THE CARBON FOOTPRINT OF THE VUB 2016

ecolife

VUB VRIJE UNIVERSITEIT BRUSSEL

TABLE OF CONTENTS

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

The VUB (Vrije Universiteit Brussel) wants to perform a baseline measurement of its carbon footprint for its main campuses in the Brussels Capital Region (Campus Jette and Etterbeek). Together with an internal working group at the VUB, Ecolife calculated the carbon footprint of the university 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 universities in Belgium, such as the ULB (Université Libre de Bruxelles). The baseline measurement offers a customized tool to recalculate footprint in the future.

The carbon footprint of the VUB was carried out according to the Bilan Carbone® 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 with ISO standardization.

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:	Vrije Universiteit Brussel (VUB)
Address:	Pleinlaan 2, 1050 Elsene
Contact person:	Rebecca Lefevere
Mail:	Rebecca.Lefevere@vub.be
Tel:	+32 (0)2 629 14 76
Examined sites:	Campus Etterbeek & Campus Jette
Data year:	2016

Executor

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

Date first draft report:	August 2017
Date publication final report:	November 2017

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* CH4 (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 is equivalent to 34 ton of CO_2. Each greenhouse gas can be translated into tons of CO_2-equivalents.

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

3.3. What is our carbon footprint?

If we divide the global greenhouse gas emissions by 7 billion people, then 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).

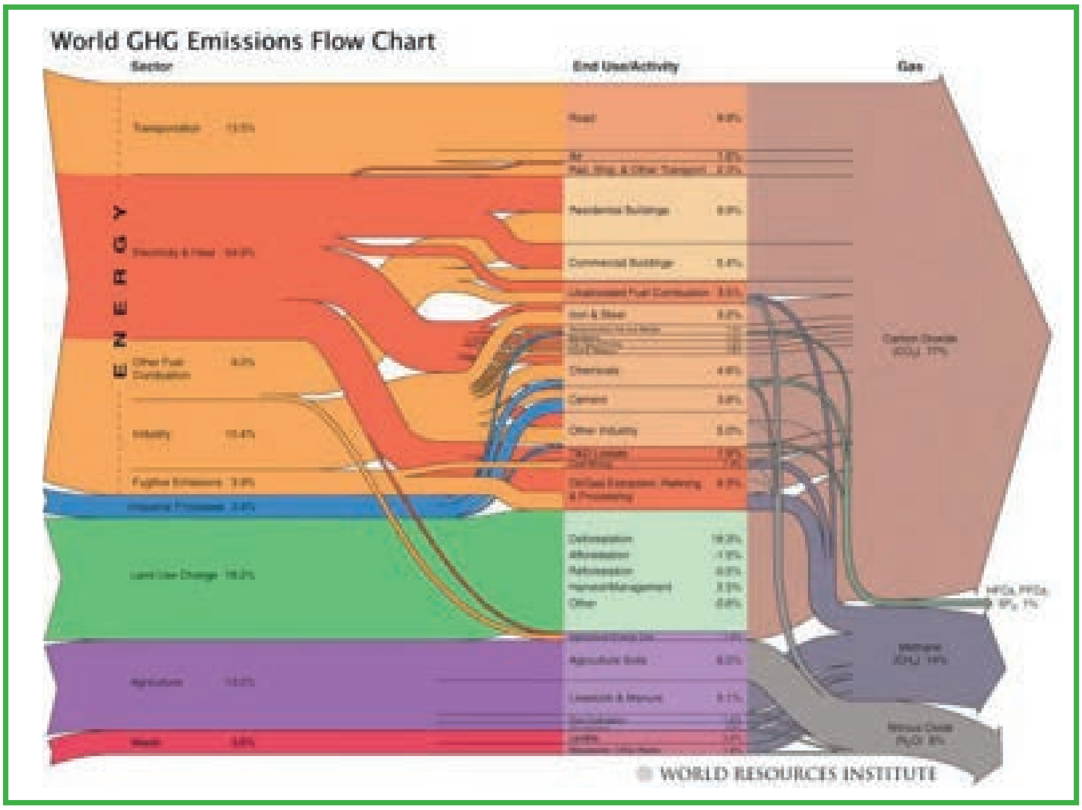

Figure 1: Subdivisions of the carbon footprint by sector, activity and greenhouse gas

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, which causes the climate to warm up. When the atmospheric temperature increases more than 1.5°C above the 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. We then 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.

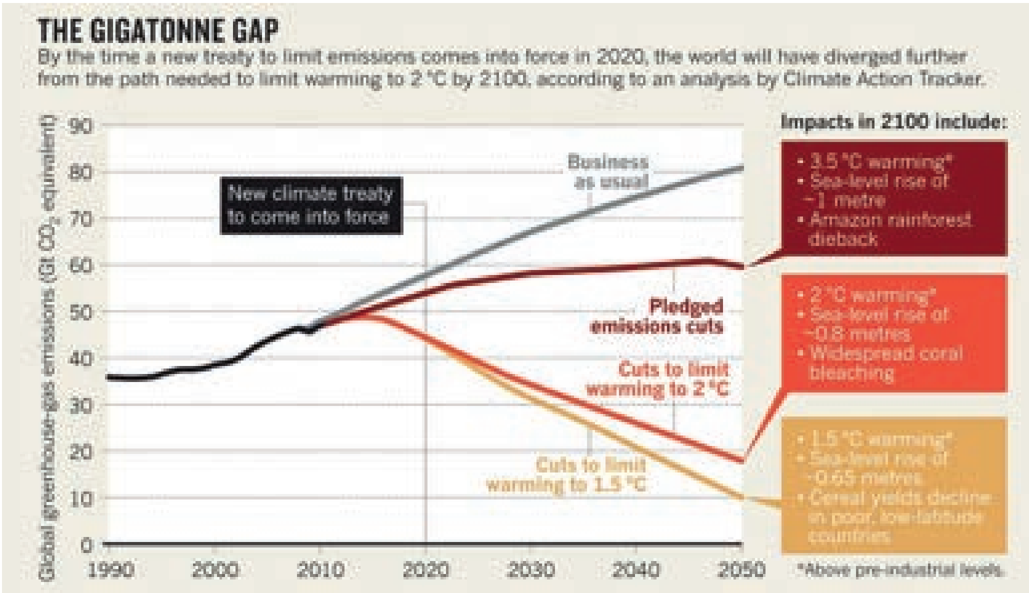

Figure 2: Reduction of the carbon footprint according to climate targets [3]

3.5. Why calculating the carbon footprint of an organization?

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

First, a high carbon footprint creates financial vulnerability for an organization. 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 probably 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.

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

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

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

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

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

3.6. What is included in the carbon footprint of an organization?

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

Scope 1 (direct GHG emissions) consists of all the direct greenhouse gas emissions on the site or by the cars owned by the organization or company. This involves the 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 on the site. These indirect emissions are the 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 from 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 organizations' carbon footprint.

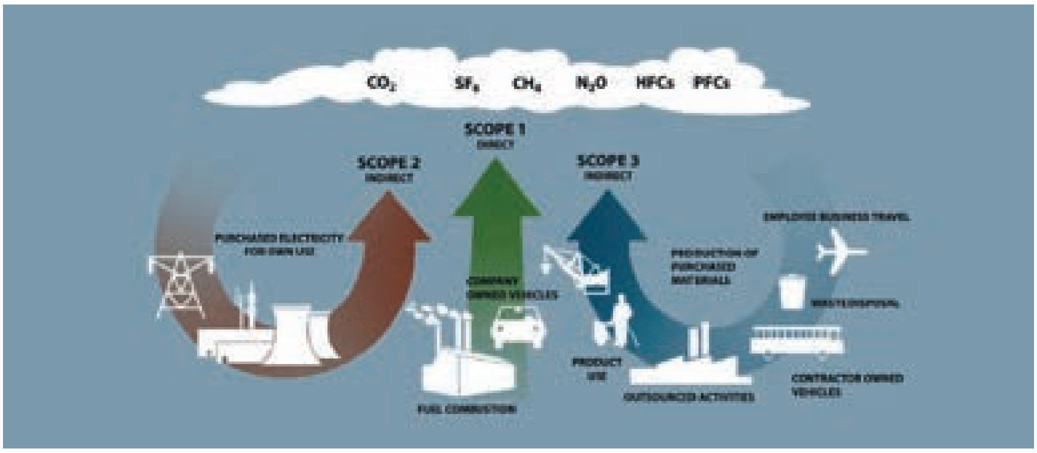

Figure 3: ISO scopes

4. METHODOLOGY

The assessment of an organisations' carbon footprint is conducted with the following methodological steps:

- Definition of the scope;
- Selection of impact categories;
- Data collection;
- Calculation and analysis of the results, and
- Establishing actions for reductions.

4.1. Definition of the scope

In consultation with the VUB, taking into account the available data and the scope used in the ULB carbon footprint study (CO_2Logic 2016), the carbon footprint of the VUB has the following scope.

Sites:

- the campuses at Etterbeek and Jette,
- administrative, research and education buildings, including sporting facilities on Etterbeek (see next section for the list of included buildings),
- student homes owned by VUB (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 located 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 (IT, furniture), student mobility (including airplane travel for foreign students studying at the VUB), student courses paper use, energy use and general waste generated at the student homes on the campuses,
- food consumption (meals) at the student restaurants.

In the figures below the campuses of Etterbeek and Jette with all their facilities are presented.

Figure 4: Campus Etterbeek

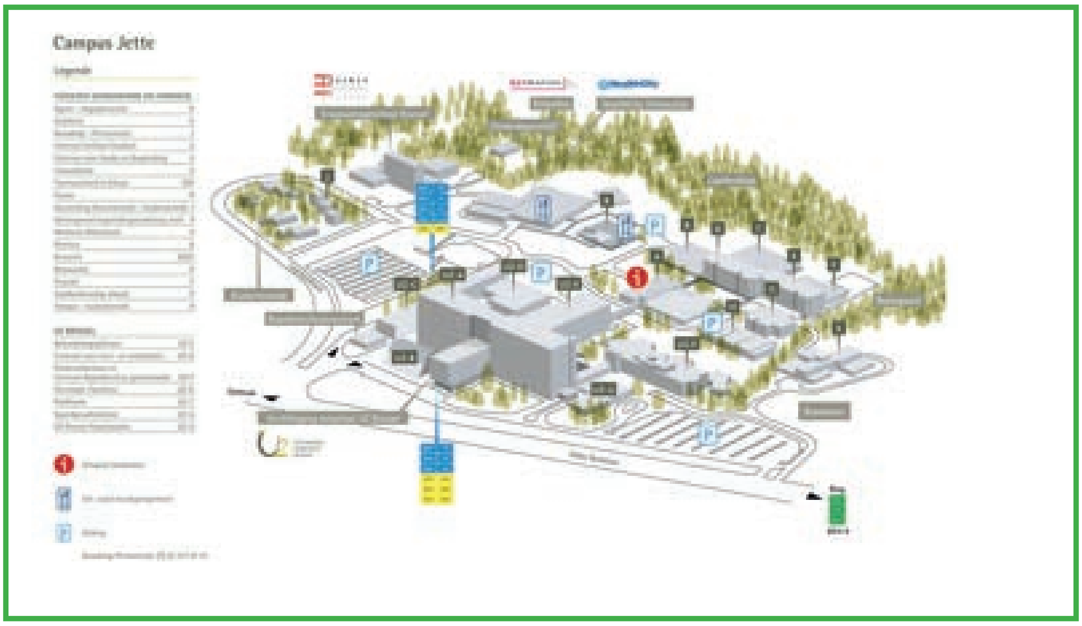

Figure 5: Campus Jette

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

- private student homes not owned by the VUB;
- food consumption at places other than the student restaurants at the campuses;
- equipment and furniture of the student homes owned by the VUB (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);
- spin-offs of the VUB;
- water consumption (not included due to expected negligible share to the total footprint).

