UCLouvain

LOUVAIN
School of Management

Louvain School of Management

How to radically reduce air travel emissions for student mobilities?

UCLouvain case study

Author: Ségolène D'Hooghe
Supervisor: Axel Gosseries
Academic year 2022-2023
Dissertation for the Master of Management Engineering with specialization in Corporate Sustainable Management
Daytime schedule

Acknowledgements

My first thanks go to Pr. Axel Gosseries, my master thesis supervisor, for his help, availability from day one and constructive comments. His feedbacks provided essential guidance for developing my ideas and fulfil this master thesis.

From reflexion, exchange of ideas and support through this process, I would like to thank warmly my family and friends. Special thanks to Louis, my partner, who has been an amazing support and adviser throughout this year and master thesis.

These results could not have been achieved without the help of the people that I interviewed. Thanks to Natacha Buntinx, Bart Stoffels, Marc Servais, Gaël Vandenbroucke, and Ina Aust-Gronarz for their contribution and the critical information they provided. Thanks also to the one hundred thirty-five respondents of my quantitative survey, helping me to get insights about direct and indirect impacts of students' mobilities.

Table of contents

Introduction

2025.

This is the last deadline for humans to reverse the trend of greenhouse gas (GHG) emissions to maintain a livable world according to the International Panel on Climate Change (IPCC,2022b). This ultimate warning comes after two decades of experiencing the first consequences of climate change. This includes rising sea levels, coral bleaching, heat-related human mortality, and many others (IPCC, 2022a). While scientists have been warning us about this threat since the late 1980s, global CO_2 emissions rose by over 50% from 1990 to 2020 (IEA, 2022b). In fact, they never decreased except during economic recessions (IEA, 2023) as observed in Appendix 1.

While citizens are increasingly aware of environmental challenges, our lifestyles and habits are still in many cases unsustainable. Some habits go in the right direction. For example, bicycle use for work-home commuting has increased by 80% between 2005 and 2021 in Belgium (SPF Mobilité et Transport, 2023). Unfortunately, while the average Belgian uses more his/her bicycle, he/she also flies much more. Over the last two decades, air travel has gone from 1.8 Bn passengers in 2000 to 4.6 Bn passengers in 2019 (IEA, 2020). People fly more, for work and leisure purposes. This comes at a very high environmental cost as air travel is five times more emissive than travelling by train (BBC News, 2019).

Among air travelers, young people are increasingly looking for new experiences abroad. One important way for young people to access travel opportunities is through mobility programs in universities and higher education institutions. Student's mobility refers to "*the cross-border movement of people to pursue their studies abroad, either for a full degree or for part of it*" (Alves & Terzieva, 2023, p.4). The Erasmus + Programme is an EU exchange program for students, researchers, and teachers founded in 1987. It aims at promoting cooperation, quality, inclusion, equity, creativity, and innovation for individuals in sports, youth, and education (European Commission, 2022). In 2020, Erasmus + Programme gave 107 000 students the opportunity to discover other European countries. In this thesis, we will call these mobilities "European mobilities". Other programs like "Mercator" give students the opportunity to travel to other continents, we will call these mobilities "transcontinental mobilities".

This master thesis investigates the question of "***how to radically reduce air travel emissions for student mobilities***" with a specific focus of the Belgian university UCLouvain. We consider that reduction should be attained at all costs, meaning that all options are considered, even the option of cancelling student mobilities. This would be considered in the worst case where student mobilities are not compatible with climate goals. This thesis does not discuss social aspects in depth as student mobility is not considered as a primary need for humans. Additionally, we consider that reducing GHG emissions is already in itself a social measure as this is the only way to keep a livable environment on Earth for all humans.

This master thesis aims to provide concrete measures that could directly be implemented. For this reason, it only looks at measures implementable at the university level, as the European Union (EU) seems out of reach for a master thesis.

Part 1 explains why energy sufficiency, i.e., voluntarily reducing energy consumption, is key in the fight against global warming as technology alone will not be enough to limit global warming below 2°C. Part 2 then reviews and evaluates the potential of different levers of action for reducing mobility-induced air travel. It also looks at what measures are acceptable and which measures have already been implemented by universities. Part 3 investigates strategies for reducing air travel by reducing the distance of mobilities. Lastly, part 4 looks at how buses can replace air travel for European mobilities.

Part 1: Why should we reduce student mobility air travel?

This first part aims to motivate the research question by explaining why green technologies will be insufficient to meet the Paris Climate Agreement and that energy sufficiency measures, i.e., voluntarily reducing energy consumption, are crucial in the fight against global warming, including in the air travel industry. Then, this first part also looks at the contribution of air travel to global warming, and more specifically, at the carbon footprint of mobility air travel by shedding light on direct as well as indirect impacts of mobilities.

1. Why cannot we rely exclusively on technology to fight climate change?

As of 2023, 195 parties have signed the Paris Climate Agreements which aims at limiting *"global warming to well below 2, preferably to 1.5 degrees Celsius, compared to pre-industrial levels*" (United Nations, n. d., para. 2). Yet, global GHG emissions keep increasing with a 0.9% rise in 2022 (IEA, 2023). According to the last report of the IPCC, "*without a strengthening of policies beyond those that are implemented by the end of 2020, GHG emissions are projected to rise beyond 2025, leading to a median global warming of 3.2 [2.2 to 3.5] °C by 2100*" (IPCC, 2022, p.17). It is clear that the current strategy adopted by world leaders does not work. So far, governments have put their hopes into renewable energy sources and energy efficiency[1] technologies as a way to reduce GHG emissions while maintaining economic growth. This vision is embodied by the European Green New Deal, whose goal is to reach net zero emissions by 2050 while generating "*green growth*", or "*economic growth decoupled from resource use*" (European Commission, 2019, para1). Although GHG emissions of some European countries has decreased over the last decade, in most cases, it was not thanks to renewable energy. For example, by progressively replacing coal use by lesser emissive natural gas, Belgian emissions decreased by 21% between 2000 and 2019 (IEA, 2022a). Indeed, emissions related to natural gas are 418g/kWh while 1060 g/kWh for coal (Ademe, 2021). The following figure shows Belgium's total energy supply over time:

[1] Energy efficiency consists in reducing energy use for the same economic output (IEA, 2019).

