UANTWERP'S CARBON FOOTPRINT 2018

ecolife

Universiteit Antwerpen

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1. INTRODUCTION

The UAntwerp (Universiteit Antwerpen) wants to perform a baseline measurement of its carbon footprint for its main Antwerp campuses (Campus Drie Eiken, Groenenborger, Mutsaard, Middelheim and Stad). Together with an internal working group at the UAntwerp, Ecolife calculated the university's carbon footprint as well as the reduction potential of possible climate actions. The purpose of this baseline measurement is to serve as a basis for a climate action plan (in a later phase) and to be compared with other Belgian universities, such as the Brussels University, VUB (Vrije Universiteit Brussel) and the University of Louvain or KULeuven. The baseline measurement offers a customised tool to recalculate the footprint in the future.

The carbon footprint of the UAntwerp was carried out conform the Bilan Carbone® (version 8) methodology of the French Association Bilan Carbone, with CO_2 emission values adapted to a Belgian context. This Bilan Carbone® methodology is compatible with the Greenhouse Gas Protocol (GHGP) and ISO standardisation.

After a general explanation of a carbon footprint, this report contains a detailed description of the calculation methodology, with data sources, method of collection and processing of consumption data and the Bilan Carbone® calculation tool. The results are presented per activity or impact category, including uncertainty estimates, and compared with other universities and colleges. Simulations are presented to reduce the carbon footprint, and suggestions are made to compensate the remaining, non-reducible CO_2 emissions.

2. ADMINISTRATIVE INFORMATION

Client

Name:	Universiteit Antwerpen (UAntwerp)
Address:	Prinsstraat 13, 2000 Antwerpen
Contact person:	Marleen Clerinx
Mail:	marleen.clerinx@uantwerpen.be
Tel:	+32 (0)3 265 20 21
Examined sites:	Campuses Drie Eiken Groenenborger Middelheim Mutsaard Stad
Data year:	2018

Executor

Auditor:	Stijn Bruers
Organisation:	Ecolife vzw
Address:	Valkerijgang 26, 3000 Leuven
Mail:	stijn.bruers@ecolife.be
Tel:	+32 (0)16 22 21 03

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3. THE CARBON FOOTPRINT

3.1. What is the carbon footprint?

The carbon footprint measures the anthropogenic emissions of Kyoto greenhouse gases.[1] These are the gases included in the Kyoto-protocol (1997):

- *Carbon dioxide* CO_2 (sources: burning of fossil fuels, production of cement, deforestation, change in land use);
- *Methane* CH_4 (sources: agriculture, production processes, natural gas leaks);
- *Nitrous oxide* N_2O (sources: agriculture);
- *Fluorinated gases and halocarbons* SF_6, HFCs, PFCs (sources: cooling systems).

3.2. What is the unit of the carbon footprint?

The contribution of each greenhouse gas to the greenhouse effect depends on its 'global warming potential', the extent to which it traps heat and thus contributes to climate change. The global warming potential is used to calculate the equivalent amount of carbon dioxide required to heat the earth equally over the next 100 years. For example, 1 ton of methane equals 34 ton of CO_2. Each greenhouse gas can be translated into tons of CO_2 equivalents.

The carbon footprint of an organisation is thus expressed in ton of CO_2e per year. The effects of different gases can be added according to this method, which makes the carbon footprint an aggregated indicator to measure the impact on the climate.

3.3. What is our carbon footprint?

If we divide the global greenhouse gas emissions by 7 billion people, an average person on Earth has a carbon footprint of about 7 ton of CO_2e per year, of which three quarters consist of CO_2, mainly from the energy sector (see Figure 1 of the World Resources Institute for a division of greenhouse gas, activity and sector). The carbon footprint of an average person in Belgium is 20 tons CO_2e per year.[2]

1 Biological short-cycle emissions from e.g. human respiration or wood combustion do not contribute to the carbon footprint, provided that CO_2 is captured by planting new trees or crops for human consumption. Emissions of changes in land use (for example, burning forests if the forests are not re-planted) are included in the carbon footprint.

2 Vercalsteren A., Boonen K., Christis M., Dams Y., Dils E., Geerken T. & Van der Linden A. (VITO), Vander Putten E. (VMM) (2017), Koolstofvoetafdruk van de Vlaamse consumptie, studie uitgevoerd in opdracht van de Vlaamse Milieumaatschappij, MIRA, MIRA/2017/03, VITO, VITO/2017/SMAT/R. This corresponds with Eureapa, a tool to calculate and compare the footprints of nations (www.eureapa.net).

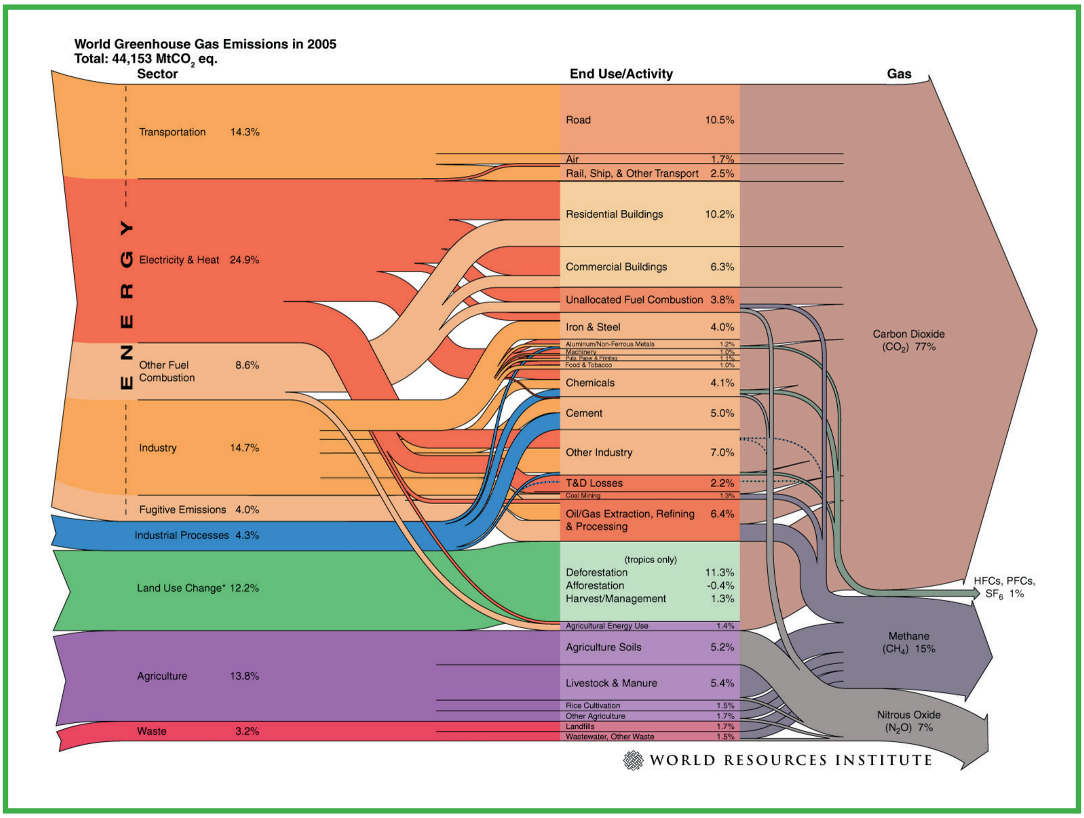

Figure 1: Subdivisions of the carbon footprint by sector, activity and greenhouse gas.

3.4. What is the planetary boundary of the carbon footprint?

The atmosphere, the biosphere and the hydrosphere (the oceans) have limited capacity to absorb and process greenhouse gas emissions. There are currently more than 400 particles of CO_2 per million particles in the atmosphere, causing the climate to warm up. When the atmospheric temperature increases more than 1.5°C above pre-industrial level (200 years ago), severe climate changes may occur. If current emissions are maintained, the expected temperature increase is about 4 degrees.

If we want to limit global warming below 1.5°C, we must reduce the global carbon footprint by a factor of 5 over the next 40 years (see Figure 2). Keeping in mind an increasing world population, from 7 to 9 billion people, the carbon footprint per person needs to go down a little extra. In that way we reach about 1 ton CO_2e per person per year by 2050. By 2050, emissions must rapidly fall further to 0 ton CO_2e. This is not impossible if all energy comes from renewable sources and if emissions from land use change are avoided.

To achieve climate targets, an average Belgian must reduce its carbon footprint by 2050 with 95% (from 20 tons to 1 ton CO_2e). For a linear reduction path, this means an annual reduction of 3%, or a 30% reduction within 10 years.

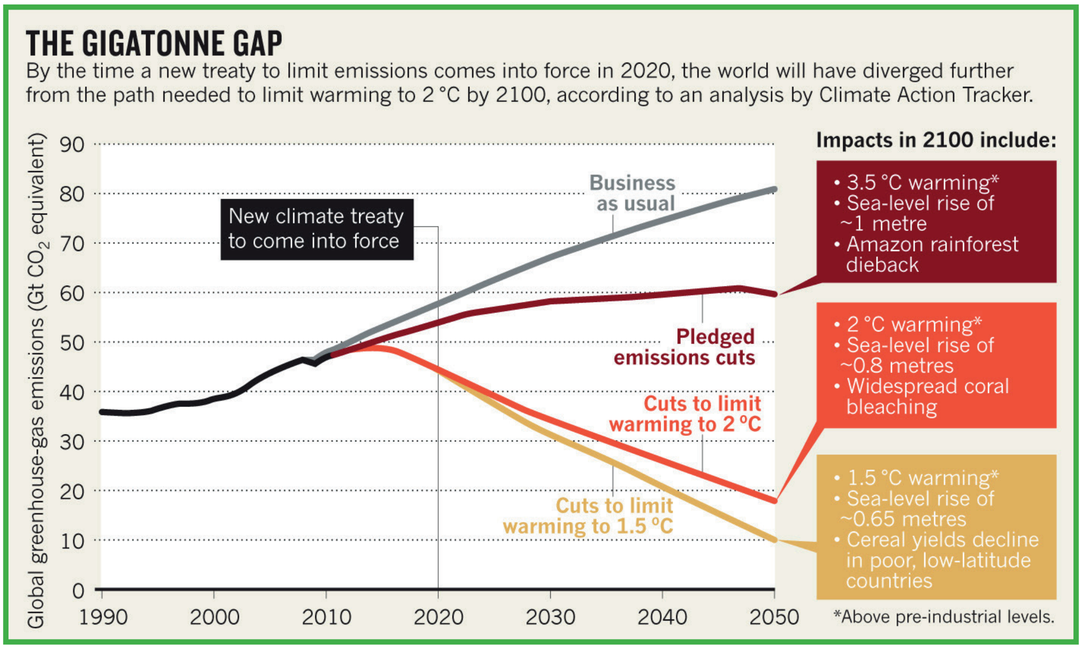

Figure 2: Reduction of the carbon footprint according to climate targets.[3]

3.5. Why calculating the carbon footprint of an organisation?

Over the years, multiple footprint indicators have been developed to measure environmental impact, for example the ecological, carbon, water, material and nitrogen footprint. Of all footprint indicators, companies and governments use the carbon footprint the most. The standardisation of the carbon footprint is also currently the most developed. Companies and organisations are getting more and more interested in their carbon footprint mainly for two reasons: financial vulnerability and social responsibility.

Firstly, a high carbon footprint creates financial vulnerability for an organisation. The carbon footprint is strongly linked to the use of fossil fuels, and fossil fuel prices may increase or fluctuate in the future. Also, in the future different kinds of CO_2 taxation will most likely become more important. A calculation of the carbon footprint gives an insight into the expected future costs of greenhouse gas emissions and fluctuating energy prices.

Secondly, a calculation of the carbon footprint of an organisation is also in line with corporate social responsibility (CSR), global climate targets and the UN Sustainable Development Goals (SDGs). Reducing its climate footprint is more and more regarded as an organisation's social responsibility.

When determining which organisation's activities should be included in the carbon footprint, both financial vulnerability and social responsibility should be taken into account. If the organisation is not responsible for emissions or if the emissions do not involve financial vulnerability for the organisation, the emissions do not have to be included in the organisation's carbon footprint.

For organisations, projects and products, the carbon footprint has been standardised in ISO Standards 14064-1 (for organisations and companies), 14064-2 (for projects) and 14067 (for products).

3 Tollefson, J. (2011) Durban maps path to climate treaty, Nature 480, 299–300.

Furthermore, the Bilan Carbone® methodology (www.association+carbone.fr), developed at the time by the French ADEME, is used in a lot of Western European countries and can at the moment be considered as the reference methodology for calculating the carbon footprint of companies and regions. The in this study used Bilan Carbone® method conforms with ISO standards and Greenhouse Gas Protocol.

3.6. What is included in the organisation's carbon footprint?

The carbon footprint consists of the on-site direct emissions of an organisation versus indirect emissions outside the location of the organisation. Those indirect emissions can be caused by energy consumption both onsite and elsewhere. As a consequence, according to ISO standards, the carbon footprint is subdivided into three scopes.

Scope 1 (direct GHG emissions) consists of all the direct greenhouse gas emissions onsite or by the cars the organisation or company ownes. This involves its' own fuel consumption for heating, machinery and mobility, as well as possible leaks of cooling gases from cooling installations.

Scope 2 (electricity indirect GHG emissions) consists of the indirect greenhouse gas emissions as a result of the direct consumption of purchased electricity onsite. These indirect emissions are emissions at the electricity power plants.

Finally, Scope 3 (other indirect GHG emissions) contains all other indirect emissions, related to the production of purchased products (goods and services), the processing of waste, commuting, transport and business travel (excluding own company cars, which are included in scope 1). Based on data from many organisations that have conducted comprehensive assessments of their Scope 3 emissions, it is evident that Scope 3 GHG are by far the largest component of most organisations' carbon footprint.

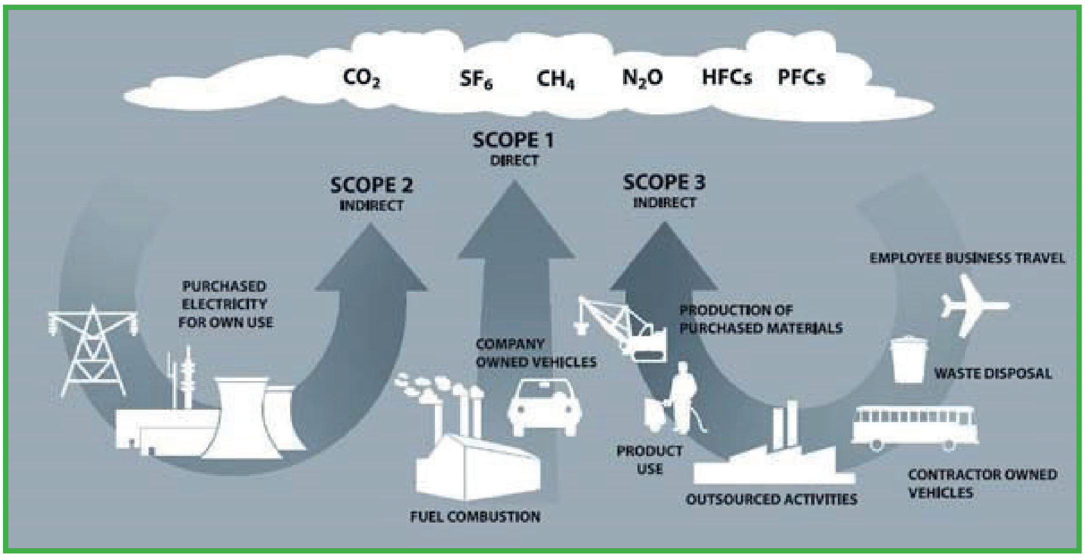

Figure 3: ISO scopes

4. METHODOLOGY

The assessment of an organisation's carbon footprint is conducted through the following methodological steps:

- Scope definition;
- Selection of impact categories;
- Data collection;
- Calculation and result analysis, and
- Establishing actions for reductions.

4.1. Scope definition

Together with the UAntwerp, taking into account the available data and the scope used in the VUB's and KULeuven's carbon footprint studies (Ecolife 2017, Futureproofed 2010), the carbon footprint of the UAntwerp has the following scope.