4.2. Impact categories

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

1. Energy: emissions related to direct energy use (natural gas, electricity used on the 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 restaurant, ICT-equipment and services;
4. Direct waste: emissions from the transport and treatment of waste collected at the VUB;
5. End-of-life: emissions from the transport and treatment of waste generated for the VUB related activities but not collected at VUB (e.g. paper for student courses);
6. Transporting people: emissions from employee commuting, business travel and student mobility, including direct emissions and indirect emissions from the production of the fuels and vehicles;
7. Capital goods: embodied energy related emissions from the production, construction and renovation of infrastructure, equipment, furniture and vehicles owned by the VUB.

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 based on LCA-studies (life cycle analysis) and used in the Bilan Carbone® V7.4 Excel file, except for recycled paper, where the value of EcoInvent 2.0 LCA-database is used. The consumption and infrastructure data, presented in the table below, are data collected by the VUB and processed by Ecolife.

4.3.2. Reference year and data quality

Consumption and infrastructure data of the VUB were collected by Rebecca Lefevere and Maarten Ipers for the year 2016. For the assessment of the number of students, the academic year 2016-2017 was used.

The uncertainty values of the footprint intensities were taken from the Bilan Carbone® V7.4 file. The quality of the consumption and infrastructure data was discussed at meetings with the VUB staff consisting of Lisa Wouters, Hubert Rahier, Dimitri Devuyst, Serge Gillot and Maarten Messagie. Data uncertainty values were estimated using the following rules (conform with the ULB carbon footprint):

- 5% uncertainty on internal data from own direct measurements with local meters (e.g. kWh electricity) or accurately counted (e.g. number of meals);
- 10% uncertainty on internal data with conversion factor (e.g. kg paper based on number of sheets);
- 20% uncertainty on data extrapolated with assumptions (e.g. leaks of cooling gases, km travel based on surveys);
- 50% uncertainty on data with very uncertain extrapolations (e.g. amount of furniture based on euro expenditures).

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 collecting all the data by the VUB, these data were processed by Stijn Bruers (Ecolife) to become suitable for the Bilan Carbone® method, according to the 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 both the campuses Etterbeek and Jette were calculated.

	Impact category	Etterbeek	Jette	Unit	Uncertainty
	number of students	13.918	1.500		0%
	number of employees	2.693	484		0%
Energy	natural gas (LHV)	24.272.869	10.265.521	kWh	5%
	purchased electricity, biomass	15.520.866	6.402.261	kWh	5%
	avoided grey electricity production from own produced electricity (from PV and CHP)		-628.544	kWh	5%
Non-energy direct emissions of Kyoto halocarbons	leaks cooling installationsn during use, R134a	0,008	0,007	tonnes	20%
	leaks cooling installationsn during use, R404a	0,005	0,000	tonnes	20%
	leaks cooling installationsn during use, R407c	0,017	0,019	tonnes	20%
	leaks cooling installationsn during use, R410a	0,017	0,007	tonnes	20%
	leaks cooling installationsn during use, R507	0,001	0,000	tonnes	20%
Inputs	common metals	5,3	0,0	tonnes	20%
	plastics (PET)	1,2	0,0	tonnes	20%
	paper (student courses) from recycled material	36	3,9	tonnes	10%
	paper from recycled material	5,7	0,7	tonnes	5%
	paper from new material	75	8,8	tonnes	5%
	cardboard	0,4	0,0	tonnes	20%
	medical products	4,7	13,8	tonnes	5%
	industrial products	12,3	4,5	tonnes	5%
	computer and office equipment	464.121	83.731	euros	5%
Agricultural products (food)	typical meal (with beef)	18.865	2.472	number of meals	5%
	typical meal (with porc)	57.465	7.529	number of meals	5%
	typical meal (with chicken)	52.587	6.890	number of meals	5%
	seafood meal (with fish)	30.443	3.989	number of meals	5%
	seafood meal (with shrimp)	3.593	471	number of meals	5%
	vegetarian meal (with cheese)	21.066	2.760	number of meals	5%
	vegan meal	18.803	2.464	number of meals	5%
Direct waste	average household waste - incineration	396	182	tonnes	5%
	steel or tinplate - recycling	5,3	0,0	tonnes	20%
	plastic (PET) - recycling	1,2	0,0	tonnes	20%
	paper - recycling	81	10	tonnes	5%
	cardboard - recycling	0,4	0,0	tonnes	20%
	SIW (Special Industrial Waste) - stabilisation and storage	6,1	2,2	tonnes	5%
	SIW (Special Industrial Waste) - incineration	6,1	2,2	tonnes	5%
	DMW (Dangerous Medical Waste) - incineration	4,7	13,8	tonnes	5%
End of life	paper (student courses) from recycled material	36	3,9	tonnes	5%
	leaks cooling installations, R134a	0,041	0,033	tonnes	20%
	leaks cooling installations, R404a	0,023	0,001	tonnes	20%
	leaks cooling installations, R407c	0,086	0,097	tonnes	20%
	leaks cooling installations, R410a	0,083	0,035	tonnes	20%
	leaks cooling installations, R507	0,007	0,000	tonnes	20%

	Impact category	Etterbeek	Jette	Unit	Uncertainty
Transporting people - employee commuting	average passenger car	4.467.248	2.133.339	vehicle.km	20%
	bus & coach (urban networks)	557.285	70.287	passenger.km	20%
	train in Belgium	14.131.435	1.110.557	passenger.km	20%
	subway / tram / trolley	1.232.027	187.735	passenger.km	20%
Transporting people - employee business travel	average passenger car	922.898	316.169	vehicle.km	20%
	train in Belgium	1.447.135	119.518	passenger.km	20%
	train in Germany	23.407	4.293	passenger.km	20%
	train in Netherlands	29.956	5.494	passenger.km	20%
	train in United-Kingdom	27.801	5.099	passenger.km	20%
	train in France, TGV	46.730	8.570	passenger.km	20%
	plane, 100-180 seats, 0-1000 km	99.665	18.279	passenger.km	20%
	plane, 180-250 seats, 1000-2000 km	1.139.307	208.952	passenger.km	20%
	plane, 180-250 seats, 2000-3000 km	992.910	182.102	passenger.km	20%
	plane, 180-250 seats, 3000-4000 km	527.875	96.814	passenger.km	20%
	plane, 180-250 seats, 4000-5000 km	206.250	37.827	passenger.km	20%
	plane, > 250 seats, 5000-6000 km	102.457	18.791	passenger.km	20%
	plane, > 250 seats, 6000-7000 km	443.623	81.362	passenger.km	20%
	plane, > 250 seats, 7000-8000 km	0	0	passenger.km	20%
	plane, > 250 seats, 8000-9000 km	26.609	4.880	passenger.km	20%
	plane, > 250 seats, 9000-10000 km	0	0	passenger.km	20%
	plane, > 250 seats, 10000-11000 km	91.172	16.721	passenger.km	20%
	plane, > 250 seats, > 11000 km	14.299.071	2.622.490	passenger.km	20%
Transporting people - students' travels	average passenger car	13.374.248	2.310.262	vehicle.km	20%
	bus & coach (urban networks)	6.166.591	698.331	passenger.km	20%
	train in Belgium	45.024.982	1.943.383	passenger.km	20%
	train abroad	2.303.267	248.233	passenger.km	20%
	subway / tram / trolley	4.690.284	291.742	passenger.km	20%
	plane, 180-250 seats, 1000-2000 km	1.890.830	203.782	passenger.km	20%
	plane, 180-250 seats, 5000-6000 km	12.004.267	1.293.749	passenger.km	20%
Capital goods	buildings (dwellings, concrete)	32.588	7.383	m^2 floor area	20%
	buildings (education, concrete)	197.471	40.649	m^2 floor area	20%
	depreciation period buildings	40	40	years	
	TC2 or "normal" parking areas (bitumen)	27.272	5.694	m^2 surface area	20%
	depreciation period parking areas	40	40	years	
	vehicles	18	0	tonnes	20%
	depreciation period buildings	10	10	years	
	furniture	7.873.913	2.313.488	euros	50%
	depreciation period furniture	20	20	years	
	IT	4.033.167	826.052	euros	50%
	depreciation period IT	5	5	years	

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, such as furniture, have lower contributions to the total carbon footprint of the VUB.

As the results in the next chapter demonstrate, transporting people has a large share of the carbon footprint, and its data uncertainty is estimated to be 20%. Therefore, in order to keep sufficiently track of the footprint reductions of sustainable mobility actions, more accurate transport data might be required in future calculations of the footprint.

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	• Etterbeek: Pleinlaan 2, 5 & 9, student homes, Schoofslaan, Triomflaan and Nieuwelaan. • Jette: campus, student homes and student restaurant.
Assumptions	For the local CHP-installation (Combined Heat and Power cogeneration), we assume an efficiency of 50% (meaning that 1 kWh thermal heat corresponds with 2 kWh primary energy). For Pleinlaan 5 and 9, we assume resp. 59% and 46% of the buildings are in use by the VUB.
Calculation equations	• Footprint = footprint intensity gas (kg CO_2/kWh primary energy) x kWh primary energy. • kWh primary energy = kWh thermal natural gas + kWh primary energy for CHP. • kWh primary energy for CHP = kWh thermal heat / CHP efficiency.

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	• Etterbeek: Pleinlaan 2, 5 & 9, student homes, Schoofslaan, Triomflaan and Nieuwelaan. • Jette: campus, student homes and student restaurant.

Assumptions	When PV (photovoltaic) and CHP (Combined Heat – Power) electricity is locally produced and sold to the grid, we can assume that this replaces average electricity production. Hence, the generation of average Belgian (grey) electricity is avoided. This means that selling green electricity counts as carbon credits and has a negative carbon footprint.
Calculation equations	• Footprint = footprint purchased electricity – footprint produced and sold electricity. • Footprint purchased electricity = footprint intensity green electricity from biomass (kg CO_2/kWh) x kWh purchased electricity. • Footprint produced electricity = footprint intensity Belgian average electricity mix (kg CO_2/kWh) x profit from produced and sold electricity from CHP and PV (euro) / price of electricity (euro/kWh).