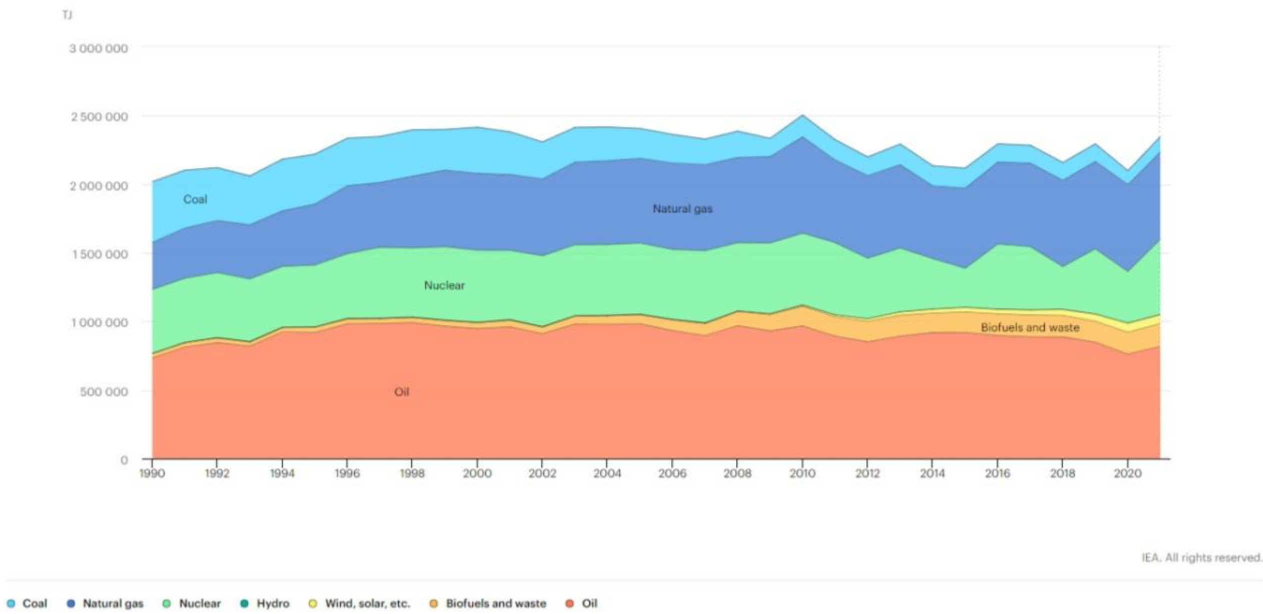


Figure 1: Total energy supply by source in Belgium between 1990-2021 expressed in terajoule (TJ) (IEA, 2022a).

The previous figure shows that total energy supply stayed at the same level between 1990 and 2020. Despite the investments and all the hype around wind and solar, these energy sources only represented 3.1% of Belgium's total energy supply in 2020 (IEA, 2022a). Although the 21% decrease in emissions is a good thing, it is only a short-term solution as on the long run, natural gas will itself need to be replaced by less emissive energy sources. The most promising energy sources for this purpose are biomass, hydropower, solar energy, and wind energy. While a lot of hopes are put into these new forms of energy, they have important physical limitations.

Biomass is the process of transforming organic matter into energy and can be used to produce fuel and heating (Connaissance des Énergies, 2013 & Université Paris Cité, 2022). It consists in growing crops and transforming them into fuel. Although biomass has several advantages such as being available everywhere and being a low emissive energy source, it requires a lot of land area which inevitably results in a reduction of agricultural land that can induce a food crisis, deforestation, and biodiversity loss (Connaissance des Énergies, 2013).

Hydropower is a great low-carbon energy source and it is readily available. It is the third-largest source of electricity generation (electricity being only part of total energy supply) with 17% of global power supply in 2020, after natural gas and coal (IEA, 2021) and has the lowest cost among renewable energy sources. For instance, hydropower prices in France range between 15€ and 20€ per MWh compared to 50€/MWh for nuclear and 82 €/MWh for onshore wind power (Grébonval, 2023). The one big problem is that hydropower needs elevation. Only territories featuring mountain ranges like France, Austria or Norway can develop significant hydropower capacity. Even for those countries, hydropower is often limited by geological and environmental constraints.

Contrarily to hydropower, solar and wind energy have very large potential but are intermittent energy sources. This means that besides windmills and solar farms, one should build storage capacity to store the energy produced, making renewable energy much more expensive. This is why storage capacities currently only stands at 17 GW worldwide (Mulhern, 2022) whereas France's production stands somewhere around 60 GW a month (Electricity Maps, 2022). A 100% renewable future is hence unlikely to happen in the near future.

When it comes to the aviation sector, batteries being too heavy, biofuels and hydrogen are often seen as the best ways to decarbonize air travel. In 2022, the European Commission decided to increase the minimum percentage of renewable fuels in European airports to 2% by 2025 and 37% by 2040, using biofuels and hydrogen (Parlement européen, 2022). On the one hand, as already discussed, biofuels require a lot of land area which is a big limitation. On the other hand, hydrogen is no energy source as it is not readily available in a natural state. It needs to be produced using another energy source (nuclear, natural gas, …) which only shifts the problem to *what energy do we produce hydrogen with*? Hydrogen can only be used as a way to store energy and this comes at a cost: if we use wind or solar in order to produce hydrogen, the "power-to-gas-to-power" energy efficiency[2] is only of 25% to 35% (RTE, 2020) requiring 3 to 4 times more solar panels or windmills to get the same amount of energy when energy is stored through hydrogen.

Despite all of the efforts from European governments, the share of renewable energy to the total energy supply stays very low (IEA, 2022b) and fossil fuels are still leading by far as the major energy supply source. Energy expert Jean-Marc Jancovici explains in his numerous talks why renewable energy sources struggle to replace fossil fuels. He argues that by mastering science and technologies, humans were able to surround themselves with a wide range of machines, boosting economic output and allowing for the development of modern society. The one

[2] The "power-to-gas-to-power" energy efficiency is the efficiency obtained between the moment when the electricity is transformed to be stored into hydrogen through an electrolysis and then converted back into electricity (RTE, 2020). Hydrogen represents a major advantage knowing that renewable energies are intermittent as it is a way to store electricity. However, the maximum efficiency after the storage is a maximum of 35%: for example, if a wind turbine produces 10 kWh that is then stored as hydrogen, the final quantity of electricity after converting the hydrogen back into electricity is about 2.5 to 3.5 kWh, which represents a significant energy loss while renewable energy resources are scarce. (RTE, 2020).

problem is that these machines require huge amounts of energy to operate. Jancovici (2019) argues that the best available energy sources for that purpose are fossil fuels, and that renewable energy are in fact the energy of the past. Indeed, windmills and sailboats already used wind energy while solar energy was used to dry people's laundry. Until the industrial revolution, biomass was the main energy source as wood was used for domestic heating and industrial purposes, resulting in massive deforestation right before we started using fossil fuels. Finally, watermills were already taking advantage of hydropower for processing grains. It is then not a surprise if renewable energy sources fail to replace fossil fuels as our ancestors transitioned the other way: from renewable sources to fossil fuels.

Jancovici (2019) also warns against putting hopes into energy efficiency technologies, as rebound effect mitigates gains. The rebound effect is when decreased costs (or emissions) lead to increased consumption. A recent study (Hamamoto, 2019) found that the purchase of a hybrid electric vehicle led to an increase in total mileage. A more general study found out an average 76% rebound effect on energy use, meaning that a 20% initial decrease in energy consumption only ends up in a 4.8% decrease (20% times 76%) after taking the rebound effect into account (Wei & Liu, 2017).

The idea of "*green growth*", where economic output can be decoupled from GHG emissions is being more and more challenged by Jancovici and other public speakers. A recent scientific paper reviewed the literature on GDP-resource and GHG emissions decoupling and found that "*the analyzed literature provides ample evidence that a continuation of past trends will not yield absolute reductions of resource use or GHG emissions*" (Harbel et al., 2020, p.34). It concludes as "*large rapid absolute reductions of resource use and GHG emissions cannot be achieved through observed decoupling rates, hence decoupling needs to be complemented by sufficiency-oriented strategies and strict enforcement of absolute reduction targets*" (Harbel et al., 2020, p.1). The authors of the paper argue that sufficiency-oriented[3] strategies are necessary in order to meet GHG reductions goals.