Sites:

- the five student campuses Drie Eiken, Groenenborger, Middelheim, Mutsaard and Stad[4],
- administrative, research and education buildings,
- student homes owned by UAntwerp (these were included because for energy use and waste generated, only the data for the whole campus were available, including both educational buildings and student homes),
- the student restaurants at the campuses.

Activities:

- activities related to administration and academic research: research equipment, waste generation, business travel, employee commuting,
- activities related to education: educational equipment (ICT), student mobility (including airplane travel for foreign students studying at the UAntwerp), energy use and general waste generated at the student homes on the campuses,
- food consumption (meals) at the student restaurants.

Not included in the carbon footprint are (due to lack of data):

- private student homes not owned by the UAntwerp;
- student courses paper use;
- food consumption at places other than the student restaurants at the campuses;
- equipment and furniture of the student homes owned by the UAntwerp (including the student homes on the campuses);
- transport of goods other than the transport of waste collection;
- mobility (airplane, car, train) from non-student visitors (e.g. guest lecturers);
- UAntwerp's spin-offs;
- water consumption (not included due to expected negligible share to the total footprint).

4 The total footprint calculation also includes the ICT equipment, vehicles, material use and waste of non-student sites (Hoboken, Fort).

4.2. Impact categories

According to the Bilan Carbone® methodology, the carbon footprint of the UAntwerp consists of 7 relevant impact categories.

1. Energy: emissions related to direct energy use (natural gas, electricity used on campuses);
2. Non-energy: leaks of halocarbons from cooling installations;
3. Inputs: emissions from the production of purchased materials and services, including meals at student restaurants, ICT equipment and services;
4. Direct waste: emissions from transport and treatment of waste collected at the UA;
5. End-of-life: emissions from transport and treatment of waste generated for UA related activities but not collected at UAntwerp (e.g. paper for student courses);
6. Transporting people: emissions from employee commuting, business travel and student mobility, including direct and indirect emissions from the production of fuels and vehicles;
7. Capital goods: embodied energy related emissions from the production, construction and renovation of infrastructure, equipment and vehicles owned by the UAntwerp.

4.3. Data collection

4.3.1. Approach

There are two types of data: emission factors or footprint intensities (e.g. kg CO_2e per unit consumption) and consumption and infrastructure data. The footprint intensities are data from the Base Carbone LCA (life cycle analysis) database that is used in the Bilan Carbone® V8 Excel file, except for recycled paper, laptops and electric cars and bikes.[5] The consumption and infrastructure data, presented in the table below, are data collected by the UAntwerp and processed by Ecolife.

4.3.2. Reference year and data quality

Consumption and infrastructure data of the UAntwerp for the year 2018 were collected by Marleen Clerinx, Anja De Borchgrave, Wim Willems, Johannes Teuchies, Peter Ceulemans and Carla Uwents. For data that depend on the academic year, such as the number of students, the academic year 2017-2018 was used.

The uncertainty values of the footprint intensities were taken from the Bilan Carbone® V8 file. Data uncertainty values were estimated using the following rules:

- 5% uncertainty on internal data from own direct measurements with local meters (e.g. kWh electricity) or accurately counted (e.g. number of meals);
- 15% uncertainty on internal data with conversion factor (e.g. kg paper based on number of sheets);
- 30% uncertainty on data extrapolated with assumptions (e.g. leaks of cooling gases, km travel based on own surveys);

5 For recycled paper, the value of EcoInvent 2.0 LCA-database is used.
The production footprint of laptops is based on the EuP preparatory study, TREN/D1/40-2005, Lot 3 Personal computers and monitors. Intermediate draft report Task 4 Technical analysis existing products And Task 5 Definition of base-case, of the IVF Industrial Research and Development Corporation.
Indirect emissions data for production and use of electric cars are based on: Ricardo AEA (2013), Current and Future Lifecycle Emissions of Key 'Low Carbon' Technologies and Alternatives.
Indirect emissions data for production and use of electric bikes are based on: Del Duce, A. (2011), Life Cycle Assessment of conventional and electric bicycles, EMPA Materials Science & Technology.

- 50% uncertainty on data with very uncertain extrapolations (e.g. student mobility based on modal split from other universities).

All the data for ISO Scope 1 and 2 have uncertainty levels below 20%, which is within the internationally accepted limit of data uncertainty according the Bilan Carbone® method.

4.3.3. Overview of input data

After the UAntwerp's collecting of all data, it was processed by Stijn Bruers (Ecolife) to become suitable for the Bilan Carbone® method, conform methodology described in the previous chapter. The following table contains all the relevant input data to be used in the Bilan Carbone® Excel sheets. Data for the five campuses were calculated: Campus Drie Eiken (CDE), Campus Groenenborger (CGB), Campus Middelheim (CMI), Campus Mutsaard (CMU) and Campus Stad (CST).

	Impact category	CDE	CGB	CMI	CMU	CST	Total	Unit	Uncer-tainty
	number of students	4 236	4 336	294	1 620	10 374	20 860		0%
	number of employees (FTE)	1 986	930	63	131	1 662	4 805		0%
Energy	natural gas (LHV)	12 314 955	6 358 514	1 920 218	1 800 652	9 164 394	31 558 733	kWh	5%
	oil fuel	0	0	0	0	1 271 472	1 271 472	kWh	5%
	purchased electricity, Belgian average	9 955 743	5 531 077	1 475 871	444 940	4 339 307	21 746 938	kWh	5%
Non-energy direct emissions of Kyoto halocarbons	leaks cooling installations during use, R22	0,001	2,169	0,483	0,000	0,000	2,653	kg	30%
	leaks cooling installations during use, R134a	0,004	2,820	0,000	0,000	0,000	2,824	kg	30%
	leaks cooling installations during use, R404a	0,500	0,060	0,180	0,000	0,000	0,740	kg	30%
	leaks cooling installations during use, R407c	0,007	8,850	3,480	0,000	0,000	12,337	kg	30%
	leaks cooling installations during use, R410a	0,090	13,902	8,313	0,000	0,000	22,305	kg	30%
	leaks cooling installations during use, R507	0,000	0,180	0,000	0,000	0,000	0,180	kg	30%
Capital goods	buildings (education establishment, concrete structure)	89 547	46 006	13 865	28 159	151 772	329 349	m^2 floor area	30%
	depreciation period buildings	40	40	40	40	40	40	years	
	parking areas (bitumen)	62 781	21 263	11 305	0	0	95 349	m^2 surface area	30%
	depreciation period parking areas	40	40	40	40	40	40	years	
	vehicles	12	12	11	0	2	134	tonnes	30%
	depreciation period vehicles	5	5	5	5	5	5	years	
	photocopiers	34	13	16	0	66	129	number	5%
	printers						557	number	5%
	depreciation period copiers & printers	10	10	10	10	10	10	years	
	laptops	808	118	264	43	2 412	3 756	number	5%
	desktops	1 241	259	770	193	2 565	5 162	number	5%
	LCD-screen (37")	30	11	135	0	28	205	number	5%
	depreciation period computers	5	5	5	5	5	5	years	
Inputs	common metals	0,6	0,6	0,5	0,0	0,0	1,7	tonnes	30%
	plastics	0,2	0,5	0,1	0,0	0,1	0,8	tonnes	30%
	paper and cardboard from recycled material	98,6	34,0	9,4	0,1	71,8	213,9	tonnes	30%
	glass	7,9	1,2	2,8	0,0	30,2	42,3	tonnes	30%
	medical products	18,2	0,0	0,0	0,0	0,0	18,2	tonnes	30%
	industrial, chemical and electronic products	36,0	18,9	6,6	0,3	0,0	62,2	tonnes	30%
	general items for residual waste	22,2	22,0	1,9	0,1	12,5	72,1	tonnes	30%
Direct waste	average household waste - incineration	22,2	22,0	1,9	0,1	12,5	72,1	tonnes	30%
	mineral wastes (metals, glass) - recycling	8,4	1,8	3,3	0,0	30,3	44,0	tonnes	30%
	plastic waste - recycling	0,2	0,5	0,1	0,0	0,1	0,8	tonnes	30%
	paper - recycling	98,6	34,0	9,4	0,1	71,8	213,9	tonnes	30%
	SIW (Special Industrial Waste)	36,0	18,9	6,6	0,3	0,0	62,2	tonnes	30%
	DMW (Dangerous Medical Waste)	18,2	0,0	0,0	0,0	0,0	18,2	tonnes	30%

End of life	leaks cooling installations, R22	0,003	10,845	2,415	0,000	0,000	13,263	kg	30%
	leaks cooling installations, R134a	0,020	14,100	0,000	0,000	0,000	14,120	kg	30%
	leaks cooling installations, R404a	2,500	0,300	0,900	0,000	0,000	3,700	kg	30%
	leaks cooling installations, R407c	0,037	44,250	17,400	0,000	0,000	61,687	kg	30%
	leaks cooling installations, R410a	0,448	69,510	41,565	0,000	0,000	111,523	kg	30%
	leaks cooling installations, R507	0,000	0,900	0,000	0,000	0,000	0,900	kg	30%
	Impact category	**CDE**	**CGB**	**CMI**	**CMU**	**CST**	**Total**	**Unit**	**Uncer-tainty**
Transporting people - employee commuting	average passenger car - combustion engine	9 299 369	2 499 353	213 451	253 656	3 213 559	15 479 389	vehicle.km	30%
	average passenger car - electric	130 175	78 105	1 687	2 475	31 352	243 794	passenger.km	30%
	bus, subway, tram (urban networks)	486 618	316 471	30 315	65 223	826 304	1 724 929	passenger.km	30%
	train	3 167 485	2 342 596	147 332	867 666	10 992 416	17 517 495	passenger.km	30%
	electric bike	260 774	142 372	10 179	11 700	148 228	573 253	passenger.km	30%
	motorbike	210 170	86 103	4 709	4 978	63 065	369 025	passenger.km	30%
Transporting people - business travel	car (gasoline)						10 785	liter	15%
	car (diesel)						19 135	liter	15%
	bus, subway, tram (urban networks)						13 100	passenger.km	30%
	train in Belgium						135 500	passenger.km	30%
	train in Germany						400	passenger.km	30%
	train in Netherlands						3 480	passenger.km	30%
	train in United-Kingdom						4 240	passenger.km	30%
	train in France, TGV						2 040	passenger.km	30%
	plane, 100-180 seats, 0-1000 km						621 696	passenger.km	30%
	plane, 180-250 seats, 1000-2000 km						595 123	passenger.km	30%
	plane, 180-250 seats, 2000-3000 km						521 462	passenger.km	30%
	plane, 180-250 seats, 3000-4000 km						432 474	passenger.km	30%
	plane, 180-250 seats, 4000-5000 km						446 586	passenger.km	30%
	plane, > 250 seats, 5000-6000 km						719 160	passenger.km	30%
	plane, > 250 seats, 6000-7000 km						2 069 836	passenger.km	30%
	plane, > 250 seats, 7000-8000 km						1 136 500	passenger.km	30%
	plane, > 250 seats, 8000-9000 km						823 363	passenger.km	30%
	plane, > 250 seats, 9000-10000 km						1 254 634	passenger.km	30%
	plane, > 250 seats, 10000-11000 km						1 219 109	passenger.km	30%
	plane, > 250 seats, > 11000 km						1 392 495	passenger.km	30%
Transporting people - students' travels	average passenger car						16 206 051	vehicle.km	50%
	bus, subway, tram (urban networks)						12 240 882	passenger.km	50%
	train in Belgium						48 530 154	passenger.km	50%
	train abroad (Netherlands)						10 503 000	passenger.km	50%
	plane, short-haul						949	no of flights	50%
	plane, long-haul						803	no of flights	50%
Agricultural prod-ucts (food)	typical meal (with beef)	6 344	717	3 780	145	5 804	16 789	no of meals	15%
	typical meal (with porc)	19 031	2 151	11 340	434	17 411	50 366	no of meals	15%
	typical meal (with chicken)	19 031	2 151	11 340	434	17 411	50 366	no of meals	15%
	seafood meal (with fish)	6 344	717	3 780	145	5 804	16 789	no of meals	15%
	vegetarian meal (with cheese)	12 688	1 434	7 560	289	11 607	33 578	no of meals	15%
	vegan meal							no of meals	15%

Table 1: Consumption and infrastructure data

In general, the collected data were considered to be sufficiently accurate, with mostly uncertainties below or equal to 20%. Data with higher uncertainties, in particular student travel, are due to rough extrapolations from other universities (VUB and KULeuven). In future footprint calculations, these data need to become more accurate using student mobility surveys.

4.4. Calculation method

Each impact category has several consumption activities. For example, the impact category 'energy' consists of the consumption of fuels (e.g. natural gas) and electricity (e.g. from biomass). The impact category 'business travel' consists of travel by car, train, bus and airplane.

The footprint of a consumption activity is always the product of the consumption amount (e.g. kWh, kg, km or euro) and the footprint intensity (kg CO_2e per kWh, kg, km or euro).

4.4.1. Energy

Energy: natural gas

Description	The direct energy emissions from natural gas (ISO scope 1) result from the use of natural gas (kWh) for heating and appliances.
Scope	All buildings at the 5 campuses, including student homes and student restaurants.
Assumptions	For campus Mutsaard, year 2017 is used and 50% of total energy use is accounted to UAntwerp.
Calculation equations	• Footprint = footprint intensity gas (kg CO_2/kWh primary energy) x kWh primary energy (thermal energy of natural gas).

Energy: electricity

Description	The direct energy emissions from electricity (ISO scope 2) consist of the emissions at the power plants and result from the use of electricity (kWh).
Scope	All buildings at the 5 campuses, including student homes and student restaurants.
Assumptions	For campus Mutsaard, year 2017 was used and 50% of total energy use is accounted to UAntwerp. All electricity is bought from NV Vlaams EnergieBedrijf (VEB), which buys guarantees of origin of renewable sources, such as Norwegian hydropower, to sell its energy as green electricity. However, at the moment of publication of this report, it is not clear whether the method of buying guarantees of origin gives sufficient incentives to produce more green electricity. VEB is also not included in the Greenpeace ranking (www. mijngroenestroom.be). Therefore, for the moment the electricity footprint of VEB is calculated according to the energy mix of its supply, which is 0,35 kg CO_2e/kWh.
Calculation equations	• Footprint = footprint purchased electricity – footprint produced and sold electricity. • Footprint purchased electricity = footprint intensity VEB electricity (kg CO_2/kWh) x kWh purchased electricity. • Footprint produced electricity = 0 for UAntwerp in 2018.

4.4.2. Non-energy

Description	The direct, non-energy emissions (ISO scope 1) consist of leaks of greenhouse gases (Kyoto halocarbons) of cooling installations during operation.
Scope	• List of 170 cooling installations for air conditioning. • Campuses Drie Eiken, Groenenborger and Middelheim (no data were available for the cooling installations of Komida at campus Stad).
Assumptions	The cooling installations use six Kyoto halocarbon cooling gases: R22, R134a, R404a, R407c, R410a and R507.
Calculation equations	• Footprint (per type of cooling gas) = cooling power (kW) x expected emissions during operation per cooling power (kg cooling gas/kW) x footprint intensity of cooling gas (kg CO_2-equivalents/kg cooling gas). • Expected emissions during operation per cooling power (according to the Bilan Carbone® module) = 0,3 kg cooling gas per kW cooling power x 10% annual leakage.

4.4.3. Inputs

Inputs: materials and products

Description	The indirect emissions (ISO scope 3) for inputs are emissions from the production of all materials that end up in the direct waste.
Scope	Volume of metals, plastics, glass, paper/cardboard, medical/chemical products and industrial/electronic products are based on waste data (kg) for the five campuses.
Assumptions	All materials are assumed new, except paper and cardboard, which are assumed to be from recycled material. PMD-waste density is 10 kg/m^3 and contains 1/3 recyclable metals, 5/9 recyclable plastics and 1/9 cardboard. General items for residual waste are assumed to contain ½ plastics and ½ biological sources (paper, cardboard, textiles, wood). Total inputs for campuses Groenenborger and Middelheim are allocated to those campuses separately according to number of employees. Chemical products are assumed to have the same average footprint intensity as products for hazardous medical waste. Electronic products are assumed to have the same footprint intensities as products for industrial waste. See impact category 'direct waste' for further details.
Calculation equations	Footprint of production = amount of materials (kg) x footprint intensity for the production of the recycled or new material (kg CO_2/kg material).