4.4.2. Non-energy

Description	The direct, non-energy emissions (ISO scope 1) consist of the leaks of greenhouse gases (Kyoto halocarbons) of cooling installations during operation.
Scope	• List of 300 cooling installations for air conditioning. • Etterbeek: Pleinlaan 2, 5 & 9, Triomflaan. • Jette: whole campus.
Assumptions	There are five Kyoto halocarbon cooling gases: R134a, R404a, R407c, R410a en 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 the emissions from the production of all materials that end up in the direct waste.
Scope	• Volume of metals, plastics, cardboard, medical products, industrial products are based on waste data (kg) for Etterbeek and Jette. • Volume of paper is based on waste data (kg) for Etterbeek and Jette plus student courses.
Assumptions	All materials are assumed new, except cardboard, paper for student courses and 7% of other paper, which are assumed to be from recycled material.
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). • Amount of paper from student courses = number of pages (from courses Overkoepelende Studentendienst + Cursusdienst VUB) x weight per page.

Inputs: meals

Description	The indirect emissions (ISO scope 3) for meals are the emissions from the production of agricultural products (food) consumed at the student restaurants.
Scope	Student restaurants Etterbeek and Jette.
Assumptions	There are seven types of meal: with beef, pork, chicken, fish, shrimp, vegetarian with cheese and vegan.
Calculation equations	Footprint (per type of meal) = number of meals x footprint intensity of meal (kg CO_2e/meal).

Inputs: office equipment

Description	The indirect emissions (ISO scope 3) for office equipment are the emissions from the production of purchased computer and office equipment (e.g. small electronics).
Scope	Purchases of small equipment for offices ('kleine kantoorbenodigdheden') Etterbeek and Jette.
Assumptions	We assume that the small electronic equipment is not included in the direct waste data.
Calculation equations	Footprint = purchases (euro) x footprint intensity (monetary ratio) of computer and office equipment (kg CO_2/ euro).

4.4.4. Direct waste

Description	The indirect emissions (ISO scope 3) for direct waste are the emissions from the waste treatment of the collected waste at the VUB.
Scope	The volumes of metals, plastics, paper/cardboard, medical products, industrial products and average household waste are based on waste data (kg) for Etterbeek and Jette.
Assumptions	• Emissions can be avoided with recycling (avoiding the production of new materials) and incineration with energy recuperation (avoiding production of electricity from non-waste sources). • Metals, plastics, paper and cardboard are 100% recycled. Household waste and dangerous medical waste is 100% incinerated. Special industrial waste is 50% stabilisation and storage and 50% incineration. Paper waste consists of 7% from recycled material.

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). • Negative footprint of avoided emissions from incineration = avoided production of new electricity (kWh) due to electricity production from waste incineration x footprint intensities of production (kg CO2/kWh for average Belgian electricity mix). • Amount of metals = metal waste + 1/3 PMD-waste. • Amount of plastics = ½ PMD-waste. • Amount of household waste = 'restafval' and 'groot vuil'. • Amount of cardboard waste = 0% of paper waste + 1/6 PMD-waste. • Amount of special industrial waste = chemical waste. • Amount of dangerous medical waste = RMA.

4.4.5. End-of-life

End-of-life: paper

Description	The indirect emissions (ISO scope 3) for end-of-life of paper are the emissions from the waste treatment of the paper courses used by the students and collected at the student homes.
Scope	Paper waste from student courses.
Assumptions	The paper waste treatment is a mix of recycling and incineration according to the average Belgian treatment of paper waste.
Calculation equations	• Footprint of waste treatment = amount of materials (kg) x footprint intensity for average Belgian treatment of paper waste (kg CO_2/kg material). • Negative footprint of avoided emissions of waste treatment = avoided production of new materials (kg) and electricity (kWh) due to recycling of paper and electricity production from paper waste incineration x footprint intensities of production (kg CO_2/kWh for average Belgian electricity mix, kg CO_2/kg material for production of new paper). • Amount of paper from student courses = number of pages (courses Overkoepelende Studentendienst + Cursusdienst VUB) x weight per page.

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 300 cooling installations. Etterbeek: Pleinlaan 2, 5 & 9, Triomflaan. • Jette: whole campus.
Assumptions	There are five Kyoto halocarbon cooling gases: 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 the direct emissions of the vehicles and the indirect emissions of the production of fuels, vehicles and transport infrastructure.
Scope	Vehiclekilometres with cars, passengerkilometres with bus, train and tram/subway.
Assumptions	We assume working days at the VUB site are 80% of all working days. The other 20% are days when employees work at home or at another site (business travel).
Calculation equations	• The total distance travelled per year for an employee (of campus Etterbeek or Jette) = distance per working day (based on the postal code of home address and campus site) x 2 rides per day x 5 days per week x percentage employment rate x 80% (working days at VUB) x 44 working weeks per year. • The total distance travelled for all employees (per campus site) is the sum of the distances travelled over all employees, using the list of all active employees. • To calculate the distances travelled per mode of transport (car, train, bus, tram/metro), we use the mobility survey 2014. First the distances per working day for surveyed employees are calculated based on postal codes. These distances are multiplied with the number of working days per week (5 for full-time employees and 2,5 for part-time). Each distance is divided in distances travelled by car, train, bus and tram according to the survey answers. If first or final part of the trajectory is done with a different means of transport, first and final parts each account for 10% of the total distance. Dividing the sum of all distances travelled per means of transport with the total distances travelled of all the surveyed employees gives a weighted average of percentages per means of transport, weighted by the distances travelled.

	• With these weighted percentages and the total distances travelled for all employees, we can calculate the total distances for Etterbeek and Jette for each means of transport. • Footprint = distance travelled (km) x footprint intensity (kg CO_2/km).

Transporting people: employee business travel

Description	The emissions (ISO scope 3) for employee business travel are the direct emissions of the vehicles and the indirect emissions of the production of fuels, vehicles and transport infrastructure.
Scope	Domestic and international travel with cars, trains and airplanes.
Assumptions	• Allocation to Etterbeek and Jette of distance travelled by car is based on the number of travels with private cars and service cars for Etterbeek and Jette. • The distance with trains for domestic travels is extrapolated from the distance travelled with cars, using the ratio of the number of travels with trains and cars for Etterbeek and Jette staff members based on the mobility survey 2014 (number of travels and percentages by car and train for surveyed staff members). • The distance with trains for international travels is calculated using the transportation expense notes: for each country (Germany, Netherlands, United-Kingdom and France), the distances of destination from Brussels are calculated. The allocation of the total distances travelled is based on the number of staff members of Etterbeek and Jette. • The distances of flights are calculated using the transportation expense notes: the distances from Brussels airport to destinations are calculated for all travels with known destination. Total distances are extrapolated using the ratio of the total number of flights and the number of flights with known destination. Total distances are divided in 12 categories, from flights of 0-1000 km to flights of more than 11000 km. • A part of the flight expense notes is from outgoing, non-Erasmus exchange students with a VLIR UOS travel grant. These flights should not be included in the VUB footprint, so the distances of these flights are subtracted from the total. These distances are calculated based on the number of non-Erasmus students with a VLIR UOS travel grant and the countries of destination, assuming one back and forth flight per year per student. • The footprint intensity of a flight also contains emissions not covered by the Kyoto protocol, in particular water vapour at high altitudes (strato-spheric greenhouse effect).
Calculation equations	• Distance cars = kilometre and fuel compensation (euro) / compensation price (euro/km). • Distance with trains for domestic travels = distance travelled with cars x number of travels with train / number of travels with cars. • Footprint per means of transport = distance travelled (km) x footprint intensity for means of transport (kg CO_2/km). • Footprint per flight distance category = distance travelled (km) x foot-print intensity of category (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	• For Belgian students studying at the VUB: vehiclekilometres with cars, passengerkilometres with bus, train and tram/subway. • For international students, registered at the VUB: distances with car, train and airplane.
Assumptions	• For the Belgian students, we have to make a distinction between commuter students who travel from home to the campus all days they have classes or exams, and residential students who travel from home to their student rooms once a week. The student mobility of the residential students from their student rooms to the campus is mostly done by foot, bike or tram/metro on relatively short distances, so this footprint is considered negligible and is not calculated. • Distance per travel per student of a commuter student is calculated based on postal codes of home address of a commuter student in the student mobility survey (Dutch and English). • The distance from home to student room of a residential student is calculated based on postal codes of home address of all residential students. • For foreign students registered at the VUB (both Erasmus and non-Erasmus students), distances by car, train and airplane are calculated based on the number of students and the distances of the countries of origin. For neighbouring countries, we assume an average distance of 500 km, 5 back and forth travels per year, 70% with train and 30% by car. • For non-neighbouring EU-countries, we assume an average distance between 1000 and 2000 km, 2 travels per year, by airplane. For non-EU students, we assume an average distance between 5000 and 6000 km, 1 travel per year, by airplane. The distances are allocated to Etterbeek and Jette according to the ratio of total number of students at Etterbeek and Jette. • The footprint of outgoing students (VUB-students who study at another university and travel to another country) are not included in the VUB-footprint.

Calculation equations	• Total distance travelled per commuter student = distance per travel per student (km) x 116 days per year x 2 travels per day. • Total distance travelled per commuter student by means of transport (car, train, bus and tram/metro) is based on estimated percentages of used means of transport per travel. If more than one means of transport is used, then 80% of the distance is for main means of transport and 20% for secondary means (or 10% plus 10% for secondary and tertiary means). If the main means of transport is unclear (contains two types), then 50% of the distance is travelled with one type of transport and 50% with the other. If the means of transport is car with carpooling, then 50% of the car travelled distance is used. • Total distance travelled by campus (Etterbeek or Jette) by means of transport (car, train, bus and tram/metro) for all surveyed commuter students is the sum of distances travelled by means of transport by campus over all surveyed commuter students. • Average distance travelled by a residential student = the average home-student room distance (averaged over all residential students) x 34 weeks per year x 2 travels per week. For car transport, roughly 50% of the students are brought by their parents, which means a doubling of displacements. Therefore, the car travel footprint is multiplied with an extra factor 1,5. • Total distances travelled by campus (Etterbeek or Jette) by means of transport (car, train, bus and tram/metro) for all surveyed residential students = the average distances travelled of a residential student x the number of surveyed residential students in the student mobility survey x the average of estimated percentage of the used means of transport (according to the student mobility survey), averaged over all surveyed residential students in the student mobility survey. • Total distances travelled by campus (Etterbeek or Jette) by means of transport (car, train, bus and tram/metro) for all students is the sum of the distances travelled of the surveyed commuter students and residential students, extrapolated using the ratio of the total number of students and the number of surveyed students. • Footprint per means of transport = distance travelled (km) x footprint intensity for means of transport (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	Buildings Etterbeek: B, B1, C, D, E, F, G, I', K, KB, Ke, L1, L3, L4, M, N1, NL, P, Q, R, S, V, W, Z, Restaurant, Sportopolis, Plainlaan 5, Pleinlaan 9, student homes Schoofslaan, Triomflaan and U-residence. Buildings Jette: A, B, C, D, E, F, G, H, K, R, student homes, MEBO (I, II & III) and KRO.
Assumptions	There are two types of buildings: offices and education buildings. 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.