Jancovici's views, while disheartening, seem to fit more with reality than "technology optimistic views" as technologies are bound by the laws of physics and efficiency gains are highly mitigated by rebound effect. Although being very unpopular, energy-sufficiency measures are therefore strictly necessary to effectively reduce GHG emissions. This strongly

[3] Energy sufficiency consists in deliberately reducing energy consumption. This could be achieved for example through quotas or taxes on energy-intensive products.

applies to the air travel sector: we cannot hope for hydrogen airplanes or other overrated technologies to drastically reduce airplane GHG emissions. Flights will have to be reduced, or at least limited, but to what extent? What does that mean for student mobilities using air travel? Should it also be reduced? To answer those questions, we first need to quantify the GHG emissions of aviation as well as Erasmus air travel emissions, how is aviation contributing to global GHG emissions and how much of it is due to students mobilities?

2. What is the contribution of student mobility air travel to GHG emissions?

2.1. Is aviation's contribution to global GHG emissions insignificant?

Aviation is estimated to account for 2.5% of global CO_2 emissions, 1.9% of global GHG emissions (when mixing in CH_4 and other greenhouse gases) and accounts for 3.5% of global "effective radiative power"[4] (ERP) (Ritchie, 2020). These numbers include both passenger and freight aviation although passenger transport amounts to 81% of aviation emissions and freight the remaining ones (Overton, 2022). As these numbers are not very big, most people argue that reducing air travel would not have a significant impact on GHG emissions. But this is a flawed reasoning for two reasons.

First, average emissions numbers hide huge disparities as illustrated by the following figure. This figure displays the data in logarithmic scale, +1 on the graph corresponds to x2.7 of total number of passengers (as $e^{+1} \cong 2.7$).

[4] Effective radiative power (ERP) measures how much warming is occurring at a given time. GHG induce ERP during a certain period of time until they are taken out of the atmosphere. This difference between 2.5% and 3.5% is due to aircraft-induced cloudiness which induces ERP just like GHG but quickly disappears (Carbone4, 2020).

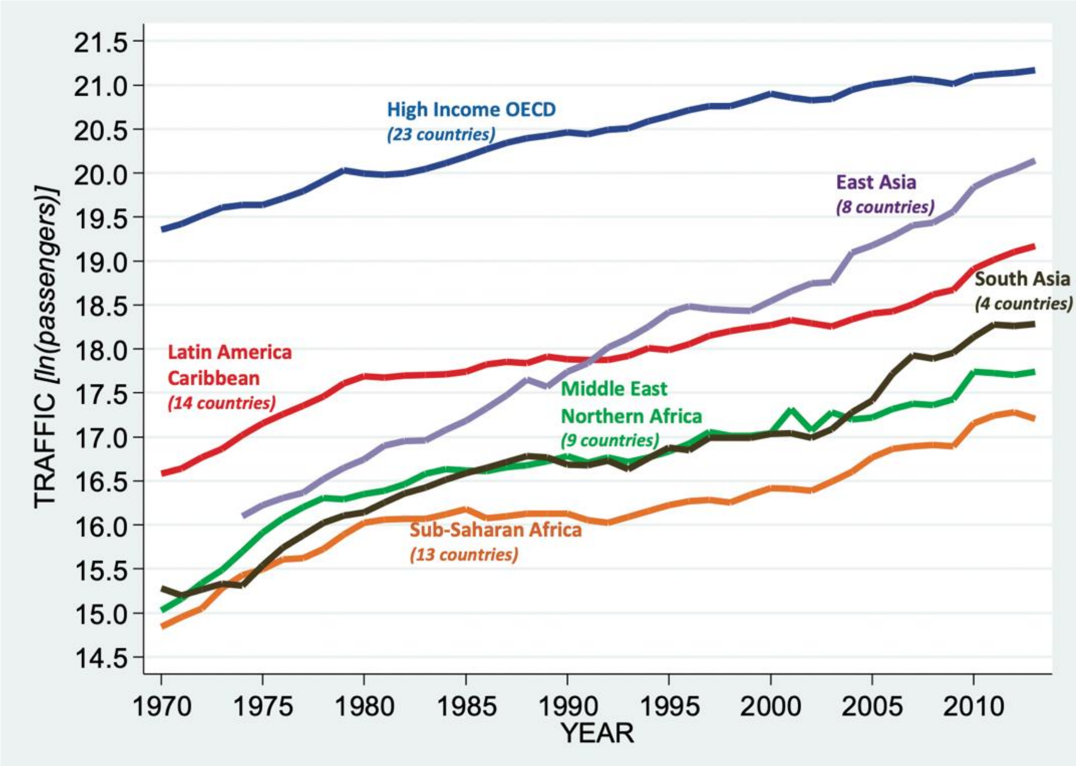


Figure 2: Evolution of passenger air traffic in a log scale between 1970 and 2013 from ICAO database (Bourguignon & Darpeix, 2016).

OECD citizens fly way more than the rest of the world. When doing the math over the previous figure, we find that OECD citizens, representing 17.5% of world population in 2015, accounted for 1.5 Bn passengers which is more than the 82.5 % rest of the world which only accounted for 0.95 Bn passengers (Bourguignon & Darpeix, 2016). When looking at one OECD country such as France, we find that air travel jumps to 7.3% of France's carbon footprint (Louis et al., 2020) which is already much greater than the 2.5% global average.

A recent research paper of Chancel & Piketty (2015) shed even more light on flying inequalities and that for the top 1% households, air travel accounts for 41% of carbon footprint falling to 13% for the top 10%, and 1% for the middle 40%. The reason why air travel is small in the average human carbon footprint is because the average human does not fly. A study looking at population shares found that in 2018, 11% of the world population flew, with only 2 to 4% of people taking an international flight (Gössling & Humpe, 2020). It also found out that 1% of the world population was responsible for 50% of aviation GHG emissions.

Looking at the average numbers, people aware about climate change and willing to take action might keep flying thinking that it only accounts for 2 to 3% of their carbon footprint. However, given the low proportion of citizens flying due to inequalities between different countries and between low and high incomes earners, it becomes clear that aviation has a considerable impact on individual carbon footprint of citizens who fly on a regular basis and that the number of 2.5% of global CO_2 emissions is not representative of the potential to reduce carbon footprint for these citizens. One could now ask what *"flying on a regular basis"* means. At what point are a person's flying habits unsustainable?

One egalitarian approach is to determine an equal yearly carbon budget for all humans. This budget determines how much emissions every human can cause each year. By equally dividing the amount of GHG that can released before reaching 2°C of warming among all human beings, independent carbon consultancy firm Carbone 4, found an annual carbon budget of about 2 t. To put in perspective, the average carbon footprint of a Frenchman is of 10.8 t CO_2e/year cap (Dugast & Soyeux, 2019) and more than 16 t CO_2e/year cap for a Belgian citizen (Moerman, 2020). We can already see that if all humans were living like the average Frenchman or Belgian, there would be no way to keep global warming below 2 degrees. The following figure compares the 2t budget with the emissions of various flights.

