portfolio focused on contributing to the grand challenges as described in the UN Sustainable Development Goals (SDG) [UN 2019, p.18]. The education report will list all MOOCs and ProfEds created by the faculties of TU Delft and their relation with the topic sustainability. Also here, sometimes the topic of sustainability is integrated and sometimes there is a relationship but not explicitly mentioned or taught. Architecture and the Built Environment stands out in that almost all the MOOCs created by the faculty have the topic of sustainability integrated. The other faculties offer some MOOCs and ProfEds integrating sustainability. The faculty of Aerospace Engineering offers not one MOOC or ProfEd that fully integrates sustainability.

3 MOOCs of IDE are focused on circular economy and circular design, and two of them (Introduction to CE and Sustainable Packaging) are in the top 3 of TUD MOOCs when it comes to generated income (i.e. participants requesting a certificate).

Appendix C: CRE&FM's KPIs for Construction & Renovation

The table below (in Dutch) presents the KPIs regarding sustainable construction and renovation, focussing on the sustainability goals of TU Delft (carbon neutrality, circularity climate adaptiveness, liveability, demonstration).

Constructie & Renovatie	**KPI**	**Doel**
CO_2-neutraal		
Netto energiegebruik	kWh	0 kWh/jaar
Netto energiegebruik	X% van de nieuw gebouwde gebouwen zijn energie producerend	80%
Netto energiegebruik	X% van de nieuw gerenoveerde gebouwen zijn energieneutraal	50%
Broeikasgassen	ton CO_2-eq	0 ton /jaar
Duurzame productie van warmte en koude	X% van finaal warmtegebruik dat netto zelf duurzaam wordt opgewekt	100%
Duurzame productie van elektriciteit	X% van finaal elektriciteitsgebruik dat netto zelf duurzaam wordt opgewekt	100%
Financiën	In X% van het totaal aantal projecten op de TU Delft wordt TCO meegenomen	100%
Financiën	X% van de projecten op de TU Delft wordt de schaduwprijs van 150 ton CO_2 meegenomen	100%
Circulair		
Materiaalgebruik	X% van het materiaal is geoogst uit bestaande gebouwen	10% (Hangt van aanbod af)
Materiaalgebruik	X% van de vrijgekomen materialen vanuit TU Delft Campus worden hergebruikt in het gebouw	80%
Materiaalgebruik	X% van de gebruikte materialen in het gebouw zijn circulair (PM circulair -> definitie nodig)	80%
Materiaalgebruik	X% van alle materialen zijn losmaakbaar	80%
Materiaalgebruik	X% van de materialen zijn natuurlijke en/of niet-toxische materialen	100%
Materiaalgebruik	X% van de projecten past het principe van de R-ladder toe	100%
Materiaalgebruik	X% van de projecten past het principe van de S-lagen toe	100%
Materiaal registratie	X% van het gebruikte materialen/producten worden geregistreerd (e.g. materialenpaspoort, centrale database)	100%

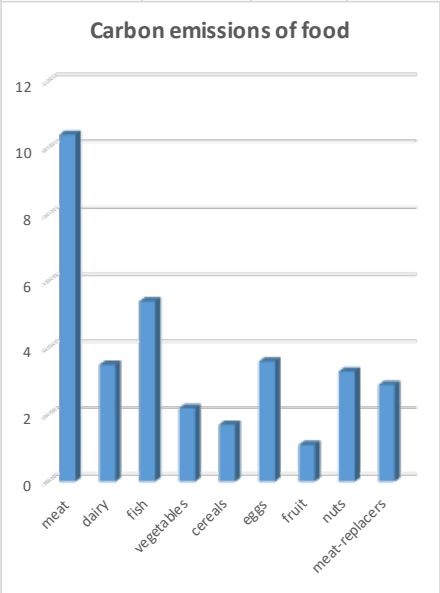
Systeemgebruik	X% van nieuwe technische systemen zijn zo gemaakt dat onderhoud circulair kan plaatsvinden	100%
Afval	X% van het afval wordt hoogwaardig gerecycled en verwerkt	80%
Afvalpunten	In een straal van X m is er een afvaleiland	?? m
Drinkwater	X l per persoon per dag (120 l pppd is in NL gemiddeld)	50 l pppd
Aanbesteding	In X% van het totaal aantal aanbestedingen wordt het principe van circulaire contracten uitgetest	100%
Klimaatadaptief		
Gebouw	Bij het ontwerp van X% van de gebouwen op de TU Delft Campus wordt de NSS gebruikt	100%
Gebouwen	X% van de gebouwen op de TU Delft Campus zijn klimaatadaptief ontworpen	100%
Daken	X% van de daken op de TU Delft Campus - waarbij het mogelijk is - wordt gebruikt als groen, blauw, geel of bruin dak (definitie van de kleuren nodig)	80%
Hemelwater[3]	X% van het hemelwater wordt opgevangen via de daken	80%
Hemelwater	X% van het opgevangen hemelwater wordt functioneel gebruikt in de gebouwen	50%
Hemelwater	X% van het opgevangen hemelwater wordt geborgen rondom de gebouwen	50%
Afvalwater	X% van het afvalwater wordt gezuiverd en nutriënten is herwonnen	50%
Verharding	X% van de verharding direct rondom het gebouw is infiltratieverharding	50%
Bijdragend aan leefkwaliteit		
Natuur[1]	X% van de m^2 van de TU Delft Campus	30%?
Gebouw	X% van de gebouwen op de TU Delft Campus past het principe van natuur inclusief bouwen toe	100%
Groen	Voor X% van de geïdentificeerde gebieden met hittestress is een groene coolspot gerealiseerd	75%
Groen	Binnen X m is er een groene schaduwplek vanuit een gebouw	50 m
Groen	X% langs fietspaden en wandelpaden zijn beplant (gezondheid, hittestress, CO_2 opname)	80%
Biodiversiteit en Habitats	X% van de huidige biodiversiteit en habitats worden behouden (of op de juiste manier verplaatst)	100%
Biodiversiteit	Stijging van X% van het huidige aandeel dierreservaten (vogelhuisjes, vliermuizenkasten, insectenhotels) Of In een straal van X m is er een dierreservaat (vogelhuisjes, vliermuizenkasten, insectenhotels, bijenkorf)	50% X m