Capital goods: roads and car parks

Description	The indirect emissions (ISO scope 3) for parking area are the emissions from the construction and renovation of the area.
Scope	Parking area Etterbeek: impermeable surfaces. Parking area Jette: extrapolated from parking area Etterbeek using ratio of building area of Jette and Etterbeek.
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 the emissions from the production of cars.
Scope	All service vehicles
Assumptions	The depreciation period of cars is 10 years. A car weights on average 1,5 tonnes.
Calculation equations	Footprint of vehicles = number of vehicles x average weight of vehicle (1,5 ton/car) x footprint intensity of average car (kg CO_2/car) / depreciation period.

Capital goods: furniture

Description	The indirect emissions (ISO scope 3) for furniture are the emissions from the production of furniture.
Scope	Purchasing value of all furniture classrooms plus tables and chairs in PC-rooms plus tables, chairs and cabinets staff members.
Assumptions	The depreciation period of furniture is 20 years. The monetary value of furniture of classrooms in Jette is based on the number of chairs in the classrooms, multiplied by the ratio of total monetary value of classroom furniture and number of chairs for Etterbeek classrooms.
Calculation equations	• Footprint of furniture = monetary value (euro) x footprint intensity (kg CO_2/euro) / depreciation period. • Monetary value of furniture of staff members = average equipment per staff member x number of staff members.

Capital goods: IT

Description	The indirect emissions (ISO scope 3) for IT are the emissions from the production of IT-equipment.
Scope	Purchasing value of all audiovisual equipment of classrooms plus audiovisual equipment, computers and printers in PC-rooms plus computers and printers for staff members.
Assumptions	The depreciation period of IT-equipmet is 5 years. The monetary value of audiovisual equipment of classrooms in Jette is based on the number of beamers in the classrooms, multiplied by the ratio of total monetary value of classroom audiovisual equipment and number of beamers for Etterbeek classrooms.
Calculation equations	• Footprint of IT equipment = monetary value (euro) x footprint intensity (kg CO_2/euro) / depreciation period. • Monetary value of computers of staff members = average equipment per staff member x number of staff members.

5. RESULTS

This chapter contains the results of the carbon footprint calculation of the VUB for data year 2016. First, 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 VUB footprint. Finally, the footprint for the three ISO scopes is briefly discussed.

5.1. Total carbon footprint

The carbon footprint of the VUB is **34 869 ton CO_2e**. As a comparison, this is the equivalent of driving 125 million kilometres with a car. It also corresponds with the total yearly carbon footprint of almost 1600 average people in Belgium (0,014% of the total Belgian carbon footprint). It requires 1,3 million trees to absorb this amount of CO_2 within one year.

Overview	Emissions, t CO_2e	%
Energy	9.473	27,2
Non-energy	152	0,4
Inputs	1.127	3,2
Direct waste	237	0,7
End-of-Life	770	2,2
Transporting people	19.002	54,5
Capital goods	4.108	11,8
Total	**34.869**	**100**

Table 2: Total carbon footprint results

The total uncertainty (i.e. the combination of the uncertainties of the Bilan Carbone® emission factors and the VUB consumption and infrastructure data) on the total carbon footprint is 25%.

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

- Energy use (natural gas and electricity use on the campuses): **9 473 ton CO_2e** (27%)
- Transporting people (car, public transport and airplane for employee commuting, business travel and student travel including foreign students): **19 002 ton CO_2e** (55%)
- Capital goods (embedded energy for construction of infrastructure and equipment): **4 108 ton CO_2e** (12%)

We see that half of the carbon footprint is related to transporting people and almost one third 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 6 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.

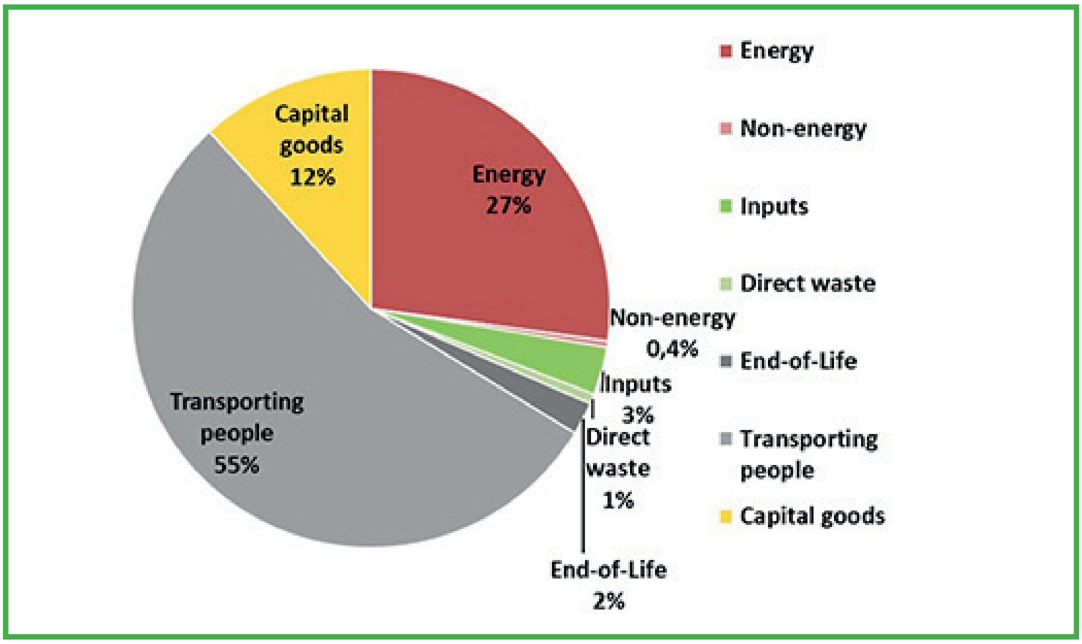

Figure 6: Contributions of impact categories to the total carbon footprint

The footprint values including the total uncertainties are given in Figure 7. These uncertainties are the combination of the uncertainties of the Bilan Carbone emission factors (footprint intensities) and the VUB consumption and infrastructure data.

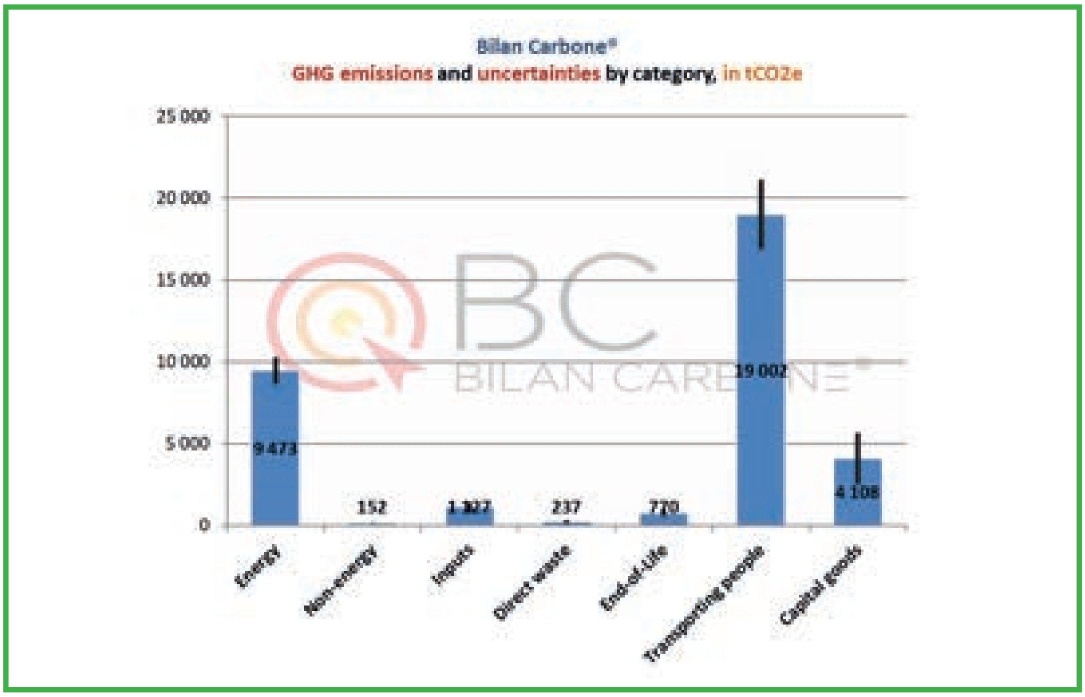

Figure 7: Carbon footprint per impact category

The footprint values and uncertainty values for all impact categories and subcategories and for the two campuses Etterbeek and Jette are summarized in Table 3.

	Emissions Etterbeek	Emissions Jette	Emissions total		Uncertainties	
	kg CO2e	kg CO2e	kg CO2e	Relatives	kg CO2e	%
Energy	**6.788.336**	**2.684.825**	**9.473.161**	**27,2%**	**792.882**	**8%**
Fuels, direct accounting	5.866.396	2.481.026	8.347.422	23,9%	508.793	6%
Electricity purchased	921.939	203.799	1.125.739	3,2%	608.105	54%
Non-energy	**95.662**	**56.423**	**152.086**	**0,4%**	**29.369**	**19%**
Kyoto halocarbons	95.662	56.423	152.086	0,4%	29.369	19%
Inputs	**940.034**	**186.968**	**1.127.002**	**3,2%**	**276.805**	**25%**
Metals	19.484	-	19.484	0,1%	16.067	82%
Plastics	3.785	-	3.785	0,0%	1.071	28%
Papers & cardboard	140.189	16.048	156.236	0,4%	25.672	16%
Chemical products	50.901	54.821	105.722	0,3%	74.938	71%
Agricultural products	300.077	39.318	339.394	1,0%	79.745	23%
Computer and office equipment	425.599	76.781	502.380	1,4%	252.443	50%
Direct waste	**156.036**	**81.411**	**237.447**	**0,7%**	**85.012**	**36%**
Incineration	143.508	66.063	209.571	0,6%	84.481	40%
Recycled or reused waste	2.903	314	3.216	0,0%	1.505	47%
Hazardous waste	9.626	15.034	24.660	0,1%	9.369	38%
End-of-Life	**486.808**	**283.032**	**769.840**	**2,2%**	**146.919**	**19%**
Papers, cardboards	8.495	916	9.411	0,0%	4.729	50%
Leaks and non-energy	478.312	282.117	760.429	2,2%	146.843	19%
Transporting people	**16.393.994**	2.607.769	**19.001.763**	**54,5%**	**2.091.601**	**11%**
Employees commuting, car	1.130.456	539.850	1.670.306	4,8%	336.358	20%
Employees commuting, public transport	778.605	65.884	844.489	2,4%	214.906	25%
Employees business, car	233.543	80.008	313.551	0,9%	63.141	20%
Employees business, public transport	76.189	6.908	83.097	0,2%	21.491	26%
Employees business, plane	3.994.503	732.603	4.727.106	13,6%	1.322.764	27%
Belgian students, car	3.423.237	591.329	4.014.565	11,5%	758.910	19%
Belgian students, public transport	3.164.040	203.910	3.367.950	9,7%	848.742	25%
Foreign students, car	252.659	27.230	279.889	0,8%	52.910	19%
Foreign students, public transport	175.792	18.946	194.738	0,6%	55.080	28%
Foreign students, plane	3.164.969	341.102	3.506.071	10,1%	1.076.652	31%
Capital goods	**3.371.847**	**702.755**	**4.107.578**	**11,8%**	**1.566.256**	**38%**
Buildings	2.527.390	527.614	3.087.980	8,9%	1.432.948	46%
Infrastructures excluding buildings	49.771	10.391	60.163	0,2%	31.406	52%
Vehicles, machines, furniture	55.003	13.252	68.255	0,2%	41.606	61%
IT	739.683	151.498	891.181	2,6%	630.160	71%

Table 3: Carbon footprint per impact category

5.2.1. Energy

Most of the footprint of direct energy use comes from the burning of natural gas on site. Electricity has a smaller contribution because it is green electricity with biomass as energy source. Electricity has a relatively large uncertainty value due to higher uncertainty of the Bilan Carbone® emission factor for biomass.