Inputs: meals

Description	The indirect emissions (ISO scope 3) for meals are emissions from the production of agricultural products (food) consumed at the student restaurants.
Scope	Student restaurants at campuses Drie Eiken (cafetaria and Komida), Groenenborger, Middelheim and Stad.
Assumptions	There are six types of meal: with beef, pork, chicken, fish, vegetarian with cheese and vegan. Only the total number of meals was given, and an estimate for the percentage of vegetarian meals. The number of meals is divided in 10% beef, 30% pork, 30% chicken, 10% fish, 20% vegetarian and 0% vegan.
Calculation equations	Footprint (per type of meal) = number of meals x footprint intensity of meal (kg CO_2e/meal).

4.4.4. Direct waste

Description	The indirect emissions (ISO scope 3) for direct waste are emissions from the waste treatment of the collected waste at the UAntwerp.
Scope	The volumes of waste (metals, glass, plastics, paper/cardboard, medical products, industrial products and average household waste) are based on discharged waste data (kg) at the five campuses. Paper/cardboard, PMD (plastic bottles, metal packaging and drinking cartons), glass and residual waste includes waste containers collected by city services.
Assumptions	• Average household waste goes to incineration and contains industrial waste class 2, household waste and residual waste collected by city services. Residual waste density is 70 kg/m^3. • PMD waste contains 1/3 metals, 1/9 cardboard and 5/9 plastics, all recyclable, at a density of 10 kg/m^3. • Mineral wastes go to recycling and contain metals (including metals from PMD-waste) and glass. • Plastic waste goes to recycling and contains plastics from PMD-waste. • Paper/cardboard waste goes to recycling and is the maximum value of two data: the waste collected by Renewi in 2017 (from 'Integraal Milieujaarverslag 2017', for campuses Drie Eiken, Groenenborger and Middelheim) and estimated data from collected paper, including confidential paper (for the five campuses) and cardboard in PMD. • Special industrial waste includes industrial waste, chemical waste and electronic waste. 50% is stabilisation and storage, 50% is incineration. • Dangerous medical waste is incinerated.
Calculation equations	• Footprint of waste treatment = amount of materials (kg) x footprint intensity for the waste treatment of the material (kg CO_2/kg material). • Negative footprint of avoided emissions from recycling = avoided production of new materials (kg) x footprint intensities of production (kg CO_2/kg material for production of new material). • Amount of metals = metal waste + 1/3 PMD-waste. • Amount of plastics = 5/9 PMD-waste. • Amount of paper = paper waste + 1/9 PMD-waste.

4.4.5. End-of-life

End-of-life: cooling gases

Description	The indirect emissions (ISO scope 3) for end-of-life of cooling gases are the leaks of Kyoto halocarbon greenhouse gases of cooling installations during end-of-life treatment.
Scope	• List of 170 cooling installations for air conditioning. • Campuses Drie Eiken, Groenenborger and Middelheim.
Assumptions	There are six Kyoto halocarbon cooling gases: R22, R134a, R404a, R407c, R410a en R507.
Calculation equations	• Footprint (per type of cooling gas) = cooling power (kW) x expected emissions during waste treatment per cooling power (kg cooling gas/kW) x footprint intensity of cooling gas (kg CO_2-equivalents/kg cooling gas). • Expected emissions during waste treatment (according to Bilan Carbone® module) = 0,3 kg cooling gas per kW cooling power x 50% leakage.

4.4.6. Transporting people

Transporting people: employee commuting

Description	The emissions (ISO scope 3) for employee commuting are direct emissions of vehicles and indirect emissions of fuel production, vehicles and transport infrastructure.
Scope	Vehicle kilometres with (electric) cars, motorbikes and electric bikes, passenger kilometres with bus/tram/subway and train.
Assumptions	A full-time employee is assumed to travel 2x205 times a year the home-campus distance. This home-campus distance is calculated based on the postal codes of employees and average distances between municipalities. The shares of transport modes (percentage of kilometres travelled by bike, car, train and bus) for six home-campus distance categories (0-5 km, 5-10 km, 10-20 km, 20-40 km, 40-80 km, 80-160 km) for UAntwerp are assumed to be the same as at the VUB.

Calculation equations	• Using detailed VUB employee commuting data, the percentages of total distances travelled by transport mode for six distance categories are calculated. For example, 16% of the total distance travelled for main trajectories (i.e. with the main means of transport) between 5 and 10 km is by bike. For all distances (between 0 and 160 km), 9% of the total distance is by bike. This means the use of a bike for the main trajectories between 5 and 10 km have relative percentages 16%/9%. • A UAntwerp employee mobility survey contains for each campus the transport modes for the main trajectory as well as the pre and post trajectories. With these data, the numbers of employees using car, electric car, car with carpooling, train, bus, tram, subway, bike, electric bike and motorbike for the main trajectory are calculated. These numbers are multiplied by the relative percentages of transport modes according to home-campus travel distance (based on the VUB-data). With these weighted numbers of employees (weighted by percentages of transport modes), the percentages of employees per transport mode per campus and per distance category are calculated. For example 66% of employees of campus Drie Eiken who travel between 5 and 10 km from home to work, travel by bike (including electric and motorbike), 17% travel by public transport and 17% by car. • The total distance travelled per ride per transport mode for an employee = distance per working day (based on the postal code of home address and campus site) x percentage of employees per transport mode for the corresponding distance category. • For carpooling, the distance travelled by an employee is divided by 2. • The total distance travelled per year per transport mode for an employee = total distance travelled per ride per transport mode x 2 rides per day x 205 working days per year x percentage employment rate. • The total distance travelled for all employees per campus site and transport mode is the sum of the distances travelled over all employees, using the list of all active employees. • Footprint = distance travelled by transport mode (km) x footprint intensity of transport mode (kg CO_2/km).

Transporting people: employee business travel

Description	The emissions (ISO scope 3) for employee business travel are direct emissions of the vehicles and indirect emissions of fuel production, vehicles and transport infrastructure.
Scope	Domestic and international travel with cars, busses, trains and airplanes.

Assumptions	• The footprint of business travel is calculated for the whole UAntwerp (not for the campuses separately). • For company cars, fuel data (litres of gasoline and diesel) from Texaco for 36 company cars are used. • For bus transport, the number of employee bus tickets (for campus Drie Eiken and Stad) are used (10 rides for one 'Lijnkaart', average distance of 10 km per ride). • Train in Belgium only includes travel to airport. The number of (one way) flights is multiplied by 50 km one way travel to the national airport by train. • Train in other countries include business travel to Germany, the Netherland, France and the UK. Railway distance is estimated based on the city of destination. • For flights, distances are calculated using co-ordinates of airports of cities of destination.
Calculation equations	• Footprint cars = fuel use (litre) / footprint intensity of fuel (kg CO_2/litre). • Footprint per transport mode (other than cars) = distance travelled (km) x footprint intensity of transport mode (kg CO_2/km).

Transporting people: student mobility

Description	The emissions (ISO scope 3) for student mobility are the direct emissions of the vehicles and the indirect emissions of the production of fuels, vehicles and transport infrastructure.
Scope	• The footprint of student mobility is calculated for the whole UAntwerp (not for the campuses separately). • Student mobility includes both commuter students who travel from home to the campus (and back) all days they have classes or exams, and residential students who travel from home to their student rooms (and back) once a week. Hence, the trajectories include: home-campus, home-student room and student room-campus. • For Belgian students studying at the UAntwerp, data include vehicle kilometres with cars and passenger kilometres with bus, train and tram/subway, as well as number of short-haul flights (for EU-students) and long-haul flights (for non-EU students) • For international students visiting the UAntwerp data includes only distances travelled by international train (the Netherlands for Dutch students) and airplane. The flights include the Antwerp Summer University (ASU) 2018 participants as well as foreign students who study at the UAntwerp during the year.

Assumptions	• The footprint of Belgian student mobility is based on extrapolations from VUB and KULeuven data.[6] Both VUB and KUL have a similar modal split[7], independent from average home-campus distance of students: 2/3 of total distance travelled by motorized vehicles, is by train, 1/5 is by car and the rest by bus, tram, subway or motorbike. We assume the UAntwerp has a similar modal split as the VUB and KUL. • ASU2018 participants and foreign students other than Dutch students are assumed to travel by plane. The airplane footprint is based on the number of short-haul flights (from an EU-country, average distance 1000 km) and long-haul flights (non-EU country, average distance 6000 km), using the ASU2018 participants list and a student mobility survey for an estimate of the number of foreign students. • Students from the Netherlands are assumed to travel to Antwerp 40 times per year, for an average distance of 2 x 100 km. ASU2018 participants from the Netherlands are assumed to travel by train for an average distance of 2 x 100 km.
Calculation equations	• Average distance travelled per student by transport mode = average distance travelled per VUB student by transport mode x average home-campus distance of UAntwerp student (based on postal codes of student home address) / average home-campus distance of VUB student. • Total distance travelled by campus = total distance travelled by student x number of students by campus. • Footprint by transport mode = distance travelled (km) x footprint intensity of transport mode (kg CO_2/km).

4.4.7. Capital goods

Capital goods: buildings

Description	The indirect emissions (ISO scope 3) for buildings are the emissions from the construction and renovation of buildings.
Scope	All buildings at the campus sites are included.
Assumptions	The buildings are assumed to be made of concrete. The depreciation period is 40 years.
Calculation equations	Footprint of buildings = surface area (m^2) x footprint intensity of average office or education building in concrete (kg CO_2/m^2) / depreciation period.

6 The UA conducted a small student mobility survey in the spring of 2019, but as discussed in the appendix 1, this survey was not yet accurate enough to be used in the carbon footprint calculation.

7 See reports 'The Carbon Footprint of the VUB 2016' (Ecolife 2017) and 'Nulmeting CO_2 emissies KU Leuven in het jaar 2010' (Futureproofed, 2013).

Capital goods: roads and car parks

Description	The indirect emissions (ISO scope 3) for parking area are emissions from the construction and renovation of the area.
Scope	Total paved area (excluding buildings).
Assumptions	The roads and parking area are assumed to be made of bitumen. The depreciation period is 40 years.
Calculation equations	Footprint of parking area = surface area (m^2) x footprint intensity of TC2 ('normal' parking area) bitumen (kg CO_2/m^2) / depreciation period.

Capital goods: vehicles

Description	The indirect emissions (ISO scope 3) for vehicles are emissions from the production of cars.
Scope	All service vehicles (company cars, vans, small trucks, trailers).
Assumptions	The depreciation period of cars is 5 years. A car weights on average 1,5 tonnes, a truck (van, trailer) 5 tonnes.
Calculation equations	Footprint of vehicles = number of vehicles x average weight of vehicle (ton/car) x footprint intensity of average car (kg CO_2/ton) / depreciation period.

Capital goods: IT

Description	The indirect emissions (ISO scope 3) for IT are emissions from the production of IT equipment.
Scope	Photocopiers, printers, laptops, desktops and LCD-screens.
Assumptions	The depreciation period of computers and screens is 5 years, for photocopiers and printers 10 years.
Calculation equations	Footprint of IT equipment = number of items x footprint intensity (kg CO_2/item) / depreciation period.

5. RESULTS

This chapter contains the results of the carbon footprint calculation of the UAntwerp for data year 2018. Firstly, the total carbon footprint will be compared with other references, such as emissions related to car travel or CO_2 absorbed by trees. Next, the footprint results per impact category are discussed. The total footprint can also be expressed per person (per employee or student), to be used as a benchmark for comparisons with other universities or future recalculations of the UAntwerp footprint.

5.1. Total carbon footprint

The carbon footprint of the UAntwerp is **41.882 ton CO_2e**. As a comparison, this is the equivalent of driving 160 million kilometres by car. It also corresponds with the total yearly carbon footprint of almost 2100 average people in Belgium (0,018% of the total Belgian carbon footprint). It requires 1,7 million trees to absorb this amount of CO_2 within one year.

Overview	Total		Uncertainties	
	t CO_2eq	Share	t CO_2eq	%
Energy	16 134	39%	888	6%
Non-energy	75	0%	20	27%
Inputs	823	2%	287	35%
Transporting people	18 457	44%	2 665	14%
Direct waste	96	0%	26	27%
Capital goods	5 923	14%	2 189	37%
End of life	373	1%	101	27%
Total	41 882	100%	3 574	9%

Table 2: Total carbon footprint results

The total uncertainty (i.e. the combination of uncertainties of the Bilan Carbone® emission factors and the UAntwerp consumption and infrastructure data) on the total carbon footprint is 9%.

The three major contributors to the carbon footprint of the UAntwerp are:

- Energy use (natural gas and electricity use on the campuses): **16.134 ton CO_2e** (39%)
- Transporting people (car, public transport and airplane for employee commuting, business travel and student travel including foreign students): **18.457 ton CO_2e** (44%)
- Capital goods (embedded energy for construction of infrastructure and equipment): **5.923 ton CO_2e** (14%)

Almost half of the carbon footprint relates to transporting people and two fifth is related to direct energy use. Therefore, the simulations and recommendations in the next chapters will mostly deal with those two impact categories. The next section describes the carbon footprint for all the impact categories in more detail.

5.2. Carbon footprint per impact category

Figure 4 presents the contributions of the six impact categories to the total carbon footprint. The categories' inputs (materials and services, including food at the student restaurants), direct waste, end-of-life (including paper from student courses) and non-energy related emissions (cooling gases) all have relatively small contributions, less than a few percent.

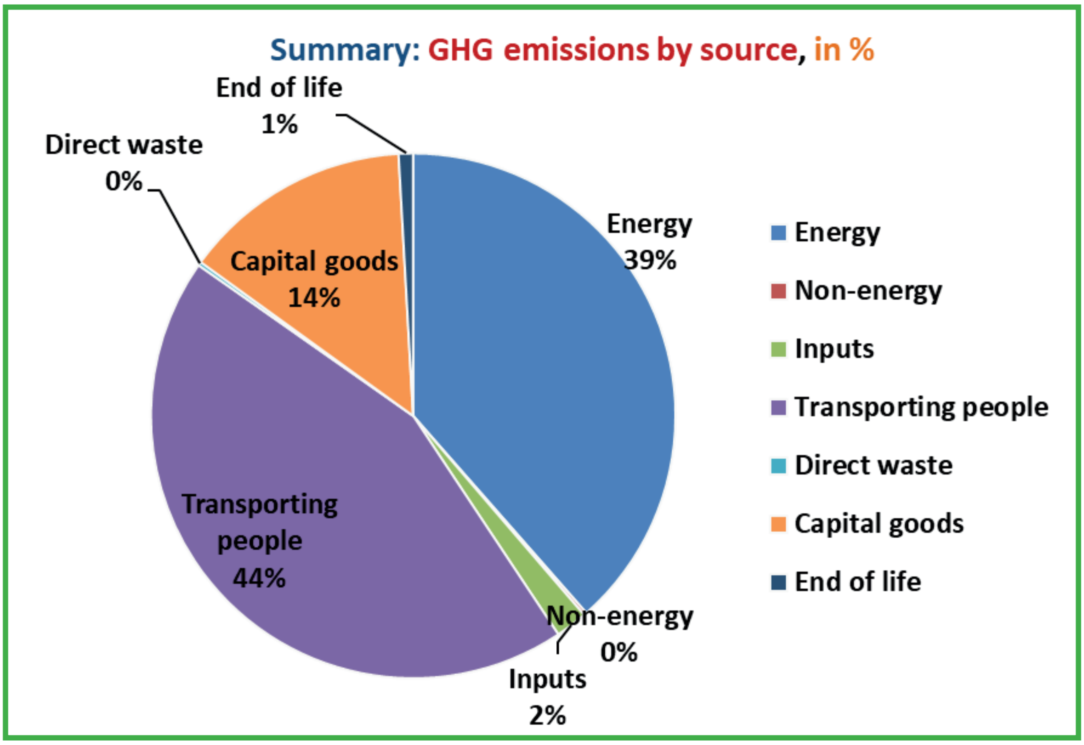

Figure 4: Contributions of impact categories to the total carbon footprint

The footprint values including the total uncertainties are given in Figure 5. These uncertainties are the combination of the uncertainties of the Bilan Carbone® emission factors (footprint intensities) and the UAntwerp consumption and infrastructure data.