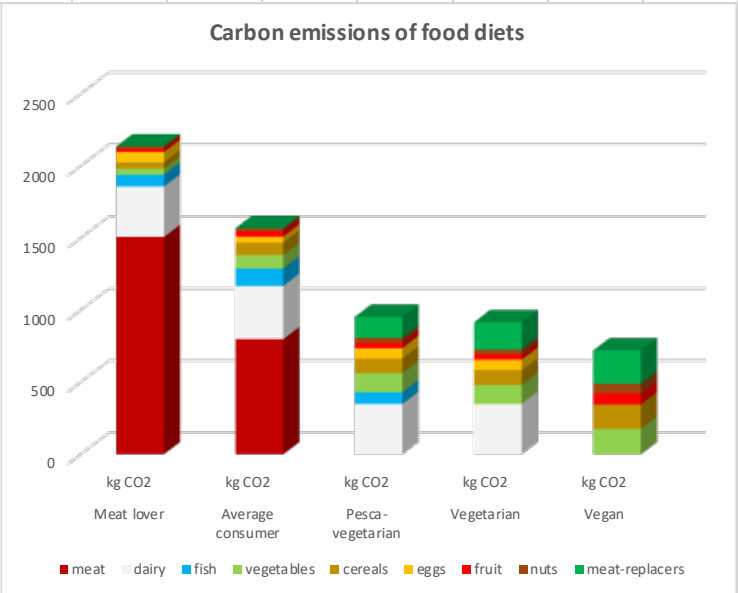
Mentale gezondheid	Medewerkerstevredenheid score 1-10	≥8
Parkeren	X% van het autoparkeren wordt gereguleerd	100%
Parkeren	X autoparkeerplekken per fte gebruikers	0,15/fte
Parkeren	X fietsparkeerplekken per fte gebruikers	1/fte
Parkeren	X% laadpalen tov het aantal autoparkeerplekken	25%
Parkeren	X% laadpunten tov het aantal fietsparkeerplekken	10%
Onze kwaliteiten en duurzaamheid tentoonstellend		
Testgebied	X% van de TU Delft Campus moet gebruikt kunnen worden voor pilotprojecten, exposities, experimenten, etc.	15%

Appendix D: Calculations of the carbon impact of food

Carbon emissions of food [as used for Dobbelsteen 2021, in Roggema 2021]

Carbon emissions of food consumption (NL)											
	typical CO2	Meat love	Average c	Pesca-veg	Vegetarian	Vegan	Meat love	Average c	Pesca-veg	Vegetarian	Vegan
	kg CO2/kg	kg	kg	kg	kg	kg	kg CO2	kg CO2	kg CO2	kg CO2	kg CO2
meat	10,4	145,0	76,8	0,0	0,0	0,0	**1508**	**799**	**0**	**0**	**0**
dairy	3,5	100,0	105,4	100,0	100,0	0,0	**350**	**369**	**350**	**350**	**0**
fish	5,4	15,0	22,6	15,0	0,0	0,0	**81**	**122**	**81**	**0**	**0**
vegetables	2,2	20,0	42,0	60,0	60,0	80,0	**44**	**92**	**132**	**132**	**176**
cereals	1,7	25,0	50,6	60,0	60,0	100,0	**43**	**86**	**102**	**102**	**170**
eggs	3,6	20,0	11,7	20,0	20,0	0,0	**72**	**42**	**72**	**72**	**0**
fruit	1,1	20,0	35,0	35,0	35,0	70,0	**22**	**39**	**39**	**39**	**77**
nuts	3,3	5,0	5,5	10,0	10,0	20,0	**17**	**18**	**33**	**33**	**66**
meat-replacers	2,9	0,0	0,7	50,0	65,0	80,0	**0**	**2**	**145**	**189**	**232**
average	3,8										
total		350,0	350,3	350,0	350,0	350,0	**2136,0**	**1568,9**	**953,5**	**916,0**	**721,0**