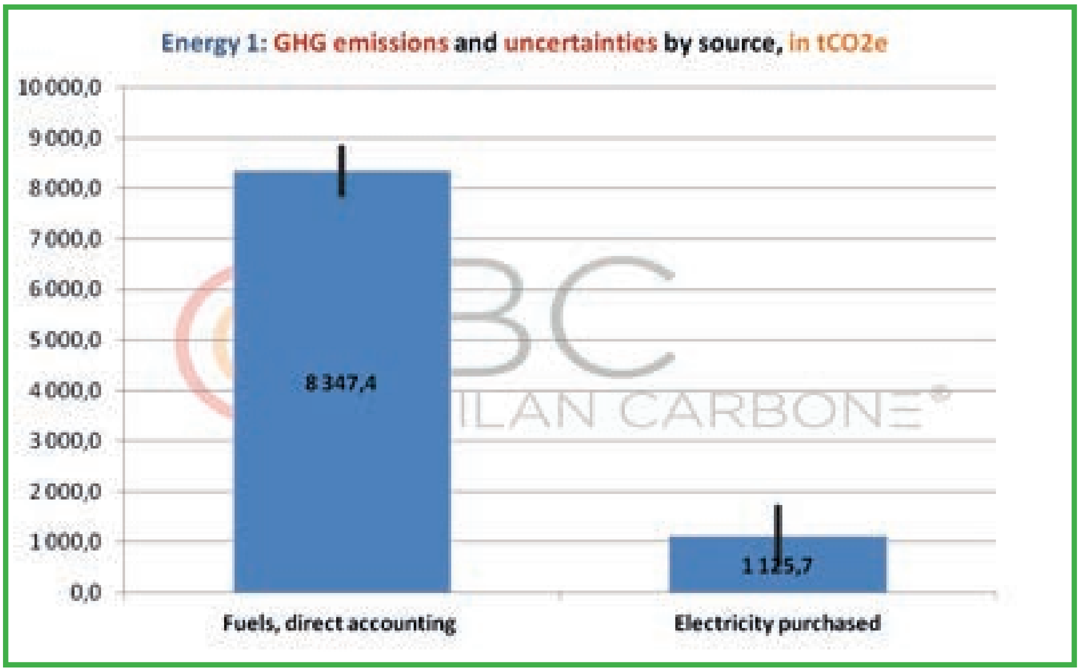

Figure 8: Carbon footprint of energy use

5.2.2. Non-energy

The non-energy related emissions of halocarbon from cooling installations is the smallest impact category which contributes less than 1% 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 a share of less than 4% it has a small contribution to the total footprint. Most of the footprint of inputs (1,6%) comes from the purchase of computer and office equipment (according to monetary ratios).

The footprint of agricultural products consists of the meals consumed at the student restaurants. It has a share of 1% 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.

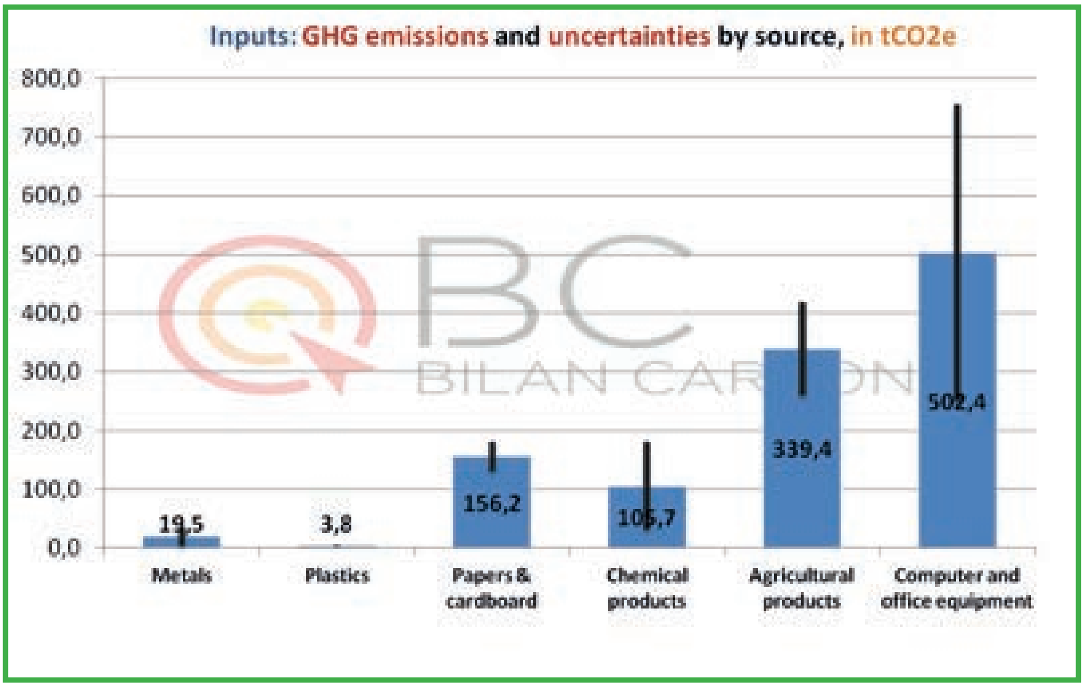

Figure 9: Carbon footprint of inputs

5.2.4. Direct waste

Most of the footprint of direct waste is from the incineration of residual waste, which in weight accounts for 80% of the total waste collected on the campuses.

5.2.5. End-of-Life

The end-of-life footprint consists of the waste generated from VUB activities but not collected on the campuses. This consists of the paper for the student courses and the leakages from dismissed cooling installations. The waste treatment of the student courses has a negligible footprint because the paper can be recycled, and even if incinerated the CO_2 emissions are biogenic. The dismissed cooling installations contribute 2,2% to the total footprint of the VUB. 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 55% of the global footprint, it is worthwhile to study this impact category more in detail. Figure 10 shows the footprint values (and uncertainty ranges) for the different subcategories of mobility.

60% of the mobility footprint is related to student mobility. Student travel by car has the highest share, closely followed by public transport and airplane (foreign students studying at the VUB) which both have a roughly equal order of magnitude (around 23% of the mobility footprint).

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 more than 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 3500 ton CO_2e, which is 10% of the total footprint. This relatively high share of student airplane travel combined with its high uncertainty of 31% means that more accurate travel data (distances and number of flights) are strongly recommended for future recalculations of the VUB footprint.

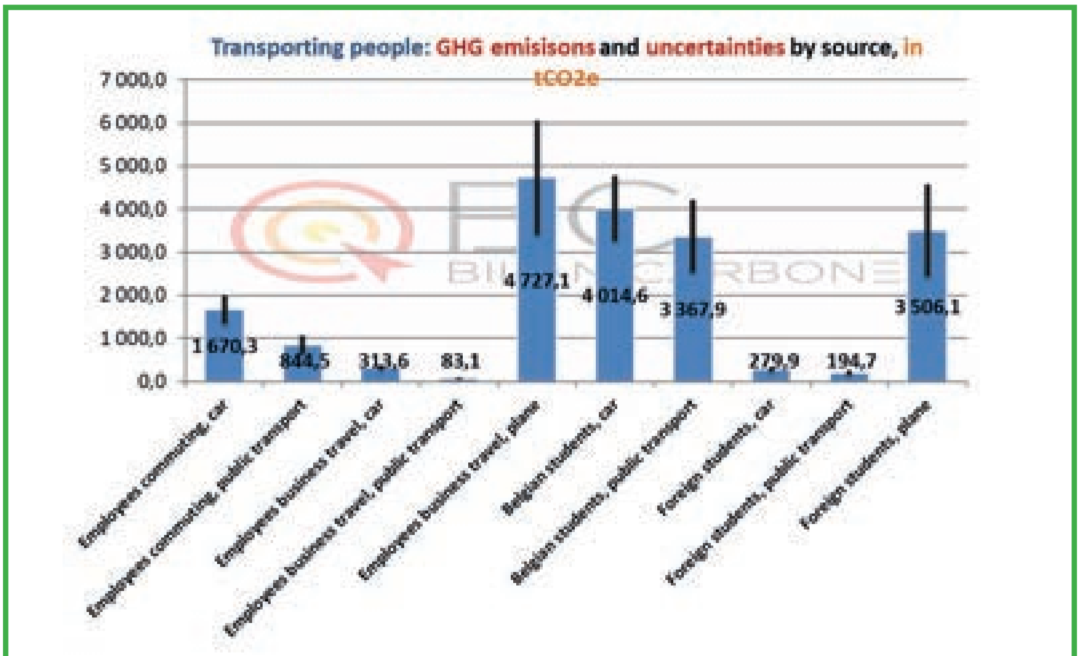

Figure 10: Carbon footprint of mobility

In terms of modal split (percentage of car versus public transport), we see a big difference between Etterbeek and Jette, where Etterbeek has a relatively much higher share of public transport and Jette has a higher share of car use. In Etterbeek, 45% of the carbon footprint of all domestic travel (commuting, business and student travel) comes from public transport, in Jette it is only 19%.