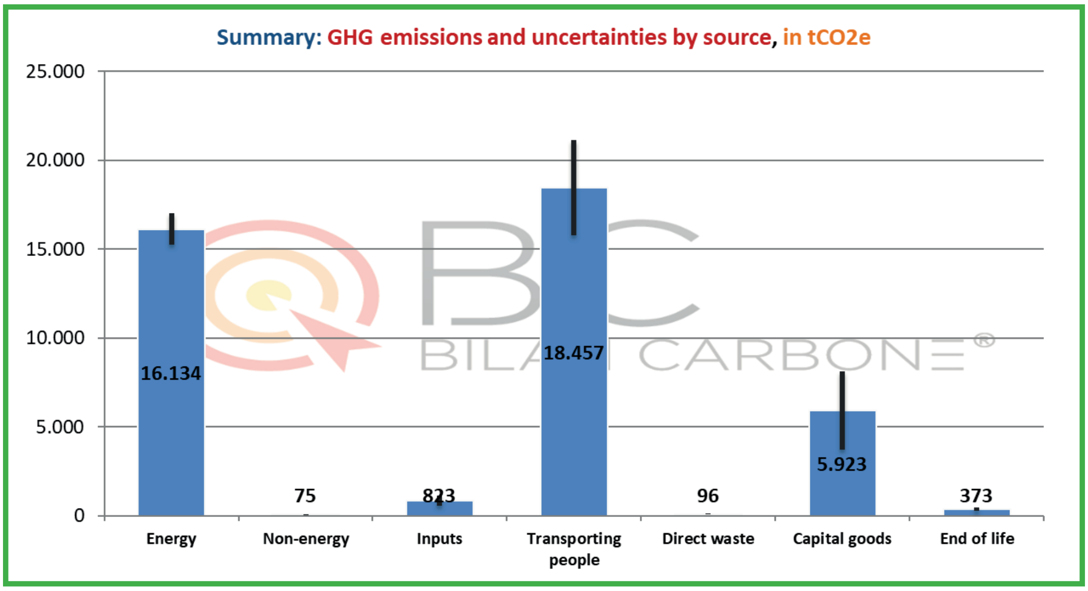

Figure 5: Carbon footprint per impact category

The footprint values and uncertainty values for all impact categories and subcategories and for the five campuses are summarised in Table 3.

	CDE	CGB	CMI	CMU	CST	Total		Uncertainties	
	kg CO_2eq	kg CO_2eq	kg CO_2eq	kg CO_2eq	kg CO_2eq	kg CO_2eq	Share	kg CO_2eq	%
Energy	**6 677 530**	**3 591 944**	**1 012 974**	**603 373**	**4 248 463**	**16 134 282**	**39%**	**887 813**	**6%**
Fuels, direct accounting	3 003 618	1 550 841	468 341	439 179	2 647 153	8 109 132	19%	329 704	4%
Electricity purchased and produced	3 673 912	2 041 102	544 632	164 194	1 601 310	8 025 150	19%	824 322	10%
Non-energy	**2 161**	**49 337**	**23 129**	**0**	**0**	**74 626**	**0,2%**	**20 242**	**27%**
Kyoto halocarbon	2 161	49 337	23 129	0	0	74 626	0,2%	20 242	27%
Inputs	**371 275**	**143 160**	**91 539**	**3 443**	**179 519**	**823 380**	**2%**	**287 318**	**35%**
Metals	2 031	2 144	1 828	11	162	6 176	0,01%	5 277	85%
Plastics	554	1 100	161	10	185	2 010	0,00%	725	36%
Glass	6 419	952	2 265	18	24 572	34 405	0,1%	12 405	36%
Papers, cardboard	46 326	15 993	4 414	50	33 755	100 537	0,2%	36 249	36%
Food	97 695	11 042	58 210	2 225	89 375	258 548	0,6%	65 934	26%
Other inputs	218 251	111 929	24 661	1 129	31 471	421 705	1,0%	276 962	66%
Transporting people	**2 644 605**	**821 367**	**67 139**	**117 716**	**1 491 334**	**18 457 284**	**44%**	**2 664 772**	**14%**
Commuting	2 644 605	821 367	67 139	117 716	1 491 334	5 142 161	12%	1 065 157	21%
Employees, car	0	0	0	0	0	78 556	0,2%	2 558	3%
Employees, other road	0	0	0	0	0	2 017	0,00%	997	49%
Employees, train	0	0	0	0	0	7 141	0,02%	2 369	33%
Employees, aircraft	0	0	0	0	0	2 544 108	6%	302 922	12%
Students, car	0	0	0	0	0	4 116 337	10%	1 492 356	36%
Students, other roead	0	0	0	0	0	1 885 096	5%	1 212 706	64%
Students, train	0	0	0	0	0	3 150 238	8%	1 336 492	42%
Students, aircraft	0	0	0	0	0	1 531 630	4%	625 044	41%
Direct waste	**54 248**	**22 626**	**5 815**	**253**	**8 091**	**96 085**	**0,2%**	**25 680**	**27%**
Mineral waste	279	58	108	1	999	1 452	0,003%	601	41%
Organic waste	3 462	1 195	330	4	2 522	7 513	0,02%	2 934	39%
Plastic waste	8	17	2	0	3	30	0,0%	13	41%
Household waste	8 047	7 980	689	28	4 541	26 115	0,1%	13 755	53%
Dangerous waste	42 452	13 376	4 686	220	25	60 974	0,1%	21 477	35%
Capital goods	**2 067 837**	**856 965**	**439 494**	**336 792**	**2 087 818**	**5 923 271**	**14%**	**2 189 177**	**37%**
Buildings	985 022	506 061	152 513	309 753	1 669 488	3 622 837	9%	2 112 459	58%
Infrastructure, excl. buildings	874 225	296 087	157 418	0	0	1 327 731	3%	445 334	34%
Vehicle, machines	13 200	13 200	11 550	0	1 650	147 400	0,4%	85 948	58%
IT	195 389	41 616	118 013	27 039	416 680	825 303	2%	352 568	43%
End of life	**10 804**	**246 684**	**115 644**	**0**	**0**	**373 132**	**0,9%**	**101 209**	**27%**
Leaks halocarbons	10 804	246 684	115 644	0	0	373 132	0,9%	101 209	27%

Table 3: Carbon footprint per impact category

5.2.1. Energy

Most part of the direct energy use's footprint relates to the burning of natural gas onsite. Electricity has a slightly smaller contribution. However, if the electricity from VEB is considered green electricity (due to the purchase of guarantees of origin from hydropower and other renewable sources), the carbon footprint of electricity would be 97% lower.

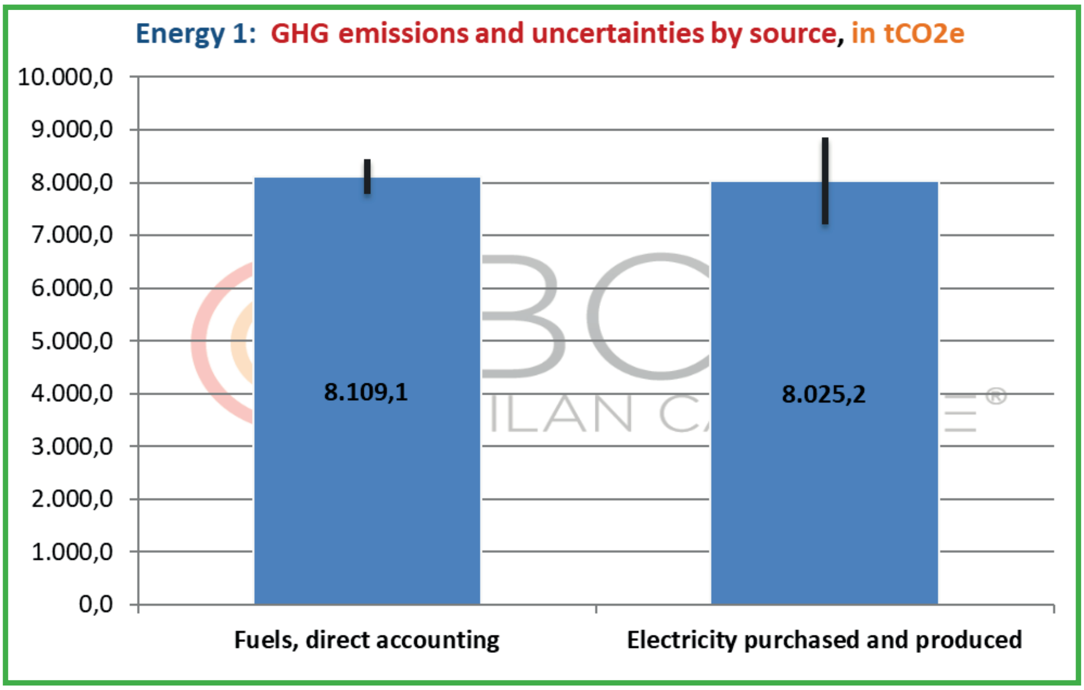

Figure 6: Carbon footprint of energy use

5.2.2. Non-energy

The non-energy related emissions of halocarbon from cooling installations is the smallest impact category which contributes 0.2% to the total footprint.

5.2.3. Inputs

The footprint of inputs corresponds with the indirect emissions (ISO Scope 3) for the production of materials. With its' 2% it has a small contribution to the total footprint. Most of the footprint of inputs (1%) comes from the purchase of electronic, ICT and office equipment.

The footprint of agricultural products consists of the meals consumed at the student restaurants. It has a share of 0.6% of the total footprint. Note that if all the meals of the students (including meals consumed at other local restaurants or the student homes) would be included, the agricultural footprint would be roughly 10 times higher. For example, the footprint calculation of the KUL (Futureproofed, 2013) includes all student meals consumed in Leuven, which has a share of 9% of the total carbon footprint of the KUL.

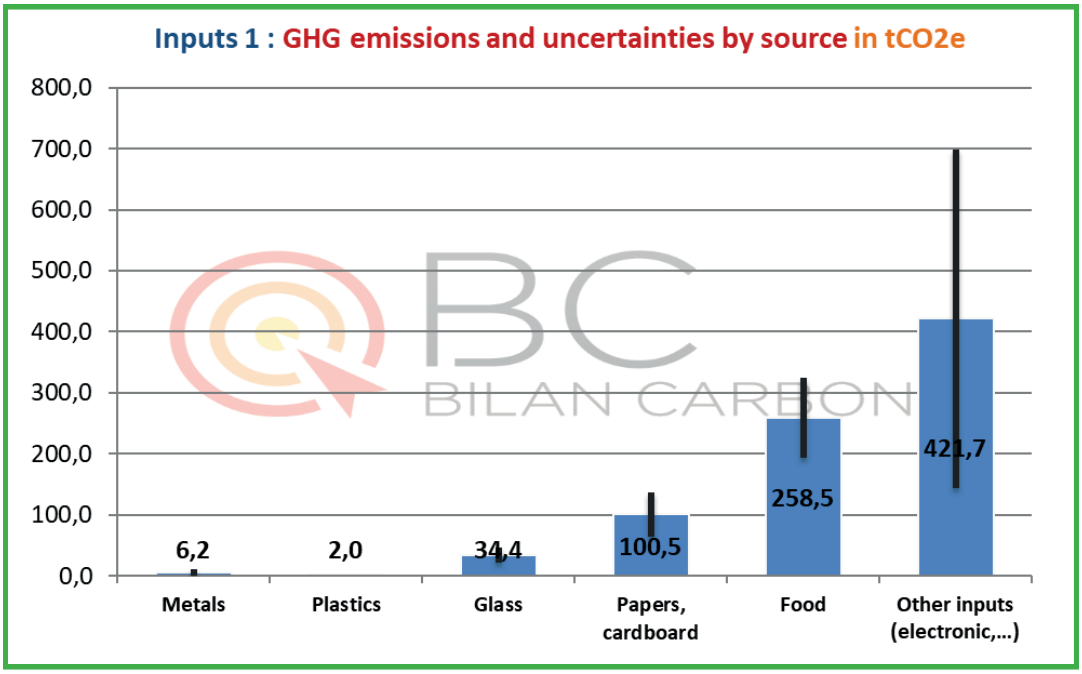

Figure 7: Carbon footprint of inputs

5.2.4. Direct waste

Most of the direct waste footprint relates to the incineration of household and dangerous (medical, chemical) waste, which in weight accounts for roughly half of the total waste collected on campuses.

5.2.5. End-of-Life

The end-of-life footprint consists the leakages of halocarbons from dismissed cooling installations. The dismissed cooling installations contribute 0.9% to the total footprint of the UAntwerp. Even if the amount of emitted cooling gases is low, these cooling gases have a high global warming potential. That explains why the footprint of these leaks are not negligible.

5.2.6. Transporting people

Because mobility (transporting people) accounts for 44% of the total footprint, it is worthwhile to study this impact category more in detail. Figure 8 shows the footprint values (and uncertainty ranges) for the different mobility subcategories.

58% of the mobility footprint is related to student mobility. This relatively high share of student commuting combined with its high uncertainty levels (around 50%) means that more accurate data (distances and number of travels per year) should be considered for future recalculations of UAntwerp's footprint.

Student travel by car has the biggest share of student commuting, closely followed by public transport. The average emission factor (footprint values in terms of emissions per km travelled) of public transport is less than one quarter of the emission factor for average cars. But public transport accounts for roughly 80% of the total distance travelled for daily student travel. This explains the fact that for student mobility the footprint of public transport is almost as high as for cars.

Airplane travel by foreign students accounts for 1500 ton CO_2e, which is 4% of the total footprint.

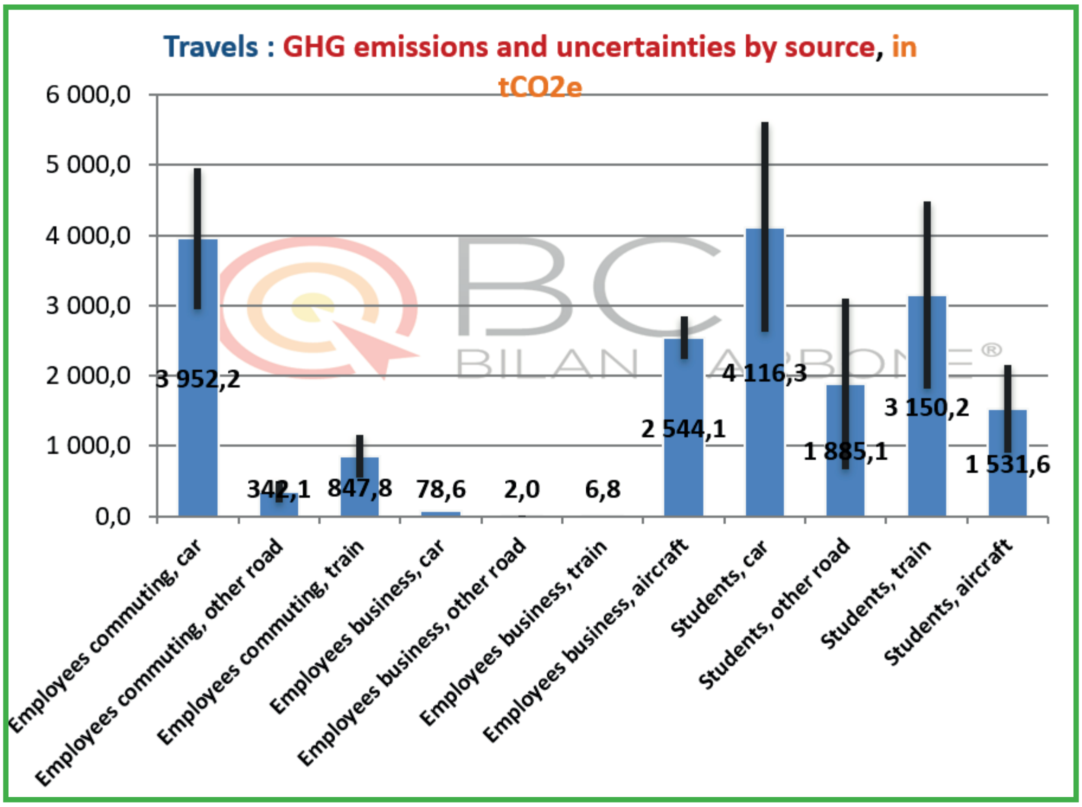

Figure 8: Carbon footprint of mobility

5.2.7. Capital goods

The final impact category is capital goods, which accounts for 14% of the total footprint. 12% of the total footprint comes from the infrastructure's embedded energy (i.e. emissions related to construction and renovation of buildings and paved surfaces) and 2% from IT (production of equipment). The production of cars owned by the UAntwerp accounts for 0.4% of the total footprint.