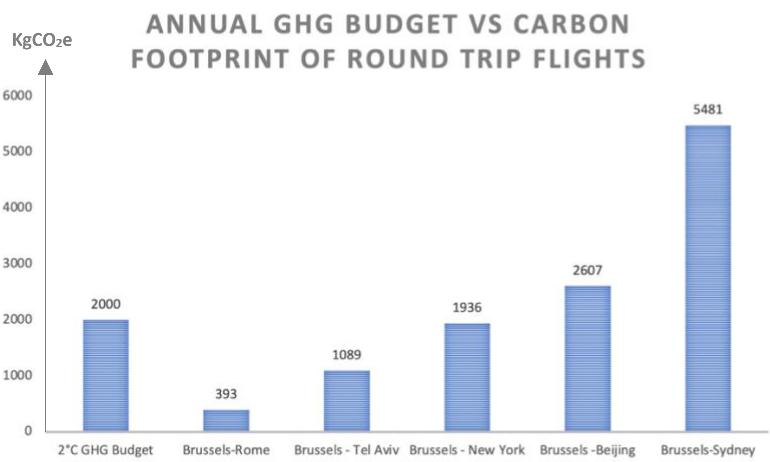


Figure 3: Annual carbon budget in accordance with 2°C global warming scenario compared with the quantity in kilograms of CO_2e of several flights (data from CO2Logic, 2023)

It is easy to see that it would be mathematically impossible to stay under 2°C of global warming with all humans taking a long-distance flight even once a year even if the rest of the year we were to go back to hunter-gatherer lifestyle. From this annual carbon budget perspective, long-distance air travel is not sustainable and short distance air travel should be highly limited. In short, even though aviation emissions only account for 2.5% of global emissions, taking one long distance flight or multiple short flights each year is already not compatible with the objectives of staying under 2°C of warming.

The second reason why the 2.5% number is misleading is because aviation CO_2 emissions are increasing very fast as illustrated by the following figure:

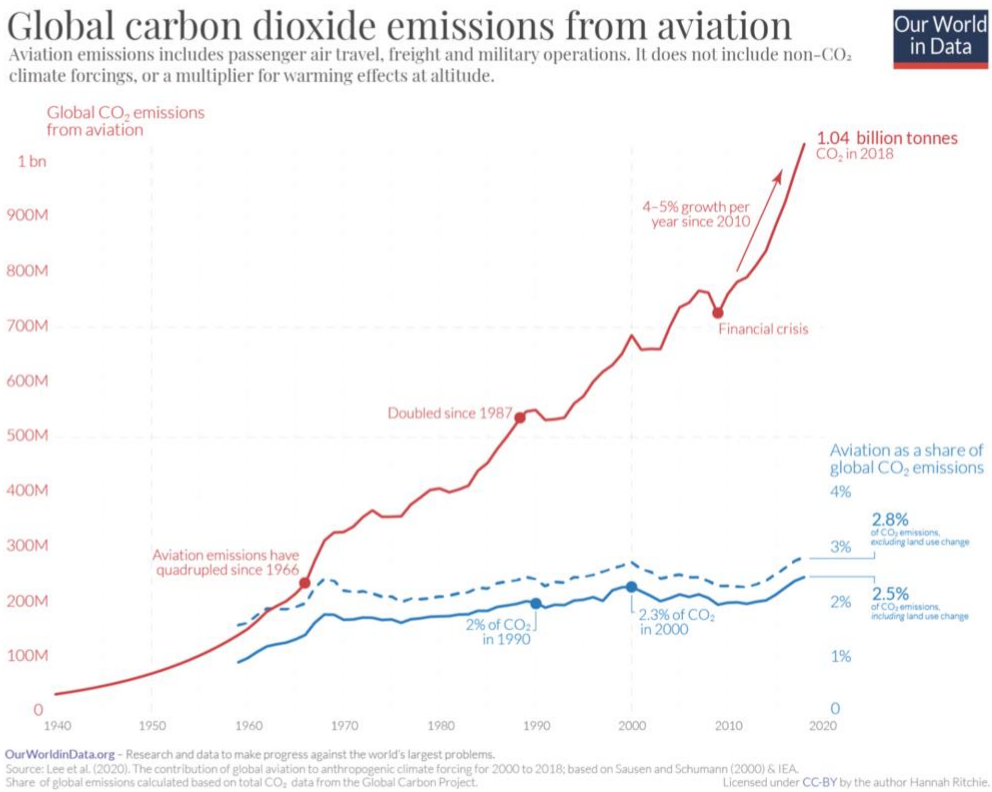


Figure 4: Evolution of global CO_2 emissions from aviation between 1940 and 2020 which includes both passenger and freight transport, from Our World in Data (Ritchie, 2020).

Air travel emissions have doubled over the last 30 years with a steady 5% growth rate between 2010 and 2019 (Ritchie, 2020). If world leaders think that current air travel emissions are neglectful, the question of how to decarbonize this sector will only become more relevant in the future. The number of 2.5% should not prevent us from having this discussion now. Additionally, the previous figure shows that technological innovation has failed to decouple increase in passengers from GHG emissions up to 2019. It would then be careless to only rely on technology to decarbonize air travel.

In conclusion, while the number of 2.5% of global CO_2 emissions might seem to be small this number grows when we look at developed countries (7.3% for France) and grows even more for wealthy individuals (41% of carbon footprint for top 1% households). Taking one long distance flight or multiple short flights each year is already not compatible with climate objectives. Additionally, for policy makers, decarbonizing air travel is an issue that will inevitably have to be addressed due to the fast increase in GHG emissions. This means that decarbonizing aviation is necessary, especially in OECD countries like France or Belgium where people fly more than in the rest of the world. One could now wonder by how much flights need to be reduced in order to meet GHG reduction goals? Should the number of flights be radically reduced starting tomorrow? Should the decrease be more progressive over time?

2.2. By how much must aviation be reduced?

A study about future viability of aviation in France revealed that the number of passengers should be cut by 2, 20 years from now, if France wants to respect the Paris Climate Agreement[5] (Louis et al., 2020). Another study conducted by The Shift Project (2021) found that even in the best-case scenarios (considering the most optimistic future with the best technologies), it would not be possible to maintain the current trend in passenger growth. Indeed, in those best-case scenarios, passengers' growth drops from 2.5% in 2025 to -3% in 2035. This means that even in the best conditions, air travel will have to decrease in the long run. These results alone justify the research question.

Should education-related air travel also decrease? One could argue that education-related air travel is more legitimate than other air travel. I still think that education-related air travel should still be decreased for different reasons. First, because all travelers have their own reasons. Some people travel for work, others to see their family. On the other hand, education-related air travel is not strictly necessary. The previous generation did not travel during their studies and still feel perfectly comfortable in today's professional world. Giving special treatment to education-related mobility would seem unfair to other travelers who will have to make reduction efforts and hence it would compromise collective efforts. Even in the case where education-related air travel is considered to be more legitimate than other air travel, it would still need to be reduced in a lesser way. In this master thesis, we will consider that education-related air travel does not get any special treatment.

[5] These calculations are based on carbon budget established in France's SNBC (Stratégie Nationale Bas Carbone).