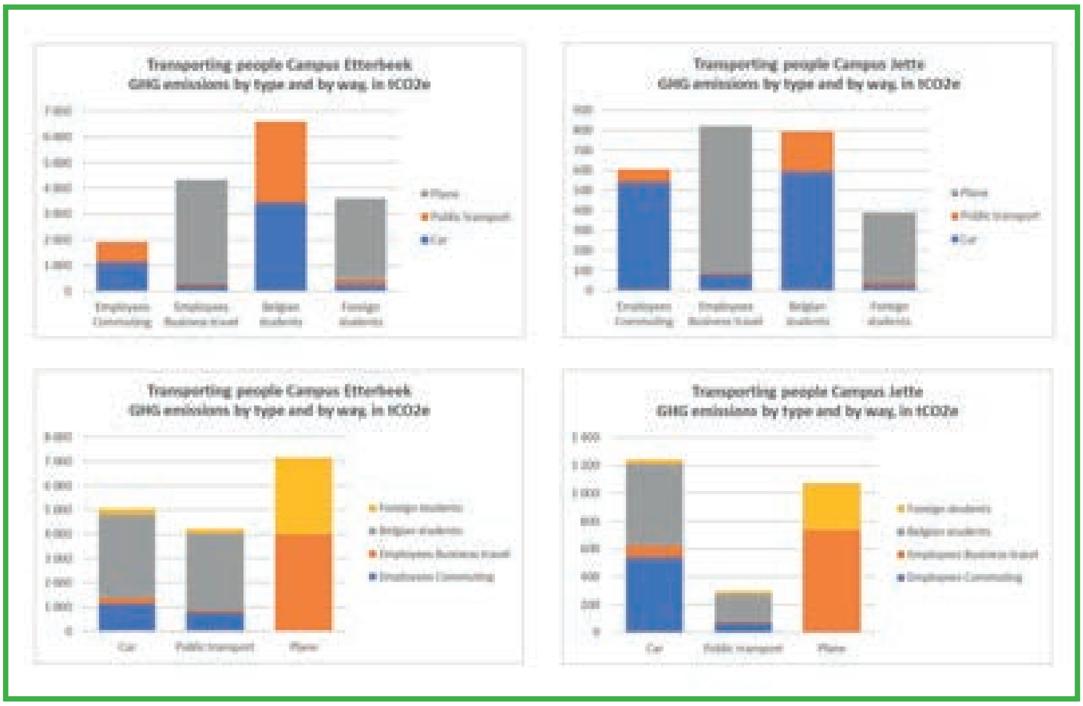

Figure 11: Transporting people by type and by way, Etterbeek and Jette

5.2.7. Capital goods

The final impact category is capital goods, which accounts for 12% of the total footprint. 9% of the total footprint is from the embedded energy of infrastructure (i.e. emissions related to construction and renovation of buildings and paved surfaces). 2,6% is from IT (production of equipment). The production of furniture and cars owned by the VUB accounts for 0,2% of the total footprint.

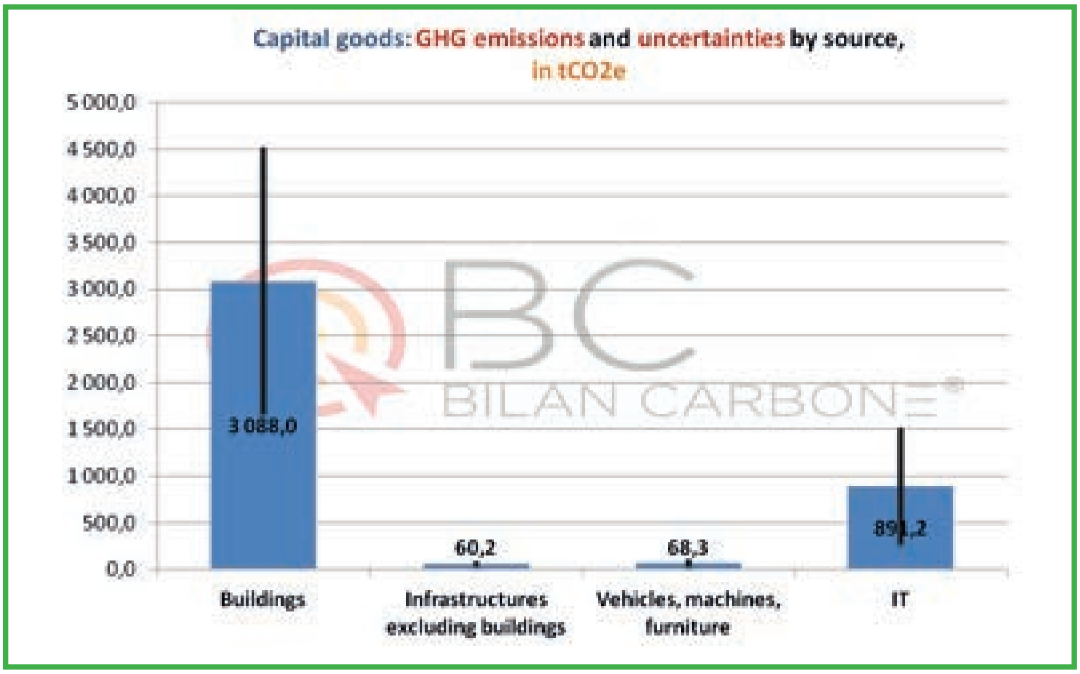

Figure 12: Carbon footprint of capital goods

5.3. Carbon footprint per employee and per student

The total footprint of the VUB 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 VUB footprint. The table below presents the footprints per employee and per student. An average student has a footprint of 2,3 ton CO_2e for all VUB-related activities in 2016.

Overview	kg CO_2e per employee	kg CO_2e per student
Energy	2.982	614
Non-energy	48	10
Inputs	355	73
Direct waste	75	15
End-of-Life	242	50
Transporting people	5.981	1.232
Capital goods	1.293	266
Total	**10.975**	**2.262**

Table 4: Total emissions per employee and student

5.4. Carbon footprint per ISO scope

The total footprint can also be divided by ISO scope, see table below. Of the total emission of Kyoto greenhouse gases (ISO scopes 1+2+3), 23% consists of scope 1 (direct emissions on-site) and 3% of scope 2 (indirect emissions from electricity). Scope 3 accounts for 74% of the total footprint and has the highest uncertainty of 23%.

The ISO scopes include the direct and indirect emissions of Kyoto greenhouse gases. Water vapour is a greenhouse gas, but due to its abundance and short lifetime in the atmosphere it is not included as a Kyoto gas. However, airplane travel also has a high altitude, stratospheric effect of water vapour. This effect doubles the global warming potential of high altitude flights compared to the greenhouse effect of only the CO_2-emissions. The high-altitude water vapour from air travel is included in a 'global' carbon footprint, which is a bit higher than the carbon footprint of ISO scopes 1+2+3.

CO_2e Extraction (t CO2e)	ISO scope 1	ISO scope 1+2	ISO scope 1+2+3	Global
Energy	7.084	8.126	9.473	9.473
Non-energy	152	152	152	152
Inputs	-	-	1.127	1.127
Direct waste	-	-	237	237
End-of-Life	-	-	770	770
Transporting people	-	-	15.272	19.002
Capital goods	-	-	4.108	4.108
Total	**7.236**	**8.278**	**31.139**	**34.869**
% of uncertainty	7%	14%	24%	26%

Table 5: Carbon footprint per ISO scope

Figure 13 shows the same results as the above table: the footprint values per ISO scope and per impact category.

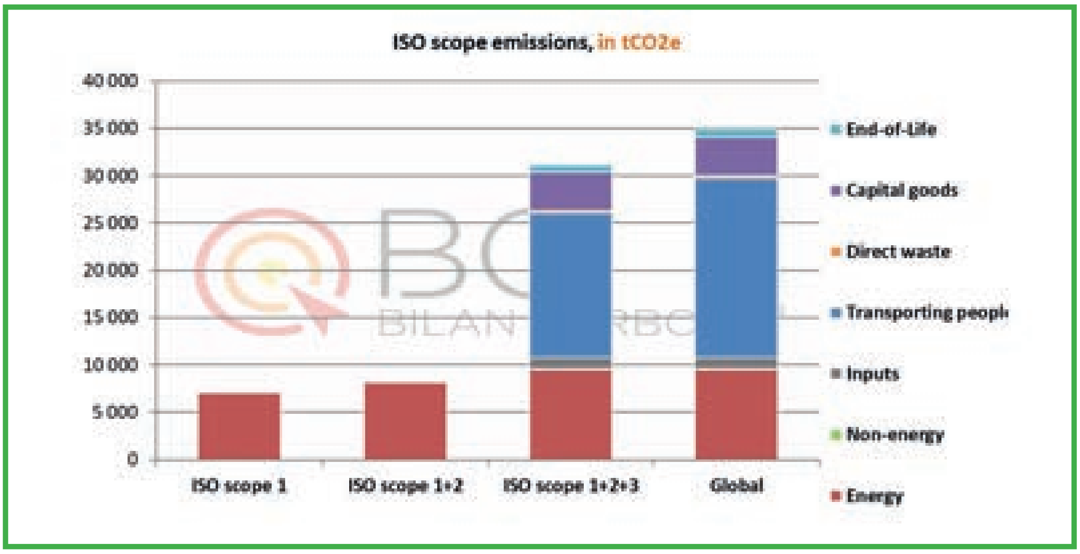

Figure 13: Carbon footprint per ISO scope

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:

- Université Libre de Bruxelles (CO_2Logic, data year 2014) [4],
- Katholieke Universiteit Leuven (Futureproofed, data year 2010) [5],
- University of Antwerp Ecosystem Management Research Group ECOBE (Ecolife, data year 2010-2011) [6],
- Katholieke Hogeschool Leuven (Ecolife, data year 2010) [7].

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 ULB's recent footprint calculation.

6.2. Methodological issues

The comparison of the VUB footprint with other universities and colleges is rather difficult due to methodological issues. Different assumptions (e.g. choices of emission factors based on different 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 a benchmarking exercise between 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 discourage simplistic comparisons of for example the footprint per student (e.g. 2 ton CO_2e for the VUB) with other footprinting studies, unless assumptions and scope are sufficiently similar and uncertainty ranges are sufficiently small.

[4] Report to be published.
[5] Vanderheyden G., Aerts J., e.a. (2013). Nulmeting CO_2 emissies KU Leuven in het jaar 2010. Studie 12428_KUL_Future-proofed, Kessel-Lo, Belgium, 48pp.
[6] Bruers S. (2012). The carbon footprint of ECOBE, academic year 2010-2011. Ecolife, Leuven, Belgium, 18pp.
[7] Bruers S. (2011). De ecologische voetafdruk berekening van de KHLeuven, 2010. Ecolife, Leuven, Belgium, 33pp.

6.3. Comparison of results

The footprinting study of the ULB (CO_2logic, 2016) is most suitable for an inter-university comparison with the VUB, because the scopes are almost identical (apart from some impact categories with a negligible footprint). The ULB has a footprint of 1,7 ton CO_2e per student, compared to 2 ton CO_2e for an average VUB student. This difference can be fully explained by the fact that the average distance travelled by VUB students is higher than ULB students. However, both ULB and VUB results are within each other's uncertainty ranges, given the 20% estimated uncertainty on mobility data and a 25% uncertainty on the total result of the VUB footprint.