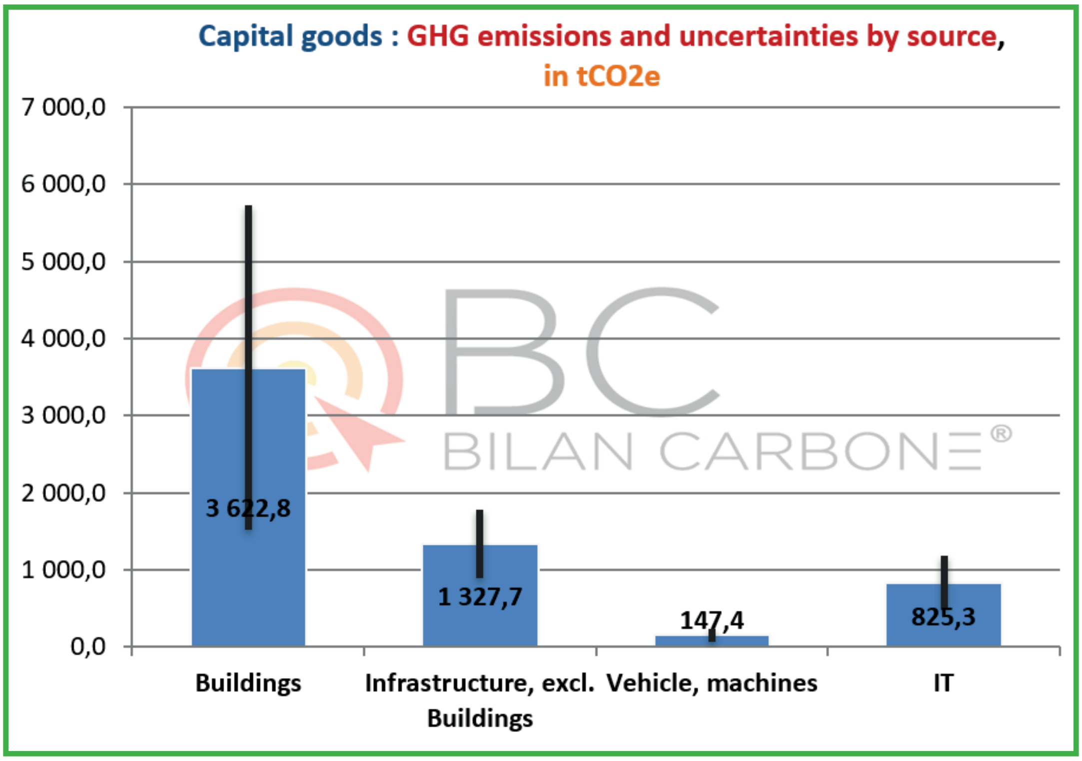

Figure 9: Carbon footprint of capital goods

5.3. Carbon footprint per employee and per student

The UAntwerp's total footprint can be divided by the number of people (employees and students) to obtain an interesting metric for benchmarking with other universities and future recalculations of the UAntwerp footprint. The table below presents the footprints per employee and per student. An average student had a footprint of 2 ton CO_2e for all UAntwerp-related activities in 2018.

Summary	Emissions, t CO_2e	t CO_2e per employee	t CO_2e per student
Energy	16 134	3,36	0,77
Non-energy	75	0,02	0,00
Inputs	823	0,17	0,04
Transporting people	18 457	3,84	0,88
Direct waste	96	0,02	0,00
Capital goods	5 923	1,23	0,28
End of life	373	0,08	0,02
Total	**41 882**	**8,72**	**2,01**

Table 4: Total emissions per employee and student

5.4. Comparison between campuses

Table 5 allows us to compare different campuses and set priorities for those campuses. The table shows the shares students, employees and people (students plus employees) for the different campuses. These shares can be used as a benchmark. The table shows the shares of footprints for fossil fuel use, electricity, employee commuting and inputs, as well as the total footprint (excluding student mobility and business travel, because these were not allocated to campuses).

Shares	CDE	CGB	CMI	CMU	CST	Total
Number of students	20%	21%	1%	8%	50%	100%
Number of FTE employees	41%	19%	1%	3%	35%	100%
Number of people	24%	21%	1%	7%	47%	100%
Fossil fuel use	38%	19%	6%	5%	32%	100%
Electricity	46%	25%	7%	2%	20%	100%
Footprint employee commuting	51%	16%	1%	2%	29%	100%
Footprint inputs and waste	46%	18%	11%	0%	20%	100%
Total footprint (excl. student mobility and business travel)	42%	20%	6%	4%	28%	100%

Table 5: Shares of footprints of campuses

Note: the total footprint shares of campus Drie Eiken (42%) and Middelheim (6%) are larger than their shares of people (resp. 24% and 1%), and the reverse is true for campus Stad (28% share of footprint compared to 47% share of people). This means that Drie Eiken and Middelheim have relatively large footprints. This is due to their relatively high levels of fossil fuel use, electricity, employee commuting and inputs/waste.

Note also that campus Drie Eiken is the second to largest campus, according to the number of people, and that energy use and mobility are the two major footprint impact categories. This means that focussing on reducing energy use and employee commuting at campus Drie Eiken should get priority.

6. COMPARISON WITH OTHER UNIVERSITIES AND COLLEGES

Footprint benchmarking is comparing one's environmental performance with a standard point of reference for measurement. The resulting benchmark then represents a defined level of performance which can be used as a reference for comparison. Benchmarks can be based on averages or percentiles of real performance, and is often based on policy-driven objectives.

The question is under which conditions benchmarking can make carbon footprint analysis more actionable and how benchmarking can leverage useful insights to enhance organisations' environmental performance in the future.

6.1. Overview of footprint studies

Several universities and colleges in Belgium and abroad have calculated their carbon or ecological footprints. Belgian examples are:

- Vrije Universiteit Brussel (Ecolife, data year 2016)[8],
- Katholieke Universiteit Leuven (Futureproofed, data year 2010)[9],
- Katholieke Hogeschool Leuven (Ecolife, data year 2010)[10].

This study did not aim at a comprehensive benchmarking with other universities. We therefore limit this benchmark to the above Belgian studies and make a comparison especially with the VUB's recent footprint calculation, because the VUB and UAntwerp footprinting methodologies are very similar.

6.2. Methodological issues

The comparison of the UAntwerp footprint with other universities and colleges is rather difficult due to methodological issues. Different assumptions (e.g. choices of emission factors based on different Life Cycle Analysis (LCA)-studies) and different scopes can make comparisons very complex. For example, some studies include energy use and waste generated at residential student rooms, others exclude student restaurants or airplane travel by foreign students.

The benefits of benchmarking universities' footprints are clear. However successful and reliable benchmarking should ensure that data are truly consistent and comparable. It is often rather difficult to ensure consistency of data input and comparable boundaries. We are not in favour of simplistic comparisons of for example the footprint per student (e.g. 2 ton CO_2e for the UAntwerp) with the footprint in other footprinting studies, unless assumptions and scope are sufficiently similar and uncertainty ranges sufficiently small.

8 Bruers S. (2017). The carbon footprint of VUB 2016. Ecolife, Leuven, Belgium.

9 Vanderheyden G., Aerts J., e.a. (2013). Nulmeting CO_2 emissies KU Leuven in het jaar 2010. Studie 12428_KUL_Futureproofed, Kessel-Lo, Belgium.

10 Bruers S. (2011). De ecologische voetafdruk berekening van de KHLeuven, 2010. Ecolife, Leuven, Belgium.

6.3. Comparison of results

Table 6 compares footprinting data of UAntwerp, VUB, KUL and KHL. The footprinting study of the VUB (Ecolife, 2017) is most suitable for an inter-university comparison with UAntwerp, because the scopes are almost identical. UAntwerp has a footprint of 1.6 ton CO_2e per person (student plus FTE employee), compared to 1.7 ton CO_2e for the VUB.

	UAntwerp 2018	VUB 2016	KULeuven 2010	KHLeuven 2010
Number of students	20 860	15 418	51 000	6 946
Number of employees (FTE)	4 805	3 177	11 800	700
Floor surface area (m^2)	329 349	278 091	720 000	39 960
Floor surface area (m^2/person)	12,8	15,0	11,5	5,2
Direct primary energy use (kWhp/m^2)	265	321	293	299
Direct primary energy use (kWhp/person)	3398	4805	2659	1564
Electricity (kWh/m^2)	66	79	80	80
Electricity (kWh/person)	847	1 179	637	417
Electricity (ton CO_2/person)	0,313	0,065	0,163	0,107
Fossil fuels, direct use (kWh/m^2)	100	124	93	100
Fossil fuels, direct use (kWh/person)	1 279	1 857	1 067	522
Fossil fuels, direct use (ton CO_2/person)	0,32	0,45	0,26	0,13
Paper (kg/person)	8,3	7,0	4,8	8,4
Total waste (kg/person)	16	40	28	15
Residual/household waste (kg/person)	3	31	13	12
Paper/cardboard waste (kg/person)	8,3	7,0	9,4	2,0
Hazardous waste	3,1	1,9	1,3	0,0
Other selectivelly collected waste (kg/person)	1,7	0,3	4,0	0,5
Car (km/person)	1 244	1 365	1 196	974
Public transport (km/person)	3 533	4 378	2 868	2 336
Airplane (km/person)	662	1 245	1 301	73
Total mobility (ton CO_2/person)	0,72	0,87	0,74	0,44
Total footprint, all impact categories incl. in UA study (ton CO_2/person)	1,6	1,7	1,9	0,9

Table 6: Comparison with VUB, KUL and KHL

We can also compare consumption data of the UAntwerp with other universities and colleges.

6.3.1. Energy

- **Energy use**: UAntwerp uses 66 kWh electricity per m^2 floor area per year and 100 kWh natural gas per m^2 floor area per year. The total primary energy use (both electricity and fossil fuels) is 265 kWhp/m^2, slightly lower than the other universities'. However, such comparisons with other universities are not reliable, because different methods can be used to determine the total floor areas. The choices to include partially heated areas and areas with low electricity use might differ, which could easily result in large deviations.

6.3.2. Inputs

- **Food**: the percentage vegetarian and vegan meals at UAntwerp restaurants (assumed to be 20%) is equal to the VUB's (20%).

6.3.3. Direct waste

- **Residual waste for incineration collected at the university**: UAntwerp only has 3 kg residual/household waste per person per year. This is much lower than the other universities' and colleges'. There may be a bias (underestimation for the UAntwerp, overestimation for the VUB) in the way the waste data are collected.

6.3.4. Transporting people

- **Car travel of all students and employees**: UAntwerp has 1244 km per person per year. This is between VUB's and KUL's. The home-campus distance of a UAntwerp student (26 km) is comparable to a KUL student's and lower than a VUB student's (34 km).
- **Public transport used by all students and employees**: UAntwerp has 3533 km per person per year, between VUB's and KUL's.

6.3.5. Capital goods

- **Building area**: the density (persons per m^2 floor surface area) of UAntwerp is between VUB's and KULeuven's.

7. SIMULATIONS

7.1. Approach

In order to look for actions that have the highest footprint saving potentials, simulations were performed, using the UAntwerp carbon footprint of 2018 as a reference. The actions and hypothetical scenarios for simulations are based on footprinting studies of universities and colleges[11]. This list not only includes potential future measures but also recently executed measures. The calculation assumptions for recently executed measures are based on data of consumption levels of 2018. The assumptions for potential future measures are based on current infrastructure data and realistic targets for future actions. Investment costs of the future actions were not calculated.

7.2. Overview of recent actions

In the past five years, UAntwerp reduced its paper use by more than 40%. That results in a reduction by 26 ton CO_2e.

Impact category	Past measures	Calculation assumptions	Ton CO_2e saved	% reduction relative to 2018
Paper use	Less paper use	134 ton recycled printing paper in 2013, 79 ton in 2018.	-26	-0,1%

Table 7: Estimated carbon footprint reductions of past measures

7.3. Overview of future actions

The table below presents simulations and possible measures that could reduce UAntwerp's future carbon footprint. Some simulations correspond with measures that are feasible in the short or long term, others are merely for didactic purposes. The simulations are ordered following the impact categories: energy use, inputs, waste, end-of-life, transporting people and capital goods. Note that the savings and reduction percentages for the different simulations in the table should not be added, because there are couplings and overlaps between different simulations which could result in counting reductions twice. Estimates of total footprint reduction of a set of feasible, recommended measures are presented in the next chapter.

11 e.g. Bruers S. (2011). De ecologische voetafdruk berekening van de KHLeuven, 2010. Ecolife.
Bruers S. (2017). The carbon footprint of VUB 2016. Ecolife, Leuven, Belgium.

Impact category	Possible measures	Calculation assumptions	Ton CO2e/year saved	% reduction relative to 2018
Energy use	Green electricity	All purchased electricity is from renewable sources	7 263	17,3%
	Solar panels	10000m^2 roof surface area for solar panels, 1,5m^2 per solar panel, 0,26 kWp per panel, yield of 850 kWh/year/kWp, 0,22 kg CO2e/kWh avoided	324	0,8%
	Wind turbine	1,5 MW, 25% efficiency factor, 0,22 kg CO2e/kWh avoided	723	1,7%
	Increased thermal insulation of buildings	10% reduction in heating energy use	811	1,9%
Inputs	Vegan meals	All meals in student restaurants are vegan. Same number of meals as in 2018.	183	0,4%
	Less paper use	10% less paper	10	0,02%
Direct waste	Selective collection of waste	50% of residual waste selectively collected for recycling	12	0,03%
Transporting people	More students are residential students with a student room in Antwerp	50% of non-residential students become residential (non-residential students decrease from 70% to 35%) and those students their distance travelled with 50%. Average home-campus distance of all students and non-residential students is resp. 26 km and 17 km. So total distance travelled decreases with 12%. Modal split of residential and non-residential students is similar.	1 002	2,4%
	Employee commuting modal shift	10% of employee commuting car travel switched to 70% train and 30% bus	323	0,8%
	Student modal shift	10% of student car travel switched to 70% train and 30% bus	282	0,7%
	Employee telecommuting (promoting working from home)	5% less employee commuting	257	0,6%
	Student telecommuting (distance learning, promoting studying from home)	5% less student travel (excluding plane)	458	1,1%
	Employee ecodriving	5% less emissions of employee car travel (commuting and business travel)	202	0,5%
	Student ecodriving	5% less emissions of student car travel	206	0,5%
	Electric cars for employees	All cars are electric. Sum of commuting and business travel. 0,26 kg CO2/kWh Belgian electricity, 0,1 kWh/km average electric car, extra 0,02 kg CO2/km for production of car battery (Ricardo AEA (2013), Current and Future Lifecycle Emissions of Key 'Low Carbon' Technologies and Alternatives.)	2 698	6,4%
	Electric cars for students	Same as above, applied to all student travel, all student cars are electric.	2 755	6,6%
	Teleconferencing	10% reduction of employee airplane business travel	254	0,6%
Capital goods	Extended lifespan of IT-equipment	10% reduction of IT-purchases	83	0,2%

Table 8: Estimated carbon footprint reductions of possible future measures

As mobility has the largest share of the footprint, the highest savings can be realised with a combination of a modal shift (more public transport), shorter travel distances (more people staying in Antwerp or more people telecommuting) and ecodriving. In the longer term (e.g. 10 years), a shift to electric cars is feasible.

The footprint reduction from increasing the percentage of residential students (with a student room in Antwerp) only includes the reduction in mobility, not the increased energy consumption at the student rooms. This increased energy consumption can be offset by the decreased energy consumption at the students domiciles (parental homes). But in reality, this offsetting is not complete, which means that total carbon emissions in the world can increase when non-residential students become residential. Hence, the footprint reduction in Table 8 corresponding to the measure to increase residential students is an overestimation of the reduction in global carbon emissions.