The question now is by how much should student mobilities be reduced? This will depend on the number of flights induced by student mobilities. The greatest the number of flights caused by mobilities, the more radical measures will be needed. One could naïvely think that the only flights induced by student mobilities are the *round-trip travels* of students between the destination and home country, but what about friends and family visiting the student? What if the student travels to neighboring countries while on mobility? What if the mobility experience makes the student want to travel more in the future? These causes, among many others, could increase the total number of flights induced by the mobility. For all potential causes, the scenario of the student going in mobility should be compared with the scenario where the student stayed home in order to determine the net effect of the mobility. Indeed, if the student travels regardless of whether he/she is on mobility or not, leisure travels cannot be attributed to the mobility. In other words, we are interested in the additional aviation use caused by the student mobility.

Quantifying the effect of these different causes would then be very helpful for designing efficient measures. For example, if visiting family and friends has greater impact than the travels of the student, refunding train tickets would not be an efficient measure. Indeed, it would reduce GHG emissions of the student's journey to and from his destination but would not have any effect on visiting family and friends as they would have no incentive to take the train too. In the next two sections, causes of additional air travel are identified and quantified. These causes are broken down into two categories: **direct emissions** (what is being emitted during the exchange period) and **indirect emissions** (what emissions are induced on the long run).

2.3. What are the direct GHG emissions of student mobilities?

Review of literature.

The first cause of direct emissions is of course **the travel of the student** to his/her destination country and **back home** once or several times for students coming back home during their mobility. One first recent survey about sustainable behaviors of 7776 Erasmus students (Green Erasmus, 2022) found results about student travel patterns before and during their European mobility and showed that students came back home on average 0.6 times/capita during mobility. As the Erasmus Programme funds European mobility, this data only gives information about European mobilities. No data was found for transcontinental mobilities. Emissions depend on the means of transportation used by students. For transcontinental travels, we can safely assume that all students will fly to their destination as there is no real alternative. Reducing air travel in this case would imply less students going to faraway destinations. For European exchanges (e.g., in the context of Erasmus Programme), the survey of Green Erasmus (2022) found out that over 7 out of 10 Erasmus students use the airplane as a way to get to and from their destination. In most of these cases, mobility of students could be maintained while reducing air travel as most pairs of European cities can be reached by using trains or buses.

The second cause of direct emissions linked to Erasmus exchanges is related to **leisure travels** for tourism purposes during the mobility. The World Tourism Organization (2016) stated that "*Erasmus Students are a key element in a constantly growing tourism market*". In a recent survey over 1967 Erasmus students (ESN & Eurail, 2020), 92% of them travelled during the mobility with an average of 3.5 round trips (including trips to go back to the home country). 50% of students took the airplane at least once during those trips. However, Green Erasmus (2022) survey found that Erasmus students took the plane for tourism on average 0.5/times/capita during their stay, (assuming that all trips were made with the airplane except for trips in the residence country and in neighboring countries) which is much less than 3.5, this can be explained by the fact that about 70% of these Erasmus students had their mobility experience between spring of 2020 and spring of 2021, a period disrupted by the pandemic. For these students, travel patterns were likely affected by Covid restrictions, hence these numbers could only be interpreted as a lower bound estimation. No other data was found. This data indicates that leisure travels are a significant cause of air travel but does not provide good estimations as the means of transportation are lacking and numbers vary a lot between the surveys. Quantifying these emissions with precision will need extra data.

The question one would now ask is whether students would have travelled more if they had stayed home. In view of the previous data, as mobilities span mostly during academic semesters, it can be safely assumed that the average student would have travelled much less than three times during an academic semester. In fact, most students do not travel during the semester. This intuition is confirmed by a survey over 126 students in Prague highlighted that "*more students are traveling while participating in the program than when they are at home*" (Durovic & Lovrentjev, 2015, p.5).

Besides coming back home and leisure travels, extra air travel can be caused by **visiting friends and family**. The Green Erasmus survey did not ask students about visiting family and friends but the previous 126 students survey (Durovic & Lovrentjev, 2015, p.5) showed that 97.6% of them were visited in the host country by their friends or family during their mobility. In addition, a 2014 survey of 551 international students in Taiwan (Lee and King, 2015) has found that 89.4% of international students strongly encouraged their friends and relatives to come and visit them and claimed that 35% were visited before completing the survey (Lee and King, 2015). Most of the visitors were 2 or less (64.1%), 29.2% were 3 to 4, 9.9% 4 to 6 and 14.9% were over 6 (Lee and King, 2015). As almost all students received visit during their mobility, flights caused by student mobilities are multiplied by a large factor that depends on the number of visiting relatives. For example, a student getting visit from his parents will triple the number of flights (not taking into account other flights than home-host countries). Again, this will be true under the hypothesis that relatives would not have travelled to another place instead of visiting the student, which is reasonable to assume. These figures confirm that visiting family and friends are a significant cause of air travel. However, the data is not very precise and does not allow us to derive a reliable estimation of the average number of visiting family and friends. Additionally, this number might be different for European and transcontinental mobilities.

Results of the survey.

As flying behaviors have rapidly evolved during the years 2010s, data quickly becomes obsolete and not much was found in the literature besides the Green Erasmus survey. That is the reason why we decided to carry out a survey to quantify the direct and indirect effects of European and transcontinental mobility. The **quantitative survey** reached 135 respondents, most of them are students from UCLouvain having done their mobility experience in 2022 and 2023. Only one respondent had his mobility during 2020 and 12% did their mobility in 2021. As this sample is quite large, the different factors needed to calculate the total carbon footprint of mobilities can be reliably estimated. A distinction was made between European mobilities (80/135 respondents) and transcontinental mobilities (55/135 respondents). All questions and possible answers are detailed in Appendix 2 and all survey's figures are in Appendix 3. It should be noted that in order not to discourage students from taking the survey, it was decided to keep it short: it consisted of 13 questions and took three minutes to answer.

First, the survey confirms that most students use the airplane to reach their destination with 86% of respondents using the plane. All students going outside of Europe used the airplane while 77% of students going to European destinations used the airplane. This result is in line with the 70% found by the Green Erasmus survey.

Secondly, more than 68% of students (92/135) did not return to Belgium during their mobility. On average, students going to European destinations came back 0.6 times with some students coming back multiple times. This is exactly what was found by the Green Erasmus survey. For transcontinental mobilities, this number decreases to 0.4. This makes sense as transcontinental tickets are generally more expensive than intra-European tickets.

Next, the survey found out that students going on transcontinental mobilities took more flights for leisure travels than students going to European destinations. For transcontinental mobilities, students took on average 2 flights for visiting the host country and 1.3 flight for visiting neighboring countries. For European mobilities, students took on average 0.4 flight in the host country and 0.5 flight for visiting neighboring countries. This difference could be explained by the fact that more alternatives to the airplane are available in Europe with a strong train infrastructure (at least compared to other continents) and by the fact that Europe is a quite dense continent, distances between major cities being generally smaller than on other continents, making it easier to travel by train, car, or coach.

Additionally, the survey showed a clear difference between European and non-European destinations regarding visiting family and friends: on average, 1.9 friends and 2.2 family members visited students in Europe, these numbers falling respectively to 0.4 and 0.9 for student on other continents. These numbers make sense as the price of transcontinental tickets is more expensive than European flights leading to less friends and family willing to visit the student. Only an average of 0.1 friend or relative took the train or bus to visit the student.