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

6.3.1. Energy

- **Energy use**: VUB uses 83 kWh electricity per m^2 floor area per year and 132 kWh natural gas per m^2 heated floor area per year. The total primary energy use is 342 kWhp/m^2. These values are a bit higher than other universities and colleges (e.g. KULeuven, KHLeuven). 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 easily result in large deviations. The EPC-values (energy labels) of buildings are more suitable for comparisons. According to Leefmilieu Brussel (may 2016), the EPC-values of the VUB-buildings are generally worse than other colleges and universities in Brussels.

6.3.2. Inputs

- **Food**: 20% of the meals at the VUB restaurant are vegetarian or vegan. This is a higher percentage than other universities, for example 5% at the KULeuven in 2010 (Future-proofed, 2013)

6.3.3. Direct waste

- **Residual waste for incineration collected at the university**: VUB has 31 kg per person per year. This is roughly twice as high as other universities and colleges (e.g. KHLeuven, KULeuven). Recycled waste seems to be lower than other universities. In weight, residual waste accounts for 80% of the total waste collected on the campuses. This percentage is higher than other universities.

6.3.4. Transporting people

- **Car travel of all students and employees**: VUB has 1365 km per person per year. This is a little bit higher (roughly 15%, within uncertainty range) than the values of some other universities such as the KULeuven.
- **Public transport used by all students and employees**: VUB has 4260 km per person per year. This is roughly 50% higher than other universities and colleges (e.g. KHLeuven, KULeuven). The main reason is the relatively much higher train transport for commuting of VUB employees. The ratio of the distance of VUB employees commuting by train relative to the employee commuting distance by car is 2,3 for the VUB, compared to 0,8 for KULeuven. For students, the ratio of public transport relative to car transport of the VUB and KULeuven are both roughly equal to 4 (which corresponds with 80% travel by public transport).

6.4. Summary

The above results indicate that the total distance travelled by VUB students is higher than other universities, but the modal split is more sustainable: the distance travelled with public transport is 4 times higher than the distance travelled by car, which is a ratio higher than for other universities. The reverse is true for waste collection: compared to other universities, a relatively higher fraction of the VUB waste is residual waste for incineration, which is less environmentally friendly. There might be room for improvement of a selective collection of waste at the VUB. However, waste has a relatively low contribution to the total carbon footprint, so expected footprint reductions of improved waste collection are relatively low.

7. SIMULATIONS

7.1. Approach

In order to look for actions that have the highest footprint saving potentials, simulations were performed, using the VUB carbon footprint of 2016 as a reference.

The actions and hypothetical scenarios for simulations were selected in consultation with the VUB, based on the energy audit for the campus Jette, other footprinting studies of universities and colleges [8] and proposals from members of the VUB core group sustainability. This list not only includes potential future measures but also recently executed measures, because in recent years the VUB has invested in some important energy saving measures.

The calculation assumptions for recently executed measures are based on data of consumption levels of previous years (2008-2015). 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 recent past, VUB has undertaken some measures that reduced a significant amount of CO_2, such as a shift to green electricity and avoiding the use of steam in the primary heating circuit. Table 6 presents the footprint savings of the two most important energy measures: green electricity and adaptation of the primary heating circuit. Negative values in the table indicate increases relative to the 2016 footprint. These measures resulted in a saving of more than 5000 ton CO_2e. Without those measures, the VUB footprint would be almost 20% higher.

Impact category	Past measures	Calculation assumptions	Ton CO_2e saved	% reduction relative to 2016
Energy use	No green electricity	Purchased electricity is Belgian average	-4854	-13,9
	Use of steam in primary circuit, no adaptations in stokehold	In 2016 adaptations to the stokehold were done. The use of steam in the primary circuit was avoided. This saved on average 4000 MWh primary energy (gas) per year (comparing 2016 with the average over the period 2008-2015).	-967	-2,8

Table 6: Estimated carbon footprint savings of recently executed measures

7.3. Overview of future actions

The table below presents simulations and possible measures that could reduce the carbon footprint of the VUB. Some simulations correspond with measures that are feasible in the short or long term, others are merely for didactic purposes.

At the moment of publication of this report, an energy audit of the VUB is being performed. As data for some measures for Jette were already available, these measures were included as simulations.

[8] e.g. Bruers S. (2011). De ecologische voetafdruk berekening van de KHLeuven, 2010. Ecolife.

Other possible measures for Etterbeek and Jette are not included in this study (e.g. installation of performant Building Management System, optimization of heating, cooling and ventilation schedules, heat recuperation of cooling machines, secondary heat net optimization and renovation of central heat generation system).

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 of the different simulations in the table should not be added together, because there are couplings and overlaps between different simulations that would result in double counting of the reductions. Estimates of total footprint reduction of a set of feasible, recommended measures are presented in the next chapter.

Impact category	Possible measures	Calculation assumptions	Ton CO_2e saved	% reduction relative to 2016
Energy use	All available roofs in Etterbeek have solar panels	17000m^2 roof surface area for solar panels, 1,5m^2 per solar panel, 0,26 kWp per panel, yield of 850 kWh/year/kWp, 0,26 kg CO2e/kWh avoided	651	1,9%
	Increased thermal insulation of buildings	10% reduction in energy use	835	2,4%
	Planned energy saving measures Jette	Based on energy audit: insulation mattrasses, optimization control installation, pump switches, outdoor LED-spots. Savings of 724 MWh heat and 144 MWh (green) electricity	183	0,5%
	Extra energy saving measures of ventilation systems Jette	Heat recovery, frequency control of fans, HR electromotor. Savings of 1165 MWh heat and 244 MWh (green) electricity	295	0,8%
	Renovation CV installation student homes Jette	Savings of 740 MWh heat and 78 MWh (green) electricity)	183	0,5%
Inputs	All meals in the restaurant are vegan	Same number of meals as in 2016	225	0,6%
Direct waste	Selective collection of waste	50% of residual waste selectively collected for recycling	121	0,3%
End-of-life	Less paper use	10% less paper for student courses	5	0,01%
Transporting people	Employees live in Brussels	10% of non-local employees move to Brussels. Average home-work distance is 8 km. Modal split is equal to current modal split of employees living in Brussels: 8,4% car, 0,6% motorbike, 5,2% train, 56,8% bus-tram	111	0,3%
	Students are residential students with a student room in Brussels	10% of non-residential students become residential. Current residential students modal split and average distance from home to student room is used and extrapolated to all students	247	0,7%
	Employee commuting modal shift	10% of employee commuting car travel switched to 70% train and 30% bus	114	0,3%
	Student modal shift	10% of student car travel switched to 70% train and 30% bus	295	0,8%
	Employee telecommuting (promoting working from home)	10% less employee commuting	251	0,7%
	Student telecommuting (distance learning, promoting studying from home)	10% less student travel (excluding plane)	792	2,3%
	Employee ecodriving	10% less emissions of employee car travel (commuting and business travel)	198	0,6%
	Student ecodriving	10% less emissions of student car travel	437	1,3%
	All employee 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.)	1.310	4%
	All student cars are electric	Same as above, applied to all student travel	2.988	8,6%
	Teleconferencing	10% reduction of employee airplane business travel	473	1,4%
Capital goods	extended lifespan if IT-equipment	10% reduction of IT-purchases	89	0,3%

Table 7: Estimated carbon footprint reductions of possible future measures

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

In addition, Table 8 presents a short list of important actions to be taken by the VUB 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 will result in a 1% reduction of the total carbon footprint of the VUB 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	Renovation student homes in Jette: CV-installation, pump switches, thermal insulation of hot water pipes	All student homes in Jette
	Extra energy saving measures of ventilation systems Jette (heat recovery, frequency control of fans, HR electromotor)	All ventilation systems
	Thermal insulation of buildings	4% reduction in heating energy
Transporting people	Modal shift (public transport instead of car)	8% of employee and student car travel switched to public transport
	Employee telecommuting (promoting working from home)	12% less employee commuting
	Student telecommuting (distance learning, promoting studying from home)	4% less student travel (excluding plane)
	Ecodriving	50% of employees and students with cars apply ecodriving
	Electric cars for employees	25% of employee cars are electric
	Teleconferencing	20% reduction of employee airplane business travel

Table 8: Targets for measures that reduce the total footprint with 1%

Remark: at the moment of publication of this report, the VUB is finishing an energy audit for the campuses Etterbeek and Jette that contains additional measures to reduce direct energy use (which accounts for 27% of the total carbon footprint). Some of the measures for the campus Jette are already included Table 8.

7.4. Summary

Table 9 summarizes the reductions of the abovementioned simulations per impact category:

- Energy: all available roofs in Etterbeek have solar panels and the proposed energy-audit measures in Jette are undertaken;
- Inputs: all meals in the student restaurant are vegan;
- Direct waste: 50% of residual waste is recycled instead of incinerated;
- End-of-life: 10% less paper use of student courses;
- Transporting people: all employee and student car travel is switched to public transport (trains on grey electricity) or electric cars on green electricity, 10% less employee airplane business travel due to teleconferencing;
- Capital goods: 10% reduction in IT purchases due to extended lifespan.

These measures give a total footprint reduction of more than 7800 ton CO_2e (23%).

C02e Overview	Emissions	Reductions		
	t CO_2e	t CO_2e	%	Residual t CO_2e
Energy	9.473	2.148	23%	7.325
Non-energy	152	-	0%	152
Inputs	1.127	225	20%	902
Direct waste	237	121	51%	117
End-of-Life	770	5	1%	765
Transporting people	19.002	5.271	28%	13.731
Capital goods	4.108	89	2%	4.018
Total	**34.869**	**7.858**	**23%**	**27.011**

Table 9: Summary of footprint reductions per impact category

8. RECOMMENDATIONS

Attainment of climate neutrality for an organization consists of two steps: a reduction of the 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 VUB'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 (**Rationalizing**); 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 VUB 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 VUB. 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. **Rationalize 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 have to 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 realized, 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 the VUB.

Some long term technological trends will presumable result in a reduction of the VUB footprint, even without a change in VUB activities. As discussed in the chapter 4 about 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, which means the footprint becomes smaller. For the footprint of the VUB, 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 the efficiency of trains and buses increases, reducing their emission factors. As the share of public transport in the total footprint of the VUB 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. With the current modal split (share of trains in total transport), a switch from grey to green electricity for trains will have a reduction potential of 2600 ton CO_2, which is 8% of the total footprint. Therefore, the VUB could lobby for trains on green electricity.
- **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 VUB. Two macro-social trends that can be mentioned are:

- **Democratization 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 also at the VUB. As a consequence, the expansion of education and research activities and infrastructure are expected to enlarge the footprint in general.

- **Internationalization 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 organization 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 organizations. 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 organizations. For the VUB 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 demonstrate, in the past few years the VUB has already reduced its carbon footprint with almost 20% due to energy saving measures and a switch to green electricity. This corresponds with a reduction target over a 7-year period. In the upcoming years, more actions are needed to meet the reduction targets. 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 almost one third of the total footprint. As purchased electricity of the VUB is already green electricity with a low footprint, almost 90% 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 refer to the energy-audits for campuses Jette and Etterbeek 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 performed 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

Although solar panels will not reduce the footprint of the VUB in the very short term because the purchased electricity is already green (i.e. with a low footprint intensity), solar panels can 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 VUB campus sites, reducing the footprint of car transport.