In this footprint study, electricity is assumed to be the production electricity mix of the electricity supplier (VEB). Although the VEB sells its electricity as green electricity by purchasing guarantees of origin, we recommend electricity suppliers that directly produce or invest in renewable energy sources, because purchasing guarantees of origin may not be a sufficient financial incentive for suppliers to invest in renewable energy. For example, if a Belgian electricity supplier buys 1 guarantee of origin for 1000 kWh of Norwegian hydropower, the Belgian supplier can sell 1000 kWh as green electricity (even if the electricity is bought from a fossil fuel or nuclear power plant). The price of one guarantee of origin is 0,1€/MWh, which is very low (less than 1% of the total price for a customer). Such a low price corresponds with a carbon reduction price of less than 1€/ton CO_2. As a comparison, this is more than an order of magnitude lower than the price of an emission permit of the European Emissions Trading System. This means selling guarantees of origin does not give sufficient financial incentives to invest in green electricity.

Furthermore, the lack of transparency of the guarantees of origin system might disincentivise customers to switch to green electricity. For example, the Norwegian electricity producer sells its hydropower to Norwegian customers, but that electricity can no longer be sold as green electricity to their Norwegian customers when the guarantees of origin have already been sold to the Belgian supplier. However, the Norwegian customers might erroneously believe that their electricity is green electricity (because the supplier produces hydropower). Due to a lack of transparency of the system, those Norwegian customers might lack further incentives to switch to green electricity suppliers.

The above two concerns about selling electricity as green by purchasing guarantees of origin means that the actual reductions of emissions with a market system of guarantees of origin is highly uncertain. This uncertainty is taken into account in the Greenpeace ranking of electricity suppliers (www.mijngroenestroom.be). Green electricity suppliers have a low score if purchasing their green electricity does not sufficiently encourage investments in renewable energy sources. At the moment of publication, VEB is not included in the Greenpeace ranking, so its green electricity score is not known. Therefore, at the moment of this report's publication we could assume that it is grey electricity (bought at the electricity spot market), and we recommend switching to another electricity supplier with a high score of at least 16/20 on the Greenpeace ranking (until the VEB is included in the ranking and gets a high score). Furthermore, to maximise certainty about emission reductions, we recommend direct investments in renewable energy, such as onsite solar panels or wind turbines.

In 2019, an new, energy efficient campus building G.Z. with 8.800 m^2 floor area was built. This building has a total primary energy use (natural gas plus electricity) of 120 kWhp per m^2 floor area, 54% lower than the total average of current UAntwerp buildings (265 kWhp/m^2). If all UAntwerp buildings were renovated according to the energy efficiency standards of G.Z., the carbon footprint will reduce with 9000 ton CO_2e. For each building renovation of 1000 m^2 floor area, a reduction of 30 ton CO_2e is realized.

Table 9 presents a short list of important actions to be taken by the UAntwerp to reduce its carbon footprint in the short term. These are targeted actions, meaning that for each action a specific target can be chosen that will result in a certain carbon footprint reduction. Each of the presented targets for each of the actions in the table this will result in a 1% reduction of the total carbon footprint of the UAntwerp on an annual basis. Therefore, these actions can be used as (part of) a strategy to reach the short-term climate target of annually reducing the total carbon footprint with 3%. One could for example pick three targets, each with a 1% reduction potential, as actions to be taken in one year.

Impact category	Recommendation	Target
Energy use	Thermal insulation of buildings	5% reduction in heating energy
	Green electricity production	10.000 m^3 solar panels or small (0,7 MW) wind turbine
Transporting people	Modal shift (public transport instead of car)	10% of employee and student car travel switched to public transport
	Employee telecommuting (promoting working from home)	5% less employee commuting
	Student telecommuting (distance learning, promoting studying from home)	3% less student travel (excluding plane)
	Ecodriving	50% of employees and students with cars apply ecodriving
	Electric cars for employees	10% of employee cars are electric
	Teleconferencing	13% reduction of employee airplane business travel

Table 9: Targets for measures that reduce the total footprint with 1%

7.4. Summary

Table 10 summarises the reductions of the above-mentioned simulations per impact category:

- Energy: 10% reduction of heating energy use, on site installation of 10.000 m^2 solar panel and one 1,5 MW wind turbine;
- Inputs: all meals in the student restaurant are vegan, 10% less paper use;
- Direct waste: 50% of residual waste is recycled instead of incinerated;
- Transporting people: all employee and student car travel is switched to public transport or electric cars, 10% less employee airplane business travel due to teleconferencing, 50% of non-residential students become residential;
- Capital goods: 10% reduction in IT purchases due to extended lifespan.

These measures give a total footprint reduction of almost 9.000 ton CO_2e (22% of the total carbon footprint).

Overview	Emissions 2018	Reductions		Residual emissions
	t CO_2eq	t CO_2eq	%	t CO_2eq
Energy	16 134	1 858	12%	14 277
Non-energy	75	0	0%	75
Inputs	823	193	23%	630
Transporting people	18 457	6 923	38%	11 534
Direct waste	96	12	12%	84
Capital goods	5 923	83	1%	5 841
End of life	373	0	0%	373
Total	**41 882**	**9 068**	**22%**	**32 814**

Table 10: Summary of footprint reductions per impact category

8. RECOMMENDATIONS

Attainment of climate neutrality for an organisation consists of two steps: a reduction of greenhouse gas emissions as much as feasible according to a climate target, and a compensation of the non-reducible emissions.

This chapter includes both reduction and compensation recommendations. The reduction measures are based on the simulations discussed in the previous chapter. The compensation measures are based on the best available evidence for the most effective and fair compensation schemes.

8.1. Climate neutrality strategy

8.1.1. Framework

For the UAntwerp's path to climate neutrality it is appropriate to follow a step-by-step approach involving both reductions of avoidable emissions and compensations of unavoidable emissions. The reduction involves three steps, known as the trias energetic and represented by the three R's of reduction:

1. Reduction of emissions by avoidance of future carbon-intensive activities **(Restricting)**;
2. Reduction of emissions by doing what you do more efficiently **(Rationalising)**; and
3. Reduction of emissions by replacing high-carbon fuels with low-carbon sources **(Replacing)**.

Future carbon actions are best selected or designed consistent with these guiding principles of an overall climate neutrality strategy.

The above trias energetic framework is a direct consequence of the structure of the carbon footprint calculation, given by the ImPACT equation: the environmental impact (e.g. carbon footprint) is the product of 4 factors:

1. **Population factor P**: the number of people. For example, the number of students and employees;
2. **Activity factor A**: the average activity per person. For example, the average distance travelled per person, number of meals consumed per person, courses taken per person, room area heated per person;
3. **Consumption factor C**: the resource consumption per unit of activity. For example, the energy use per km travelled, food use per meal, paper use per course, energy use per heated area;
4. **Technology factor T**: the greenhouse gas emissions per unit of resources used, determined by the technology. For example, the CO_2 emissions per kWh energy used, per kg food consumed, per kg paper used.

Together this impact equation reads: Im = P x A x C x T. These four factors imply that there are four ways to reduce the carbon footprint. The footprint of the UAntwerp can be reduced by reducing the number of students and employees, i.e. decreasing the population factor, but this is not a useful recommendation because education and research is the core business of the UAntwerp. So instead, as a reduction target we focus on the footprint per person, which is the product of the three remaining factors A, C and T. As these letters indicate, these are the three factors to act upon. They are the trias energetica. Specific reduction actions are:

1. **Restrict activity (reducing A)**: teleconferencing, studying at home (on-line courses), lowering room temperature, avoiding heating of non-used rooms, avoiding printing;
2. **Rationalise consumption (reducing C)**: ecodriving, choosing public transport, decreasing food waste, insulating buildings, double-sided printing;
3. **Replace technology (reducing T)**: using renewable (green) electricity, geothermal energy, plant-based food, recycled paper.

8.1.2. Strong climate neutrality

We should make a distinction between weak and strong climate neutrality. For example, suppose the climate target is a reduction of 3% per year. If total emissions are 100 ton CO_2 and after the first year a reduction of 2 ton CO_2 is realised, this is 1 ton CO_2 less than the climate target. To become weakly climate neutral, one can compensate for this 1 ton CO_2. However, we recommend a strong climate neutrality, i.e. a compensation for the remaining 98 ton CO_2.

8.1.3. Overall trends

Several overall trends can be mentioned that will influence one way or the other the carbon footprint of higher education organisations as UAntwerp.

Some long-term technological trends will presumably result in a reduction of the UAntwerp footprint, even without a change in UAntwerp activities. As discussed in chapter 4 on methodology, the footprint is basically the product of emission factors (footprint intensities) and consumption data. Due to technological innovations, the emission factors (used in the Bilan Carbone® calculator) become smaller, meaning the footprint becomes smaller. For the footprint of the UAntwerp, the three most important technological background trends are:

- **More efficient airplanes**. In the long-term airplanes can become more efficient and emit fewer greenhouse gases.
- **More efficient public transport**: it can be expected that also train and bus efficiency increases, reducing their emission factors. As the share of public transport in the total footprint of the UAntwerp is large and likely to increase after a modal shift, more efficient public transport will imply a reduction of the total carbon footprint with a few percent.
- **More efficient production of equipment**: as technology evolves and the production of equipment (cars, ICT, furniture) becomes more efficient, the emission factors for inputs and capital goods decrease, which means a reduction of the carbon footprint with a few percent.

At the same time, long-term demographic trends are assumed to increase the carbon footprint of the UAntwerp. Two macro-social trends that can be mentioned are:

- **Democratisation of higher education**: Population increase in general and a better access of a broader range of students regardless their socio-economic status in particular are expected to enlarge the inflow of students. As a consequence, the expansion of education and research activities and infrastructure are expected to enlarge the footprint in general.
- **Internationalisation of higher education**: For instance, the recruitment of international students, students, staff and scholars exchange programs, and research and education partnerships between institutions regionally and internationally are expected to enlarge the (mobility) footprint.

8.1.4. Carbon Emission targets

A first step to become climate neutral consists of setting a reduction target. How much does an organisation have to reduce its own carbon footprint for the coming years? The national climate target of Belgium can be used as a reference to deduce climate targets for Belgian organisations. In order to achieve climate targets (avoiding global temperature change below 1.5°C), an average Belgian person should reduce its carbon footprint with 3% per year. With a time-linear reduction path, this corresponds to a 30% reduction within 10 years. This reduction objective is therefore also a suitable reduction target for Belgian companies and organisations. For the UAntwerp it implies that the total footprint per person (student or employee) should reduce with 3% per year on average.

8.2. CO_2 reduction

As the simulations in the previous chapter (table 10) demonstrate, ten measures can reduce the UAntwerp carbon footprint with one quarter. This corresponds with a reduction target over an 8-year period. These actions consist of structural actions such as changes in infrastructure or policies and behavioural change actions.

The scope of this study did not include a detailed and long-term action plan. Therefore, and perhaps the most important recommendation at this stage, we recommend conducting a separate study with such an action plan for full climate neutrality as an end result. That study should involve consultations with working groups from all different faculties, including representatives of students and academic, technical and administrative staff. The recommendations in this chapter can serve as a starting point for that further study.

8.2.1. Structural actions

Direct energy use and mobility have the largest share in the footprint. We therefore recommend actions to reduce their footprints. A lot of structural actions (changes in infrastructure and policy) are possible.

Energy and capital goods

Action 1: Energy audit recommendations to reduce natural gas use

Direct energy use (electricity and gas) accounts for one fifth of the total footprint. As purchased electricity of the UAntwerp is already green electricity with a low footprint, almost all of the direct energy use footprint comes from natural gas use (mostly for heating). Therefore, priority should be given to reducing natural gas use. We recommend energy audits, especially for campus Drie Eiken, for energy reducing measures. Those measures rationalize energy consumption (i.e. decrease the consumption factor), by doing the same activities more efficiently.

Action 2: Low energy and zero energy buildings

In the longer run, after having carried out the short-term energy audit measures to reduce natural gas use, stronger energy standards for all new buildings and for renovation become necessary. To avoid locked-in situations where new buildings have poor energy performance and will consume a lot of energy for decades, we recommend that for all future procurements for construction and renovation, energy performance becomes a key decision factor and the highest energy standards should be imposed.

Action 3: Geothermal energy

On the very long term, energy reducing measures (i.e. restricting activities or rationalizing consumption) will not be enough and relying on natural gas for heating will prevent reaching climate targets. Replacement of energy source becomes crucial. Geothermal energy could drastically decrease the heating footprint, but feasibility might be a bottleneck. Research about the technical and financial feasibility of geothermal energy (heat pumps) is highly recommended.

Action 4: Installation of solar panels or wind turbines

Solar panels not only reduce the footprint of the UAntwerp in the very short term, they can also be beneficial in the longer term when combined with a shift to electric cars. The solar panels can feed the charging stations for electric cars at the UAntwerp campus sites, not only reducing the footprint of energy use but also the footprint of car transport. If onsite installation of solar panels or wind turbines is not feasible, a switch to green electricity (with a score of more than 16/20 on the Greenpeace ranking at www.mijngroenestroom.be) is recommended.

Action 5: Research and development at UAntwerp

The UAntwerp can stimulate R&D for a sustainable energy transition. As a living lab or demonstrator, the UAntwerp can further invest in several large-scale research projects with international appeal. R&D in clean energy technologies at the UAntwerp can count as a highly effective CO_2-compensation strategy, because over a few decades upcoming countries such as China and India will become by far the largest energy users, and they can benefit from clean energy technologies (co)developed at the UAntwerp. In other words: the UAntwerp can 'export' climate-friendly technologies so that global carbon emissions are drastically reduced.

Transporting people

Action 1: Online courses to facilitate studying at home and reduce student mobility

Restricting transportation activities is the first step to reduce the student mobility footprint, especially in the light of higher education democratisation, which will result in an increase in student population at the UAntwerp. Offering online courses facilitates studying at home and avoids transportation movements, especially for the commuter students who would otherwise travel each day to campus.

Action 2: Flexible working arrangements to reduce employee commuting

As with online courses, offering flexible working arrangements and part-time working at home (or closer to home) restricts transportation activities and is a first step to reduce the mobility footprint.

Action 3: Provide a budget for electric and folding bikes for students and staff

Next to restricting transportation activity, a rationalisation of energy consumption per distance travelled is important. The best way to do this is a modal shift towards lighter transportation, such as lighter cars, motorcycles and especially bikes. Vélo (city bike) and ferry subscriptions are regarded as public transport and have been fully reimbursed for some time. To further promote bike usage, a budget for Cloudbike/Mobit (bike sharing) or Bird (electric steps) subscriptions and for electric and folding bikes can be provided to staff and/or students.

Action 4: Provide infrastructure and equipment to promote bike use

Signalling of shortages of bicycle parkings can be facilitated. For example, some students of the student mobility survey complained about the lack of guarded bicycle parking areas (e.g. at building R of campus Drie Eiken and at campuses Middelheim and Stad). Also lockers for folding bicycles in the entrance hall can be provided. Finally, equipment such as rainwear, extra Vélo stations (e.g. at campus Drie Eiken) and infrastructure such as showers can be provided for people using bikes.

Action 5: Solving bottlenecks to facilitate a modal shift to public transport

Next to bikes, a modal shift to public transport should be promoted. This requires a collaboration between UAntwerp and public transport providers. The UAntwerp can take direct measures, such as:

- Guaranteeing that classes end at the scheduled time that fit with the bus hours.
- Avoiding classes at different campuses on the same day.
- Limiting evening classes at campuses with infrequent bus hours.
- Allowing students cards to be coupled to bus cards (MoBIB).

But the UAntwerp can also indirectly improve public transport, by lobbying at public transport providers for:

- more frequent buses to the campuses in the morning,
- buses with stops closer to the campuses (e.g. at the city campus instead of the Groenplaats),
- extra student shuttles that are faster than regular buses (e.g. with less bus stops and detours),
- a direct bus connection from campuses Drie Eiken, Groenenborger and Middelheim to train station Antwerp-Berchem,
- a better (direct) bus connection between Middelheim/Groenenborger and Drie Eiken,
- more peak hour trains starting at 4 pm instead of 5 pm, and
- trains on green electricity (if trains would use green electricity, the total carbon footprint of the UAntwerp will decrease with 13%).