It is now possible to estimate the impact of student mobilities as a number of flights. As numbers for European mobilities and transcontinental mobilities bear significant differences, estimations are done separately. The total number of flights found will then be multiplied by the GHG emissions for one round-trip to the destination of the student in order to estimate the total carbon footprint of one mobility. As previously discussed, a flight can be attributed to the mobility only if it would not have occurred if the mobility had not taken place. For students, it is assumed that flights would not have occurred as most students do not travel at all during the semester and hence all flights from the students (including leisure travels) are attributed to the mobility. However, as domestic flights are usually shorter than the flights to reach the destination country, the number of flights in the host countries is divided by two in Europe and by three outside of Europe in order to have the same effect as a decrease of the distance travelled. For example, a Belgian student who travelled to Boston having a domestic flight to Miami will have covered less distance to go to Miami than between Brussels and Boston. With the previous assumptions, the Boston-Miami flight is counted as a third of the Brussels-Boston flight. Regarding leisure travels in neighboring countries, the number is also divided by two in both cases as the distance is reduced compared to a trip home-host country. For visiting family and friends, one could argue that visiting the student could replace a vacation in some cases, for this reason it is assumed that half of travels would not have occurred resulting in the division by two of corresponding numbers (Appendix 3).

After summing for all causes it was found that European mobilities are directly responsible for an average of 3.6 round-trip flights compared to 3.4 round-trip flights for transcontinental mobilities. To these numbers, the contribution of indirect effects still needs to be added.

2.4. What are the indirect GHG emissions of students mobilities?

Review of literature.

As student mobilities are great opportunities for students from different countries to meet each other, one could expect some students to develop strong bonds leading to **long-distance relationships**. An international association co-founded by the European union named “Erasmus student network” (ESN) published a survey in 2005 with more than 8,000 European students. In this survey, almost 7 out of 10 students reported that they would consider being in a serious relationship with someone from a foreign country (Krzaklewska & Krupnik, 2008). This tells us that distance does not discourage students from engaging in relationships with people from other countries. But can we say that this is substantially true only for students experiencing once a foreign mobility? Probably not, as we can meet and develop a long-distance relationship by staying in our own country. However, the aim of the Erasmus Programme and of mobility programs is to promote cultural, social, and academic exchanges among students which makes Erasmus students more likely to develop long-distance relationships than other students staying home.

In addition, Erasmus students can develop a **taste for travel** during their mobility experience. According to the same ESN survey, “*almost 80% of respondents would consider moving to a foreign country*” after this experience (Krzaklewska & Krupnik, 2008, p.2). Even though this is probably not the case for all students, we can safely assume that staying home would have developed the taste for travels of students less than living abroad for half a year.

Results of the survey.

Besides what is found in literature, we also investigate indirect effects through the same survey that was used to collect data about direct effects (Appendix 2 and 3).

When asked if students are planning to meet again in the future with people they met during their mobilities, 54.8% of they said that they already planned to meet again, 33.3% said that they would consider meeting if they are on vacation in the country of these people. The last 11.85% responded “no, not particularly”. The survey did not find any significant difference between European and international mobility. This shows that at least half of students will very likely fly at least once more. For students who already planned to meet with their mobility friends, it can be assumed that this trip would not have taken place had the mobility not happened, for students who would visit their friends if passing in their country, this assumption cannot be made.

When asking students if the exchange made them want to travel more often, 62.2% of them answered “yes, it gave me a taste for travel and adventure”, 18.5% of them said that “yes, I plan to travel a little more often”, and 19.3% of them answered “no, not particularly”. We can thus conclude that about 8 out of 10 students will travel more due to this experience. Among European mobilities, 55% said that they wanted to travel more and 25% a little more. For transcontinental mobilities these numbers become 73% for more travelling and only 9% for a little more travelling. Interestingly, the sum over “more” and “little more” for both cases is very close (80% for European mobilities and 82% for transcontinental mobilities), but clearly, the effect of transcontinental mobilities is stronger with students either loving it and wanting to travel much more or students not having a good experience and not willing to travel more. In either case, this shows that student mobilities develop a taste for travel strongly for at least 60% of students and in a lesser way for about 20% of students.

As indirect effects are uncertain, only conservative hypotheses are made in order not to overestimate indirect effects. Indeed, this would give us a “lower bound”, which, if found to be significant, would lead to the conclusion that these effects are significant and should be taken into account. For that purpose, one additional flight is counted for students who already planned to meet mobility friends and 0 for others. For taste for travel, it was decided not to add any contribution as this is too uncertain.

This leads to a total of **4.1 round-trip flights for European mobilities** compared to **3.9 round-trip flights for transcontinental mobilities**. Given that the difference is quite small (about 5%), this factor will be considered to be equal to **4 for both European and transcontinental** mobilities. This is quite surprising as we would expect more flights for shorter distances as tickets are cheaper and trips are shorter.

This factor means that when a student goes on an exchange, its net impact is on average multiplied by a factor 4. It is now clear that when taking all side effects of student mobilities into account, the carbon footprint of student mobilities becomes very large. For example, a student going to Montreal in Canada (Canada being the number one destination at UCLouvain) would cause the equivalent of 8.64 t of CO_2 emissions (2.16 t round-trip flight[6]*4), which is 80% what the average Frenchman emits per year or 55% what the average Belgian emits per year, and 4.32 times the theoretical yearly carbon budget discussed previously for staying under 2°C of warming. On the other hand, a student going to Madrid would cause an equivalent of 2.672 t of CO_2 emissions (0.668 t round-trip flight [6]*4) t of CO_2 emissions which is more than 130% of the individual carbon budget to stay under 2 degrees of global warming.

It is now clear that student mobilities in their current state are unsustainable. This is especially the case as distance to the destination grows. This is why effective measures need to be taken to reduce the impact of student mobilities. It should be noted that small variations in the multiplicative factor would not have changed the conclusion of this part. If the real factor was 3 instead of 4, the impact of mobilities would still be in contradiction with climate goals and the question of how to reduce air travel of student mobilities would still be relevant. The next part explores the different possibilities to determine the best candidate measures.

3. What can we conclude from part 1?

Part 1 first explained why green technologies will not allow human societies to maintain growth in the aviation sector even though these technologies are central in the "green growth" plans of the EU. Three solutions are often discussed: electrification which is infeasible in the aviation sector because of the weight of the batteries, green hydrogen which is not an energy source but rather a way to store energy, and biofuels which would require a lot of agricultural lands for

[6] Figures are computed by multiplying the flight distance between Brussels and the city mentioned (Distance calculator, 2023) by the corresponding emission factor (0.195g of CO_2 per kWh for long-haul flights or 0.254g of CO_2 per kWh for short-haul flights) (BBC News, 2019).

their production. In view of the limitations of green technologies, energy-sufficiency, i.e., deliberately reducing energy consumption, will be necessary in order to meet climate targets. In the case of air travel, energy sufficiency consists in reducing the number of flights.

Then, we have seen that although aviation only accounts for 2.5% of global CO_2 emissions, this does not mean that it represents 2.5% of the carbon footprint of the average flying citizen. Indeed, most humans do not fly and 1% of the world population is responsible for 50% of aviation emissions. From an individual carbon footprint perspective, flying even once a year is not in line with Paris Agreement goals. This means that when people ask themselves whether to fly less, they already have the answer. Additionally, we showed that aviation emissions have been strongly increasing during the last ten years, which is the opposite of what is needed to meet climate goals. If policy makers do not take care of decarbonizing air travel now, the problem will only get bigger in the future.