food category	NL consumption		Carbon emissions per food category											NL carbon emission	
	kg/p.year	%	kg CO2e/kg									%	average	kg CO2e/p.year	%
	350,6	**100%**	2)		3)		4)		5)		**choice**	per cat		**1575**	**100%**
dairy	**105,4**	**30%**										**100%**	**3,50**	**369**	**23%**
milk	49,0		10,6		1,9				1,2	NL	1,20	48%			
cream	1,4										1,20				
yoghurt	31,0				2,2						2,20	29%			
cheese	21,0				13,5		10,0	Gouda			10,00	23%			
butter	3,0										2,20				
	7)														
eggs	**11,7**	**3%**	**5,5**		**4,8**		**3,6**		**2,0**	**NL**	**3,60**		**3,60**	**42**	**3%**
	9)														
nuts	**5,5**	**2%**			**2,3**		**3,2**				**3,20**		**3,20**	**18**	**1%**
peanuts									1,4						
walnuts									2,1						
cashew nuts									2,3						
	11)														
cereals	**50,9**	**15%**											**1,75**	**89**	**6%**
wheat			0,8								0,80				
rice					2,7						2,70				
	10)														
fruit	**35,0**	**10%**			**1,1**						**1,10**		**1,10**	**39**	**2%**
	1)														
vegetables	**42,0**	**12%**			**2,0**								**2,26**	**95**	**6%**
potatoes					2,9						2,90				
beans					2,0		1,0		1,6		1,60				
lentils					0,9		1,0				1,00				
	1)														
meat	**76,8**	**22%**										**100%**	**10,41**	**800**	**51%**
turkey					10,9										
chicken	22,2		4,6		6,9		6,8		2,6	NL	6,80	29%			
pork	36,4				12,1		7,0		4,5	NL	7,00	47%			
minced meat 50/50							13,3								
hamburger							16,8								
beef croquet							5,2								
beef	15,5		16		27,0			18,85	8,9	NL	18,85	20%			
minced meat beef							19,4								
beef steak							34,0								
lamb	2,6				39,2						39,20	3%			
lamb chop							51,0								
horse	0,1											0%			
insects							2,7								
	6)														
fish	**22,6**	**6%**										**22%**	**5,42**	**122**	**8%**
tuna	2,58				6,1	canned					6,10	41%			
cod	2,40								3,4		3,40	38%			
salmon	2,09				11,9	farmed			2,1		2,10	33%			
pollock	1,58								1,6		1,60	25%			
mussels	1,27														
herring	1,20								1,1		1,10	19%			
mackerel	1,12								0,9		0,90	18%			
hake	1,00														
squid	0,74														
tropical shrimp	0,69														
sardine	0,65														
catfish	0,60														
surimi	0,56														
trout	0,42														
clam	0,33														
plaice	0,25								5,3		5,30	4%			
others	8,30														
EU total	14,66														
	8)														
meat replacers	**0,7**	**0%**											**2,43**	**2**	**0%**
soy drink									0,6		0,60				
tempé									1,1		1,10				
tofu					2,0		3,5		2,0		2,00				
quorn							2,7		2,6		2,70				
veggie burger							2,6		1,6		2,60				
vegetable burger									1,1		1,10				
valess product									6,2		6,20				
veggie burger w/cheese							6,5								
	12)														

Sources		
1) Milieucentraal 2016		
2) DEFRA 2006		
3) Environmental Working Group 2017		
4) Blonk Consultants 2017, concerning Dutch supermarkets		
5) Blonk Consultants 2017, for Dutch produce		
6) WUR 2017, horse meat		
7) Doornewaard et al. 2017		
8) EUMOFA 2017; Eurostat 2017, plaice estimated		
9) Productschap Pluimvee & Eieren 2013: 192 eggs/p.year		
Ei Love You, www.eiloveyou.nl/vraag-antwoord/, 61 g /egg		
10) GfK 2006, for bread		
11) deduction, based on Voedingscentrum 2017,		
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