Action 6: Differentiated pricing for a modal shift to public transport

Financial incentives can increase a modal shift to public transport. For example, higher parking prices at the UAntwerp generate extra revenue that can finance subsidies for public transport (train tickets) of students.

Action 7: Green electricity for electric car charging stations

After a maximal modal shift towards bikes and public transport, the footprint of remaining car travel can be reduced by using electric cars, powered by green electricity. A transition towards electric cars can be facilitated by improving infrastructure for electric cars. Electric charging stations have been placed for cars on all UAntwerp campuses. The charging points are placed on publicly accessible parts of the parking lot so that outsiders can also use them. These electric charging stations could be powered by solar panels at the UAntwerp buildings.

Action 8: Differentiated pricing for electric cars

If feasible, parking prices at UAntwerp can be introduced. This allows for differentiated pricing to promote electric cars: higher prices for cars with combustion engines, lower prices for electric cars of students and employees. This gives a financial incentive to switch to more sustainable modes of transport. Another, similar option is differentiated pricing for reimbursing transportation costs (mileage allowance payments).

Action 9: Teleconferencing to reduce airplane travel

Airplane business travel accounts for 8% of the total footprint. Although airplane efficiency (i.e. rationalising energy consumption) is expected to improve in the future, this technological trend lies outside the influence of the UAntwerp, and more measures to reduce the airplane travel footprint are necessary. The UAntwerp can introduce a policy to discourage flying in first class (business class), which has a higher footprint. One important measure is restricting activity (reducing the activity factor), by avoiding flights. With new ICT-technologies, teleconferencing (videoconferencing) becomes an interesting opportunity.

Inputs and waste

Action 1: Reducing food waste

Although food has a small share in the current footprint calculation due to exclusion of meals consumed outside of student restaurants, there are relatively small but quick wins. Limiting the number of students or the number of meals consumed are not relevant measures to reduce the footprint of food. Therefore, a first step is a rationalisation of consumption, which means for example a reduction of food waste. There are some interesting ‘nudges’ (changes in the choice architecture) to make people reduce their food waste. One example is the use of smaller plates at the buffet. With bigger plates, people are inclined to take too much food on the plates to avoid empty space.

There is already a strong focus on the use of tap water. Non-carbonated bottled water is no longer sold in the student restaurants and more than 88 taps have been installed on the campuses.

Action 2: Further promoting plant-based food

Next to a reduction of food waste, a replacement of ingredients towards low carbon intensive food products is important. Especially further promoting plant-based meals is a quick win because the footprint of an average meat and seafood-based meal is more than three times higher than the footprint of an average vegan meal.

Action 3: Avoid printing (e.g. student theses and courses)

Avoiding paper consumption is the first step to reduce the footprint of inputs. Printing student theses, papers and courses requires a lot of paper. Avoiding printing and promoting e-reading are prime recommendations in this area.

8.2.2. Behavioural change

Changing everyday habits and behaviours of staff and students is also necessary to reduce the carbon footprint. The British DEFRA developed a 4E-model for sustainable lifestyles[12] consisting of enabling, exemplifying, engaging and encouraging behavioural change (which was later extended to a 7E-model[13]). For a research institute such as the UAntwerp, we add a fifth E: experimenting.

1. Enable sustainable behaviour

Make it easier: provide people with the support they need to make responsible choices.

Sustainable behaviour such as carpooling needs to be enabled. To do this the UAntwerp can encourage the use of existing online platforms for carsharing, carpooling or ridesharing. Avoiding waste such as plastic water bottles is enabled by providing drinking water fountains. More generally, training for employees also provides tools that enable sustainable behaviour in the workplace.

2. Exemplify sustainable behaviour

The UAntwerp can lead by example: review internal policies and take action to 'exemplify' the same behaviour.

Appoint climate ambassadors and show that UAntwerp staff sets a good example, hence engaging students and other staff members. With outreach programs and training, staff members appreciate the importance of sustainability.

3. Engage staff and students

Get people involved: involve people early on so that they understand what they need to do – help them develop a sense of personal responsibility.

Staff members can be engaged within a GreenTeam, students can be engaged with a student organisation for sustainability. There is a student organisation called GreenOffice with job students who try to bridge the gap between the university and central services and who support student associations in making their events more sustainable.

4. Encourage staff and students

Give the right signals: understand and offer benefits to change which are as important as providing regular feedback.

Financial incentives can encourage sustainable behaviour, but also eco-gamification has a large potential: provide competition with regular challenges, funny elements and rewards. Gamification means applying the ideas, designs, mechanics and tools behind good games to non-gaming environments such as work or study. A competition between GreenTeams works encouraging. Online platforms and smartphone apps for mobility and sustainable living (e.g. For Good) can assist in this gamification process. As an extra motivation, a share of the monetary savings made from reduced energy use can be donated to charities or local community causes chosen by students or staff.

12 DEFRA (2011), Framework for Sustainable Lifestyles. Department for Environment, Food & Rural Affairs, UK.
13 Bambust, F (2017) Effectief gedrag veranderen met het 7E-model. Politeia.

5. Experiment with behavioural change campaigns

Learn by doing: there's no one solution that fits, so make it fun and let trial and error lead the way.

There are several techniques to influence sustainable behavioural change, such as nudging: changing the choice architecture (e.g. contexts, messages or infrastructure) to facilitate and promote sustainable behaviour. Nudging for sustainability receives increasing attention in psychology and behavioural economics. With nudging, freedom of choice is maintained but people automatically or unconsciously make the more sustainable choices. The UAntwerp is a research institute, so we recommend doing experiments with different nudging and communication approaches. Impacts of different behavioural change strategies can be measured with e.g. randomised controlled trials. This can be done by master and PhD students in Psychology.

Examples of behavioural change campaigns suitable for experimentation at the UAntwerp are: ecodriving, energy reduction (e.g. at student homes) or plant-based food consumption at UAntwerp restaurants.

8.3. CO_2 compensation

If CO_2 reduction targets cannot be reached, it is possible to compensate for the remaining, non-reducible CO_2 emissions in order to become fully climate-neutral. This section discusses the possible compensation strategies. We make a distinction between non-financial and financial compensation and discuss examples of each in the sections below.

8.3.1. Methodological issues

There are a lot of issues involved with effective and fair CO_2-compensation. These issues relate to cost-effectiveness, additivity, timeframes, scientific certainty, generalisability, neglectedness, precaution and indemnifications. This means more than one compensation method might be required. In what follows we describe a complete, broad, effective, fair, cautious and long-term compensation strategy.

8.3.2. Non-financial CO_2-compensation

The previous section presented actions that the UAntwerp can take to directly reduce its own footprint. However, the UAntwerp can also carry out actions and campaigns that facilitate a reduction of greenhouse gas emissions not included in the footprint of the UAntwerp. These actions count as CO_2-compensation mechanisms, but are not financial in the sense that they do not involve a donation to an external organisation. The actions are performed on UAntwerp. Some interesting non-financial CO_2 compensation examples are:

- Solar panels and wind turbines. Once the UAntwerp buys green electricity (e.g. from an electricity supplier with a score higher than 16/20 on the Greenpeace ranking at www.mijngroenestroom.be), the installation of solar panels or a wind turbine will no longer result in a reduction of the electricity carbon footprint of the UAntwerp. However, the UAntwerp can sell the electricity produced by its own solar panels or wind turbine. This counts as a CO_2-compensation measure, as it results in a replacement effect, where electricity from power plants is replaced by electricity from the solar panels or wind turbine of the UAntwerp. Hence CO_2 emissions at power plants are avoided. Selling 1 kWh solar power can compensate 0,22 kg CO_2 (excluding price elasticity and rebound effects). It requires 10.000 m^2 solar panels for a CO_2 compensation equivalent to 1% of the total carbon footprint of the UAntwerp. A 1,5 MW wind turbine could compensate 2% of the total UAntwerp footprint.

- **Charging stations for electric cars**. The UAntwerp can promote a switch to electric cars by installing charging stations on its campuses. This not only results in a reduction of the UAntwerp footprint from employee and student car travel, the charging stations can also be used for other, non-UAntwerp related car transport. It is difficult to calculate how much emissions can be avoided with the installation of one charging station.
- **Vegan meals in student restaurant**. If all meals in the UAntwerp restaurant were vegan, this would result in a reduction of 0,5% of the UAntwerp footprint. This may seem negligible, but the promotion of plant-based food has wider reaching effects. Only 10% of student meals are consumed at the UAntwerp restaurant. By increasing the offer of tasty vegan meals, plant-based food becomes more normalised and as a consequence students and employees may increase their consumption of vegan meals at home as well.
- **Sustainability as part of the curriculum and research**. Ensure that sustainability in all its aspects (e.g. sustainable technologies, economics, politics, climate science, behavioural change psychology) has a bigger part in the student curriculums and research projects. This also reduces CO_2 emissions outside the scope of the UAntwerp carbon footprint, for example by changing behaviour of students and developing climate-friendly technologies.

8.3.3. Financial CO_2-compensation

Compensation strategies

Financial compensation involves donations to organisations. In general, there are five financial compensation strategies:

1. Mitigation by short-term emission avoidance: supporting projects and actions from organisations that result in avoidance of greenhouse gases elsewhere in the world.
2. Mitigation by short term absorption: donate money to organisations that plant trees to absorb one's own emissions.
3. Mitigation by long term emission avoidance: investments in research and development of technologies and market mechanism to reduce emissions in the long term.
4. Remuneration of past emissions: purchase of 'virtual emission permits', i.e. donations to the poorest people who have the lowest carbon footprints, as a way of buying from them emission permits.
5. Adaptation to past emissions: supporting health organisations to prevent climate related diseases such as malaria.

The table below presents the different compensation methods, the organisations involved, estimates of the financial costs as well as the advantages and disadvantages of the different methods. A more detailed description of the compensation methods can be found in the appendix.

The cost of compensation strategies varies from 0.3 to 100 euro per ton CO_2e. Hence, the total carbon footprint of the UAntwerp (37.000 ton CO_2e) can be compensated at a cost ranging from 12.000 to 3.7 million euro.

Strategy	Method	Organization	Cost per ton CO_2e	Advantage	Disadvantage
Mitigation by short term emission avoidance	Payment for ecosystem services (preventing deforestation)	"Coalition for Rainforest Nations (www.rainforestcoalition.org) Cool Earth (www.coolearth.org)"	2,2 euro	Highly cost effective, strong evidence of certain results, short term	"Not generalizable, keeps own emissions in the atmosphere"
	Promotion of plant-based diets	Animal Charity Evaluators top recommended charities (animalcharityevaluators.org)	3 euro	Highly cost effective, some evidence of rather certain results, short term, many cobenefits (human health, sustainability, animal welfare)	"Not generalizable, keeps own emissions in the atmosphere"
	Gold Standard or PAS 2060 approved schemes	Gold Standard (www.goldstandard.org)	15 euro	Compliant with PAS 2060 criteria	"Less cost effective, not generalizable, keeps own emissions in the atmosphere"
Mitigation by short term emission absorption	Carbon capture and storage by reforestation	Treecological (www.treecological.be)	34 euro	Certain results, short term, takes back own emissions	"Not generalizable, less cost effective "
Mitigation by long term emission avoidance	Voluntary family planning (reducing unwanted pregnancies)	Marie Stopes International (mariestopes.org)	10 euro	Very cost effective, many cobenefits (women rights, poverty reduction)	"Not generalizable, keeps own emissions in the atmosphere"
	Scientific research for climate friendly energy and transport technologies	Research institutes such as MIT Energy Initiative (energy.mit.edu)	uncertain (probably much less than social cost of carbon of 100 euro)	Allows generalizable and strong reductions in the long term	"Uncertain results, risk of rebound effect"
	Advocacy for more scientific research and development of clean energy and climate friendly technologies	Advocacy organisations such as the Clean Air Task Force (www.catf.us), the Information Technology and Innovation Foundation (www.itif.org) and Let's Fund (lets-fund.org/clean-energy/)	uncertain (probably much less than social cost of carbon of 100 euro)	Allows generalizable and strong reductions in the long term	"Uncertain results, risk of rebound effect"
	Development of clean meat	Good Food Institute (www.gfi.org)	uncertain (probably less than social cost of carbon of 100 euro)	Allows generalizable and strong reductions in the long term	"Uncertain results, risk of rebound effect"
	Economic market mechanism: carbon taxation	"Carbon Tax Center (www.carbontax.org) Citizens' Climate Lobby (citizensclimatelobby.org)"	uncertain (probably much less than social cost of carbon of 100 euro)	"Economically most effective to address climate change problem, avoids rebound effects"	Uncertain results
	Economic market mechanism: cap-and-trade improvements	Carbon Market Watch (carbonmarketwatch.org)	uncertain (probably much less than social cost of carbon of 100 euro)	"Economically most effective to address climate change problem, avoids rebound effects"	Uncertain results
Remuneration of past emissions	Purchase of virtual emission permits from poorest people	GiveDirectly (www.givedirectly.org) or Eight (eight.world)	100 euro	Most fair solution to help the poorest people	Less cost-effective
Adaptation to past emissions	Health interventions	Against Malaria Foundation (www.againstmalaria.com)	0,33 euro	"Most cost-effective"	"Not generalizable, focuses only on human health"

Table 11: CO_2 compensation strategies

8.4. Footprint monitoring and reporting

For future recalculations of the carbon footprint, the following actions are recommended.

- Provide a platform for collecting consumption and infrastructure data. This platform should be secure and accessible by the environmental co-ordinator and people responsible for sustainability, mobility, technical services, purchases and administration.
- Adopt a formalised data submission process. The collection of data should be consistent with the method described in Chapter 4.
- Especially the mobility data requires accurate follow-up measurements based on surveys and travel expenses. Data of the travel expenses should be filled in conform to a standardised format, for example containing uniform descriptions of destinations and modes of transport (airplane, train, car). Local expenses (overnight stays) should be counted separately (i.e. not added to flight expenses). Better estimates for foreign students' airplane travel (distances and number of flights) are also recommended.

9. SUMMARY

This report describes the calculation of the carbon footprint of the UAntwerp for the year 2018, following the Bilan Carbone® method, as well as recommendations to reduce the footprint. The carbon footprint measures the direct and indirect emissions of greenhouse gases included in the Kyoto Protocol (in particular carbon dioxide, methane, nitrous oxide and halocarbons), for UAntwerp activities and infrastructure. The impact categories that generate emissions are:

- direct energy use (electricity and heating);
- leaks of halocarbons from airconditioning systems;
- purchased equipment and services;
- meals at student restaurants;
- waste;
- employee commuting;
- business travel;
- student mobility;
- capital goods (infrastructure, vehicles, ICT equipment).

Included in the carbon footprint calculation are activities related to administration and academic research (research equipment, waste generation, international business travel, employee commuting) and activities related to education (educational equipment, student mobility including airplane travel for foreign students studying at the UAntwerp, paper use for student courses, meals consumed at student restaurants, and energy use and general waste generated at student homes on the campuses). The buildings include administrative, research and education buildings, and student homes and student restaurants located at the campuses.

Not included in the carbon footprint calculation are energy use and general waste generated at student homes other than the student homes at the campuses, food consumption at places other than the student restaurants at the campuses, equipment and furniture of the student homes (including the student homes on the campuses), water consumption, transport of goods other than the transport of waste collection, mobility (airplane, car, train) from non-student visitors (e.g. guest lecturers), and spin-offs of the UAntwerp.

The total carbon footprint of the UAntwerp for the year 2018 was 41.882 ton CO_2e, which corresponds with 2 ton CO_2e per student. Of this total footprint, 44% comes from transporting people (especially student travel by car, airplane and public transport), 39% from direct energy use (especially heating) and 14% from capital goods (especially construction of buildings).

A **strategy for the UAntwerp to become climate-neutral** consists of two steps. Firstly, reducing the emissions with an average rate of 3% per year to meet long-term global climate targets. Secondly, compensating the remaining emissions by effective and fair CO_2-compensation schemes. Reduction of emissions follows the trias energetica: avoiding carbon-intensive activities (Restriction), doing what you do more efficiently (Rationalisation), and replacing high-carbon fuels with low-carbon sources (Replacement). These include both (infra)structural actions and behavioural change of employees and students. Priority should be given to reducing natural gas use and mobility emissions at campus Drie Eiken.