Finally, with regard to student mobilities, we found that air travel caused by mobilities does not limit to the round-trip to go to and come back from the destination. Students come back home during their mobility, travel during their mobility and receive visits from family and friends. These numbers depend on the type of mobility: European mobility or transcontinental mobility. In order to estimate these causes, we surveyed 135 UCLouvain students. On the one hand, European students had on average more visits from family and friends than students on transcontinental mobility (4.1 versus 1.3 relatives on average). On the other hand, it was found that students on transcontinental mobility used much more the airplane for leisure purposes than students on European mobility (3.3 versus 0.9 travels on average). Additionally, students came back home on average 0.5 times during their mobility and 55% of students reported that they had already planned to meet again with their mobility friends.

When summing up for all causes of emissions, we found a similar multiplicative factor of 4 for both types of mobilities. Meaning that the real carbon footprint of a student mobility should be obtained by multiplying the carbon footprint of the round-trip to the destination by 4. Using this multiplicative factor, a Belgian student going to Montreal emits 8.64 t of CO_2 which is 4.32 times the theoretical yearly carbon budget of we want to keep global warming below 2°C. It is hence urgent to investigate ways to reduce the environmental impact of student mobilities.

Part 2: How to reduce student mobility air travel?

1. What are the levers of actions to reduce student mobility air travel?

From the perspective of the ASI framework (Bongardt et al., 2019), there are three types of levers of actions to make consumer behavior more sustainable:

- "A" for *avoid*, trying to diminish use or consumption of a service/product: in this case this would consist in **reducing the number of mobility opportunities**. Of course, reducing the number of opportunities would be an easy and effective way to reduce GHG emissions of student mobilities. However, this master thesis tries to find ways to reduce air travel emissions of mobilities while maintaining as many opportunities as possible. The difficulty lies in finding the right tradeoff between reducing environmental impact of mobilities and maintaining mobility opportunities.

- "S" for *shift*, trying to replace the service/product by another one with lesser impact. In this case, this would consist in trying to increase the number of students taking **alternative modes of transportations** to go to their mobility destination. Another way of seeing it is to ***shift*** **long distance mobilities to shorter distance mobilities**. Indeed, as already discussed in part 1, long distance mobilities are more emissive than shorter ones, hence, reducing distances would make mobilities more sustainable.

- "I" for *improve*, trying to improve the current product/service: in this case this would consist in **flying "greener"** (with hydrogen or biofuels propelled airplanes), but these technologies were shown to have very limited potential in part 1 and this is not the research question of this master thesis.

Three levers of actions are identified: reducing the number of mobility opportunities, reducing the distance of mobilities and alternative modes of transportations. For the latter one, we will assume that it can only apply to short distance mobilities. Throughout this master thesis, we will look at the case of European universities. In those cases, **European mobilities** will be considered as short distance mobilities, **transcontinental mobilities** (outside of the European continent) will be considered as long distance mobilities. It is safe to assume that most European students will never be willing to travel outside of Europe by any other mean than the airplane as this always implies multiple days (or even weeks) of travelling time and high costs. For European mobilities different options could replace the airplane. Emissions from different modes of transport are displayed in the following bar chart:

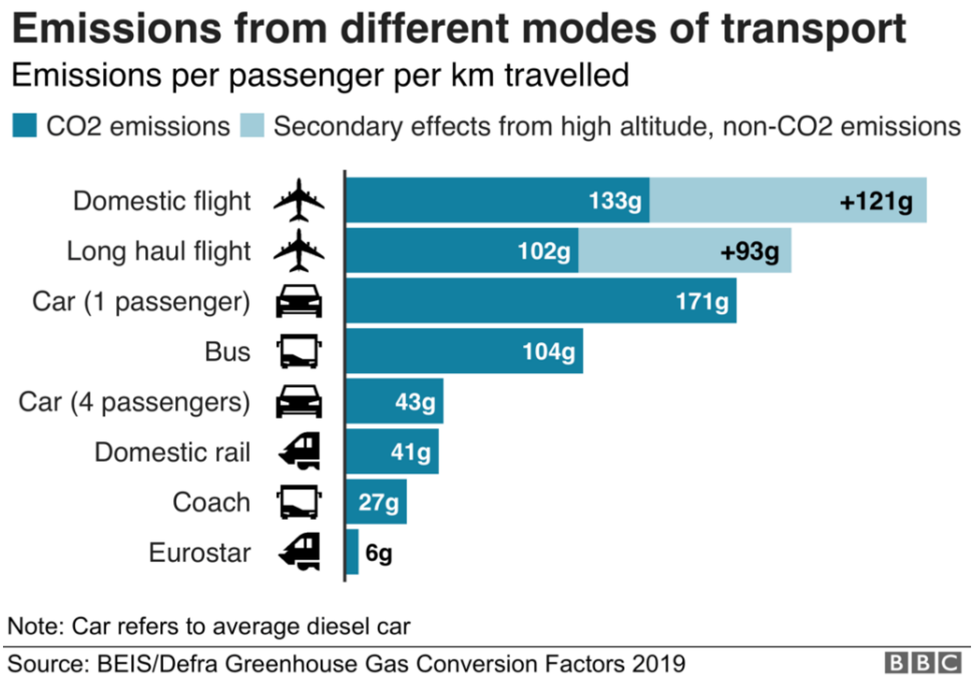


Figure 5: GHG emissions per passenger and per kilometer for different transportation means (in grams of CO_2e), data from UK government (BBC News, 2019).

In the previous figure, light blue emissions represent warming induced by planes which does not come from GHG emissions (as explained in part 1, section 2.1), these effects need to be taken into account as they also contribute to global warming. There is also a difference between domestic (short distance) and long-haul flights due to the fact that takeoffs are very energy-consuming, which leads to less GHG/km for longer flights. The distinction should be made between "bus" and "coach", buses are operated on a daily basis as part of the public transportation system and have a relatively high emission factor because of the low occupancy rate while coaches are operated for longer travels with high occupancy which leads to a smaller emission factor. We see that coaches emit almost 7 to 9 times less GHG than airplane. Trains emit 5 to 6 times less GHG than airplanes in the case of the UK train network. Those numbers vary accordingly to the occupancy rate and the country energy mix for the train, but that still gives a clear insight of the most sustainable travel modes but will always be much smaller than airplane emissions. This is why the Eurostar, which uses French electricity is less emissive than UK domestic rail.