Action 5: Research and development at VUB

The VUB can stimulate R&D for a sustainable energy transition. As a living lab or demonstrator, the VUB invests in several large-scale research projects with international appeal. Some examples include:

- seasonal energy storage,
- smart charging of electric vehicles and vehicle-to-grid support services,
- smart grid applications and VUB as energy trader,
- energy recovery from waste water.

Transporting people

Action 1: On-line 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 a democratization of higher education, which will result in an increase in student population at the VUB. Offering on-line courses facilitates studying at home and avoids transportation movements, especially for the commuter students who would otherwise travel each day to the campus.

Action 2: Flexible working arrangements to reduce employee commuting

As with on-line 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: Providing a budget for electric and folding bikes for students and staff

Next to restricting transportation activity, a rationalization 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. To promote bike usage, a budget for Villo subscriptions and for electric and folding bikes can be provided to staff and/or students. Signalling of shortages of bicycle parkings can also be facilitated. Finally, equipment such as rainwear and infrastructure such as showers can also be provided for people using bikes.

Action 4: Direct train connections to improve a modal shift to public transport

Next to bikes, a modal shift to public transport should also be promoted. Almost 80% of the total distance of domestic, motorized mobility (cars and public transport in Belgium) of students and employees is public transport. This is already a high percentage (especially public transport for employee commuting is higher than some other Belgian universities and colleges). A further modal shift might become a challenge. Nevertheless, focussing on transport is relevant, because the average distance travelled by students and employees is high, which results in a 34% share of the total footprint for domestic motorized mobility.

In terms of a shift to public transport, one bottleneck for students and employees who travel long distances, is a lack of direct train connections from Etterbeek station to other major cities in Belgium (especially to regions where many VUB students come from). In the current situation, a lot of students who travel by train need to switch to another train in Brussel-Noord, which is impractical and time consuming. Increasing the number of direct train connections requires a collaboration with the NMBS.

Next to lobbying for better train connections, lobbying for trains on green electricity is also a high impact measure. If trains would use green electricity, the total carbon footprint of the VUB will decrease with 8%. As a comparison, it requires a 64% modal shift, i.e. 64% of all car transport (of employees and students) should be switched to trains, in order to generate an 8% reduction of the total carbon footprint.

Action 5: 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 VUB generate extra revenues that can finance subsidies for public transport (train tickets) of students.

Action 6: Charging stations to enable a shift towards electric cars

After a maximal modal shift towards bikes and public transport, the footprint of the 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. In particular charging stations at VUB parking spaces, powered by solar panels at the VUB buildings, is an important stimulus.

Action 7: Differentiated pricing for electric cars

Parking prices at VUB parking spaces can be differentiated: 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.

Action 8: Teleconferencing to reduce airplane travel

Airplane business travel accounts for more than 5% of the total footprint. Although airplane efficiency (i.e. rationalizing energy consumption) is expected to improve in the future, this technological trend lies outside the influence of the VUB, and more measures to reduce the airplane travel footprint are necessary. The VUB already has a policy to discourage flying in first class (business class), that 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 the 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 rationalization 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.

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 three times higher than the footprint of an average vegan meal.

Action 3: Avoiding 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.

Action 4: Recycled paper

The production of recycled paper requires less energy and CO_2 emissions compared to new paper. Only a small fraction of the paper not used for student courses is from recycled origin. Therefore, buying recycled paper is a quick win, although a small win, because paper consumption has a share of less than 1% of the total footprint.

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 [9], consisting of enabling, exemplifying, engaging and encouraging behavioural change (which as later extended to a 7E-model [10]). For a research institute such as the VUB, 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 VUB can encourage the use of existing online platforms for car sharing, carpooling or ridesharing. Avoiding waste such as plastic water bottles is enabled by providing drinking water fountains. More generally, training for employees also provide tools that enables sustainable behaviour in the work place.

2. Exemplify sustainable behaviour

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

Appoint climate ambassadors and show that VUB staff gives the good example that engages 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 the GreenImpact program of the GreenTeam, students can be engaged with a student organization for sustainability.

[9] DEFRA (2011), Framework for Sustainable Lifestyles. Department for Environment, Food & Rural Affairs, UK.

[10] Bambust, F (2017) Effectief gedrag veranderen met het 7E-model. Politeia.

4. Encourage staff and students

Give the right signals: understand and offer the 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. As GreenImpact is developed as a competition amongst participating teams, this 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.

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 VUB 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. randomized controlled trials. This can be done by master and PhD students in psychology.

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

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, timeframes, scientific certainty, generalizability, 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 VUB can take to directly reduce its own footprint. However, the VUB can also perform actions and campaigns that facilitate a reduction of greenhouse gas emissions not included in the footprint of the VUB. These actions count as CO_2-compensation mechanisms, but they are not financial in the sense that it does not involve a donation to an external organization. The actions are performed on the sites of the VUB. Some interesting non-financial CO_2 compensation examples are:

- **Solar panels**. As the VUB already buys green electricity, the installation of solar panels will not result in a reduction of the electricity carbon footprint of the VUB. However, the VUB can sell the electricity produced by its own solar panels (which is already the case for the campus Jette). This can result in a replacement effect, where electricity from power plants is replaced by electricity from the solar panels of the VUB. Hence CO_2 emissions at power plants are avoided. Selling 1 kWh solar power can compensate 0,26 kg CO_2 (excluding price elasticity and rebound effects). It requires 8000 m^2 solar panels for a CO_2 compensation equivalent to 1% of the total carbon footprint of the VUB.
- **Charging stations** for electric cars. The VUB can promote a switch to electric cars by installing charging stations on its campuses. This not only results in a reduction of the VUB footprint from employee and student car travel, but the charging stations can also be used for other, non-VUB related car transport. It is difficult to calculate how much emissions can be avoided with the installation of one charging station.
- **Vegan meals** in the student restaurant. If all the meals in the VUB restaurant were vegan, this would result in a reduction of 0,7% of the VUB 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 VUB restaurant. By increasing the offer of tasty vegan meals, plant-based food becomes more normalized 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 the CO_2 emissions outside the scope of the VUB 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 the donation to organizations. In general, there are five financial compensation strategies:

1. Mitigation by short term emission avoidance: supporting projects and actions from organizations that result in avoidance of greenhouse gases elsewhere in the world.
2. Mitigation by short term absorption: donating money to organizations 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 organizations to prevent climate related diseases such as malaria.

The table below presents the different compensation methods, the organizations 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 VUB (31.655 ton CO_2e) can be compensated at a cost ranging from 10.500 to 3,2 million euro.

Strategy	Method	Organization	Cost per ton CO_2e	Advantage	Disadvantage
Mitigation by short term emission avoidance	Payment for ecosystem services (preventing deforestation)	Cool Earth	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	3 euro	Highly cost effective, some evidence of rather certain results, short term	"Not generalizable, keeps own emissions in the atmosphere"
Mitigation by short term emission absorption	Carbon capture and storage by reforestation	Treecological	34 euro	Certain results, short term, takes back own emissions	"Not generalizable, less cost effective "
Mitigation by long term emission avoidance	Scientific research for climate friendly energy and transport technologies	Research institutes	uncertain	Allows generalizable and strong reductions in the long term	"Uncertain results, risk of rebound effect"
	Development of clean meat	Good Food Institute	uncertain	Allows generalizable and strong reductions in the long term	"Uncertain results, risk of rebound effect"
	Economic market mechanism: carbon taxation	Carbon Tax Center	uncertain	"Economiccaly most effective to address climate change problem, avoids rebound effects"	Uncertain results
	Economic market mechanism: cap-and-trade	Carbon Market Watch	uncertain	"Economiccaly most effective to address climate change problem, avoids rebound effects"	Uncertain results
Remuneration of past emissions	Purchase of virtual emission permits	GiveDirectly	100 euro	Most fair solution to help the poorest people	Less cost-effective
Adaptation to past emissions	Health interventions	Against Malaria Foundation	0,33 euro	"Most cost-effective"	"Not generalizable, focuses only on human health"

Table 10: 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 the collection of the consumption and infrastructure data. This platform should be secure and accessible by the environmental coordinator 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 according to a uniform 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 together with the 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 VUB for the year 2016, 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 VUB 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, and capital goods (infrastructure, furniture, 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 VUB, paper use for student courses, meals consumed at the student restaurants, and energy use and general waste generated at the student homes on the campuses of Jette and Etterbeek). 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 VUB.

The total carbon footprint of the VUB for the year 2016 is 34 869 ton CO_2e, which corresponds with 2 ton CO_2e per student. Of this total footprint, 55% is due to transporting people (especially student travel by car, airplane and public transport), 27% comes from direct energy use (especially heating) and 12% from capital goods (especially construction of buildings).

A strategy for the VUB to become climate neutral consists of two steps. First: reducing the emissions with an average rate of 3% per year to meet long term global climate targets. Second: 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 (Rationalization), and replacing high-carbon fuels with low-carbon sources (Replacement). These include both (infra)structural actions and behavioural change of employees and students.

Important structural actions to reduce the footprint include: energy-audit recommendations to reduce natural gas use, using geothermal energy, installing solar panels, research and development of climate friendly technologies at the VUB, on-line 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 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, and 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) and 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 research) as well as financial compensations (e.g. supporting projects and actions from organizations that result in avoidance of greenhouse gases elsewhere in the world, donating to organizations 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 organizations 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: CO_2 COMPENSATION STRATEGIES

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

10.1. Mitigation by short term emission avoidance

Payment for ecosystem services

First, we can pick the lowest hanging fruit. A recent study in Science [11] 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 organization 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 organization to avoid CO_2-emissions.

But if there are more highly cost-effective organizations, from a risk perspective it is better to fund more than one of those organizations. If you support only one organization, it might be the case that new evidence shows that that organization 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 [12]. 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.

[11] 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.
[12] 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.

10.2. 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. 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 generalizable: 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.

10.3. 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 VUB itself 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 VUB 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.

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 price. 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, the 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°C [13]).

10.4. Remuneration of past emissions

Direct cash transfers

In our current economic system, people in rich countries don't 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 organization 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.

[13] 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/

10.5. 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 the literature, is 0,003 DALYs per ton CO_2-eq [14]. 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 organizations. One organization is the Against Malaria Foundation, also a top charity recommended by GiveWell. A donation of 100 euro to this organization 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.

[14] 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.

COLOFON

Ecolife vzw

Ecolife is een kenniscentrum voor footprinting en ecologische gedragsverandering.
Ecolife ondersteunt overheden, organisaties en bedrijven bij de realisatie van hun ecologische doelstellingen.

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

Contactpersoon:
Bruno Verbeeck
(bruno.verbeeck@ecolife.be)