Important structural actions to reduce the footprint include:

- energy audit recommendations to reduce natural gas use;
- using geothermal energy;
- installing solar panels or a wind turbine onsite;
- research and development of climate-friendly technologies at the UAntwerp;
- online courses to facilitate studying at home and reduce student mobility;
- flexible working arrangements to reduce employee commuting;
- providing a budget for electric and folding bikes for students and staff;
- lobbying for better bus and train connections;
- differentiated pricing for a modal shift to public transport and electric cars;
- charging stations on the campuses to enable a shift towards electric cars;
- teleconferencing to reduce airplane travel;
- further promoting plant-based food;
- avoiding printing of student theses and courses.

The **behavioural change strategy** consists of:

- enabling sustainable behaviour (making it easier);
- exemplifying sustainable behaviour (leading by example);
- engaging staff and students (getting people involved using social incentives);
- encouraging staff and students (giving the right signals and financial incentives);
- experimenting with behavioural change campaigns (learning by doing).

The CO_2-compensation schemes involve non-financial compensations (e.g. installing extra solar panels, promoting vegan meals, taking up sustainability as part of the curriculum and providing budgets for research of climate friendly technologies) as well as financial compensations (e.g. supporting projects and actions from organisations that result in avoiding greenhouse gases elsewhere in the world, donating to organisations that plant trees to absorb one's own emissions, investing in research and development of technologies and market mechanism to reduce emissions in the long term, purchasing of 'virtual emission permits' and supporting health organisations to prevent climate related diseases such as malaria).

An accurate footprint monitoring system for future calculations of the carbon footprint (with a platform for data collection and a formalised data submission process) and a more detailed action plan to implement the footprint reduction and compensation measures are required to achieve full climate neutrality.

10. APPENDIX 1: STUDENT MOBILITY SURVEY

In the second semester of academic year 2018-2019, an online student mobility survey was held. The table below shows the calculated distances travelled by motorised transportation modes (car, train and bus) according to the survey. These distances include home-campus travel by non-residential students, home-student room and student room-campus travel by residential students, and intercampus travel by all students who have to travel between different campuses on the same day.

Distance (km)	With student mobility survey							With extrapolation of VUB and KUL based on distance	
	CDE	CGB	CMI	CMU	CST	Total	Share of transportation mode	Total	Share of transportation mode
Car	3 250 687	3 792 834	202 153	178 376	2 428 129	9 852 179	18%	16 206 051	21%
Train	5 325 493	3 795 708	209 306	5 910 052	12 682 426	27 922 984	51%	48 530 154	63%
Bus	2 405 975	2 944 334	160 125	1 127 201	10 299 291	16 936 926	31%	12 240 882	16%
Total motorized	**10 982 155**	**10 532 876**	**571 584**	**7 215 628**	**25 409 847**	**54 712 089**	100%	**76 977 087**	100%

The results according to the mobility survey are calculated using the indicated transportation modes (e.g. car, carpooling, bus, train, motorbike, bike), the number of travels on an average week, and the distances between home, student room and campus based on postal codes for all Belgian and Dutch students in the survey who answered all relevant questions (i.e. 354 students). Dutch students are assumed to travel two times 100 km per week to their student rooms, for 36 weeks per year. To get the total distance travelled per campus, the sum of distances of surveyed students of a campus is multiplied by the ratio of the total number of students of that campus to the number of surveyed students of that campus.

The final columns in the above table show the results used in the UAntwerp carbon footprint calculation. These were calculated using the modal split and the number of travels per week of the VUB and KUL students, and the average home-campus distance of UAntwerp students (according to postal codes of all registered students at the UAntwerp).

There are three reason why the student mobility survey was not used for the 2018 UAntwerp carbon footprint.

1. The survey did not indicate the main type of transport. For example a student could indicate that s/he travels both by car, bus and train. If several motorised transportation modes were given, each mode was assumed to have an equal share of the total distance. For example, if a student travels 18 km by car and bus, this gives 9 km by car and 9 km by bus. As a consequence, the column indicating the share of transportation modes according to the survey in the above table differs from the modal split of VUB and KUL (last column in above table). Note that the shares of cars versus public transport are similar according to the two calculation methods. Only the modal split between train and bus differs.
2. A more worrisome issue with the student mobility survey, is the confusing question "On average, how many times per week did you take this route in the past semester?" Some students filled in an odd number of travels per week. This indicates that they counted the number of round trips instead of one way travels during an average week. For example, 5 travels per week correspond with 10 one way travels from home to campus and back. As a result, the distances calculated according to the survey are likely underestimations. The total distances travelled by motorised transport is 55 million km according to the survey and 77 million according to home-campus distances.

3. The survey was not sufficiently elaborated, in the sense that the share of students of the different campuses according to the survey differs from the actual share of students (i.e. the number of students registered at the different campuses). The table below shows that the students at campus Middelheim (CMI) are strongly underrepresented in the survey (i.e. they have a share of 6% in the survey, compared to 1% in reality).

Share of students per campus	CDE	CGB	CMI	CMU	CST	Total
According to survey	30%	17%	6%	4%	42%	100%
Actual	20%	21%	1%	8%	50%	100%

However, the calculation method used in the 2018 UAntwerp carbon footprint has a major flaw as well: it assumes that all five campuses have the same modal split (i.e. 1/5th by car, 2/3rd by train). The tables below shows the estimated shares of distances travelled per campus (row shares sum to 100%) and per transportation mode (column shares sum to 100%), according to the mobility survey. As can be expected, the shares of car transport are relatively high for campus Drie Eiken (CDE) and Groenenborger (CGB), compared to campus Mutsaard (CMU) and Stad (CST), because the latter are in the city centre where parking area is restricted, whereas the latter have limited access by public transport.

Share of distance per campus	CDE	CGB	CMI	CMU	CST	Total
Car	33%	38%	2%	2%	25%	100%
Train	19%	14%	1%	21%	45%	100%
Bus	14%	17%	1%	7%	61%	100%
Total motorized	20%	19%	1%	13%	46%	100%

Share of distance per transportation mode	CDE	CGB	CMI	CMU	CST	Total
Car	30%	36%	35%	2%	10%	18%
Train	48%	36%	37%	82%	50%	51%
Bus	22%	28%	28%	16%	41%	31%
Total motorized	100%	100%	100%	100%	100%	100%

For future carbon footprinting of the UAntwerp, we recommend an improved student mobility survey:

1. with a larger sample size;
2. where students can fill in their main and secondary types of transportation; and
3. where the question about the number of travels per week clearly states that one way trips should be counted, to avoid confusion.

11. APPENDIX 2: CO_2 COMPENSATION STRATEGIES

This appendix presents all the different effective and fair CO_2 compensation methods.

11.1. Mitigation by short-term emission avoidance

Payment for ecosystem services

Firstly, we can pick the lowest hanging fruit. A recent study in Science[14] demonstrates the cost-effectiveness of payments for ecosystem services: offering forest-owning households in poor countries annual payments if they conserved their forest. These financial incentives for forest owners keep their forest intact, so CO_2-emissions from deforestation are avoided. The net present cost to permanently avert a ton of CO_2 would be 2,2 euro. An organisation that offers payments for ecosystem services is (www.coolearth.org/get-involved/donate-cool-earth) which is according to Giving What We Can probably the most cost-effective organisation to avoid CO_2-emissions.

But if there are more highly cost-effective organisations, from a risk perspective it is better to fund more than one of those organisations. If you support only one organisation, it might be the case that new evidence shows that that organisation happens to be less effective than previously estimated. So if you can pick different low hanging fruits, it is better to not put too much of the same fruit in one basket.

Plant-based food

A second very cost-effective intervention is the promotion of plant-based (vegan or vegetarian) food, because vegan products have a much lower carbon footprint compared to animal products. One of the most effective strategies could be online advertisements for plant-based eating. Animal Charity Evaluators gives estimations for its cost-effectiveness. The most pessimistic or conservative estimate is 3 euro per ton of CO_2 avoided: paying 3 euro for online ads results in 1 vegetarian year (the equivalent of one person eating a vegetarian diet for 1 year). And eating vegetarian or vegan reduces the carbon footprint with roughly 1 ton CO_2-eq. per year compared to an average omnivore.[15] A donation to Animal Charity Evaluators top recommended charities is a cost-effective way to compensate CO_2.

Payments for ecosystem services and promotion of plant-based diets are probably the two lowest hanging fruits, the two most cost-effective interventions to reduce the global carbon footprint. They are able to reduce the greenhouse gas emissions in a short term (less than 10 years). Reducing emissions the next few years instead of in the far future is important, because we have to avoid exceeding hidden thresholds in the global climate system that could result in a runaway global warming due to positive feedback loops in the climate system. The earlier we reduce our global carbon footprint, the lower the risk of transgressing a hidden climate threshold.

14 Jayachandran S. e.a. (2017). Cash for carbon: A randomized trial of payments for ecosystem services to reduce deforestation. Science Vol. 357, Issue 6348, pp. 267-273.

15 Springmann M. e.a. (2016). Analysis and valuation of the health and climate change cobenefits of dietary change. Proc Natl Acad Sci. 113(15):4146-51.

11.2. Mitigation by short-term absorption

The above two methods consist of avoiding emissions elsewhere in the world. Although these are cost-effective, their fairness can be contested because these methods imply that other people have to decrease their carbon footprints and the one who pays gets the credits. Another method of CO_2-compensation is absorption of one's own emitted CO_2 by carbon capture and storage (CCS), making one's own emissions climate-neutral.

Reforestation

At this moment, the most cost-effective method for CCS is reforestation: planting trees.[16] Newly planted trees can absorb carbon for several decades, but due to the above safety reasons (avoiding critical climate system thresholds) we should absorb all our emissions within ten years. Keeping this timeframe in mind, Treecological (from Bos+) provides reforestation in Ecuador at a cost of 34 euro per ton CO_2.

Although reforestation is 10 times costlier than the first two compensation methods, it is also a rather cheap, low hanging fruit which is not generalisable: there is not enough surface area for reforestation to compensate for our global carbon footprint. Our global greenhouse gas emissions cannot be offset with merely the above cost-effective interventions.

11.3. Mitigation by long-term emission avoidance

Over the longer term, after a few years, we will need other climate-friendly solutions. We can invest in e.g. renewable energy, but our current technologies are not yet the most climate-friendly. It might be much better to invest in scientific research, to invent new climate-friendly technologies that can be applied in the future. According to some economists and the Copenhagen Consensus Center, the benefit-cost ratio of doing more energy research could be 11 euro benefits (increased social, economic and environmental good) per 1 euro spent (invested costs). That benefit-cost ratio is an order of magnitude higher than 1 and could be much higher than e.g. doubling renewable energy or doubling energy efficiency with our current technologies.

Scientific research for climate friendly technologies

The UAntwerp is a research institute where engineers develop new technologies. Because the carbon footprint of transporting people is relatively high (50% of the total carbon footprint), new climate-friendly transport technologies are needed (e.g. more efficient electric vehicles). The UAntwerp could invest in more research for climate-neutral transportation. This is a risky investment, because the results are not yet certain, but it can be expected that it will help reduce the carbon footprint in the far future (over a few decades).

Clean meat

Apart from developing more climate-friendly energy and transportation technologies, also our food system can become more climate-friendly. One possibly very effective new food technology is clean meat: lab-grown meat without the animal. The production of clean meat can become much more climate-friendly compared to the production of animal meat. The Good Food Institute, also a top charity recommended by Animal Charity Evaluators, develops and promotes clean meat.

16 Bastin, J.-F. e.a. (2019). The global tree restoration potential. Science Vol. 365, Issue 6448, pp. 76-79.

Market mechanisms

However, merely employing climate-friendly technologies will not be enough, because there is a risk for a rebound effect: the efficiency gains might be lost due to increasing consumption levels. For example, the investment in scientific research led physicists to the development of highly energy-efficient LED light bulbs. That was a very cost-effective investment because companies and households can now switch to LED lights. That is why those physicists earned a Nobel Prize. However, this lowers the electricity consumption and hence the costs. Due to lower electricity costs, households might increase the use of light bulbs or might have more money left for other consumption activities such as an extra travel by plane. This could partially negate the energy efficiency gains.

How can we avoid this rebound effect? The economically most-effective way is either a carbon tax or a cap-and-trade system (a governmental auction of tradable emission permits). There is a European Emissions Trading System (ETS) for some European industries, but this is not yet implemented in a fair and most effective way. The Carbon Market Watch and the Carbon Tax Center promote effective and fair market mechanisms.

What would the situation be if there was a global cap-and-trade system? In such a system, governments would distribute a fixed amount of emission permits. Every person on earth would get an equal share of emission permits to be used for one's own emissions or to be sold if one's own emissions are lower than the maximum fair amount of emissions (the cap) allowed per person. The poorest people have fewer emissions than the cap, so they could sell their non-used emission permits to the richest people who have more emissions than their maximum allowed level. If such a system would be present, people who have more emissions than the cap would have to buy emission permits at a price of roughly 100 euro per ton of CO_2, increasing with 5 euro per year (this would be the price of an efficient carbon tax to achieve climate targets and to reduce global warming below 1.5°[17]).

11.4. Remuneration of past emissions

Direct cash transfers

In our current economic system, people in rich countries do not buy emission permits, even though they have emissions higher than the cap. This is basically equivalent to saying that when rich people have emissions above the maximum allowed level, they are stealing emission permits worth 100 euro per ton CO_2 from the poorest people who barely emit any CO_2. Therefore, one could say that we have a duty to donate money to the poorest people, as a remuneration fee for stolen goods. An organisation that give direct cash transfers to the poorest people, is GiveDirectly, a top charity recommended by charity evaluator GiveWell. A donated of 100 euro to GiveDirectly is equivalent of buying from the poorest people a virtual emission permit of 1 ton CO_2.

11.5. Adaptation to past emissions

And last but not least, we have the choice to pay a remuneration fee for all the health damages caused by our past carbon footprint. The highest estimate of loss of healthy life-years (Disability Adjusted Life Years or DALYs) from climate change in literature, is 0,003 DALYs per

17 This value is a rough estimate of an efficient carbon tax, based on the 'high damage scenario' under 'random estimated climate sensitivity' according to: Simon Dietz & Nicholas Stern (2014). Endogenous growth, convexity of damages and climate risk: how Nordhaus' framework supports deep cuts in carbon emissions. Centre for Climate Change Economics and Policy, Working Paper No. 180 http://www.lse.ac.uk/GranthamInstitute/news/dietz_stern_june2014/

ton CO_2-eq.[18] So emitting 1 ton of CO_2 means the loss of 1,3 healthy days due to global warming. This is the health impact of malnutrition (harvest losses due to bad weather), diarrhoea, cardiovascular diseases (heat deaths), malaria (mosquito spread due to higher temperatures) and floods.

How can we compensate for these damages? Again, we can pick the lowest hanging fruit by donating money to the most cost-effective health organisations. One organisation is the Against Malaria Foundation, also a top charity recommended by GiveWell. A donation of 100 euro to this organisation results in saving 1 healthy life year. In terms of health benefits, this is the equivalent of avoiding 300 ton CO_2 emissions. This donation can also be considered as a payment for adaptation to global warming instead of mitigation of emissions. This adaptation strategy is a very low hanging fruit because it has a cost-effectiveness of merely 0,33 euro/ton CO_2, 10 times lower than the abovementioned most cost-effective mitigation strategies.

18 Goedkoop M. e.a. (2009). ReCiPe 2008. A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level. Report I: Characterisation. Ministry of Housing, Spatial Planning and Environment, the Netherlands.

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UAntwerp's Carbon Footprint 2018, Ecolife in collaboration with the UAntwerp Environmental Office, final report, November 2019.

Ecolife

Ecolife is a centre of expertise for footprinting and ecological behavioural change. Ecolife supports governments, organisations and companies in achieving their ecological objectives.

Valkerijgang 26
3000 Leuven
016 22 21 03
www.ecolife.be
info@ecolife.be

Contact

Bruno Verbeeck
bruno.verbeeck@ecolife.be
016 22 21 03