The previous chart shows that coaches, trains, or carpooling are all good alternatives to the airplane and could lead to a decrease of the order of 70% to 90% of the carbon footprint of the student travel. However, this could only apply to European mobilities. For transcontinental mobilities, alternative means of transportation are not an option. Moreover, section 2.5 showed that long distance mobilities have a higher carbon footprint than short distance mobilities, calling into question the potential of alternative means of transportations as it only applies for the part of mobilities that are less emissive. However, these numbers do not draw the full picture of the carbon footprint of mobilities, the number of students going to short/long distance mobilities should also be factored into the equation. If most students go on European mobilities, it will not make sense to only focus on transcontinental mobilities. In order to answer these questions, data from UCLouvain is analyzed. This data comprises all exchanges from 2018 to 2023, totaling 4181 students, the results are visualized on the following chart:

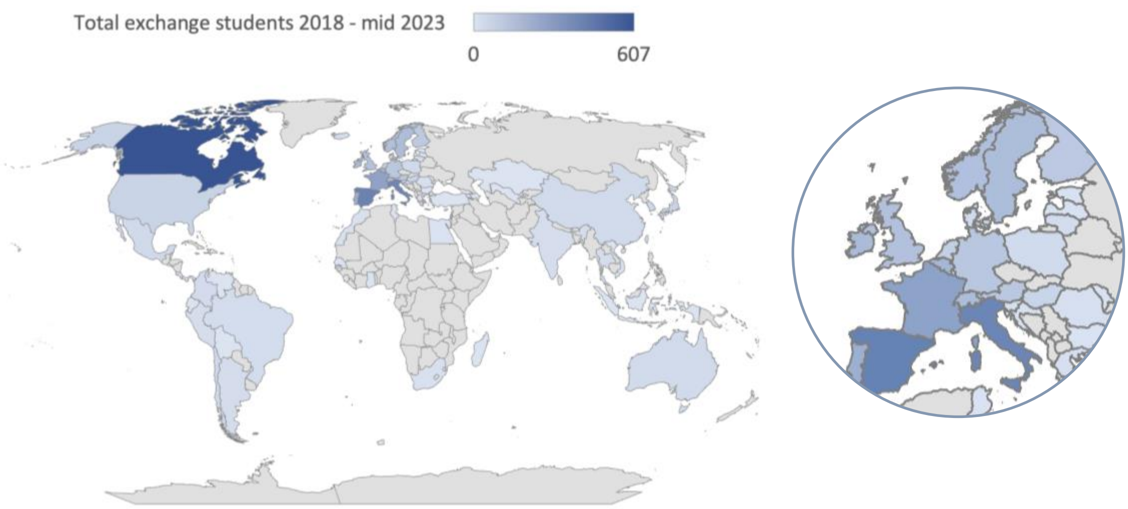


Figure 6: Spread of UCLouvain students going in mobility between mid-2018 and mid-2023.

Canada is the country where the most students go (607 out of 4181 over the last five years). Next come Mediterranean countries: Spain (411 students), Italy (395 students), France (275 students) followed by Portugal (220 students). Overall, the majority of UCLouvain students go to European destinations. From the top 15 destinations, only Canada lies outside of Europe. Of all UCLouvain students going on mobility from 2018 to 2023, 82% stayed within the European continent. Across this thesis, the year 2022 will be taken as reference, for that year 68% of mobilities are European mobilities, this difference can be explained by covid restrictions for years 2020 and 2021 (many transcontinental mobilities cancelled). When summing GHG emissions of all European and transcontinental mobilities of 2022 using the multiplicative factors determined in section 2.5, emissions for European mobilities reach 1206.8 t CO_2 (301.7

t*4) compared to 3544 t CO_2 (886 t*4) for transcontinental mobilities. Transcontinental mobilities only represent 32% of total mobilities and yet they are responsible for 74.6 % of student mobility emissions. It is then clear that transcontinental mobilities should be the primary focus of our measures. However, European mobilities cannot be neglected as they still represent 25.4% of the total carbon footprint. Additionally, if solutions for long distance mobilities imply relocating mobilities in Europe, this would make the question of how to reduce impacts of European mobilities even more relevant. For these reasons, alternative means of transportation should not be discarded as a lever of action but reducing the impacts of transcontinental mobilities should be prioritized.

The next question to ask is then "what is the relative impact of each lever of action?". Indeed, as five causes of student mobility air travel were identified in part 1 (travel home-destination, visiting family & friends, on mobility travel, long-distance relationships, and taste for travel), it is not straightforward how much each lever of action would impact each cause of air travel. For example, reducing distance will surely reduce emissions of students going to and back from their destination but it will likely have no impact on his leisure travels while on mobility. The next section tries to quantify the possible GHG reduction of each lever of action.

2. What is the relative impact of each lever of action?

Thanks to the estimations of the carbon footprint of student mobilities of section 2.5, it is now possible to estimate the potential of the three different levers of actions for reducing the total GHG emissions of student mobilities. For that purpose, three simplified different scenarios are analyzed with mobility data of 2022 from UCLouvain:

- **Removing half of mobility opportunities**. Destinations are sorted by decreasing order of distance, one spot out of two is removed in that order. For example, if the first destination is Sydney with seven spots and the second is Canberra with three spots, then four spots are removed in Sidney and one spot is removed in Canberra. This would allow us to emulate any scenario in which certain destinations are kept for reasons that are independent of distance (we discard destinations uniformly on distances).
- **Relocating all distances of more than 3000km to an average distance of 1500km**. It is assumed that students still take the plane to go to their new destinations.
- **Forcing all students going on a European mobility to take the train**.

It should be noted that these scenarios are not meant to be implemented but rather to quickly determine the potential of the different levers of action. The results are shown in the following table. Each entry of the table represents the impact of each measure targeting a specific lever of action, theoretical expectations are compared with the results for the specific scenario. For the theoretical expectations "> 0" means that one expects positive effect, ">= 0" means zero effect in some case, positive effect in other; "=0" means no effect. For the results of the different scenarios, the reduction for the specific cause is displayed (local decrease) as well as the reduction on the total carbon footprint (global decrease). For example, if leisure travel represents 30% of the total carbon footprint, a local decrease of 50% of leisure travels would lead to a global decrease of 15%.

ASI Framework	**Avoid**	**Avoid & Shift**	**Shift**
Scenario / **Lever of action**	***Reducing number of students mobilities***	***Reducing travel distance***	***Alternative means of transportation***
Travel home-destination	"> 0": positive effect (assumption that students do not travel during semester travel less if not on mobility). *-48.7% local decrease* *-17% global decrease*	">0": double effect of less kilometers and assumption that students will be more likely to take alternative modes of transportations. *-64.5% local decrease* *-13.87% global decrease*	">= 0": using alternative means of transportations will always decrease GHG emissions but can only replace short distance travels. *-19% local decrease* *-2.5% global decrease*
Visiting family & friends during mobility	> 0": positive effect *-48.7% local decrease* *-16.4% global decrease*	> 0": positive effect *-64.5% local decrease* *- 21.5% global decrease*	"= 0": assumption that friends and family's travel choice will not be affected by the student's travel choice. *-0% local decrease* *-0% global decrease*
Leisure travels	> 0": positive effect *-48.7% local decrease* *-10% global decrease*	"= 0": no impact is assumed as the distance to the destination does not influence leisure travels patterns. *-0 % local decrease* *-0% global decrease*	"= 0": assumption that it will not have any impact if students are not incentivized. *-0% local decrease* *-0% global decrease*

Long-distance relationships	"> 0": assumption that mobility experiences are more suited for students to foster relationships than standard holidays. *-48.7% local decrease* *-6.8% global decrease*	"=0": no effect is assumed as closer destinations are evenly favorable for students to develop long distance relationships *-0% local decrease* *-0% global decrease*	"= 0": no impact as the student will only be incentivized to take the train to go on mobility and not the next time, he travels to visit friends *-0% local decrease* *-0% global decrease*
Taste for travel	"> 0": assumption that students would develop a taste for travel during their mobility experiences but no quantification for this cause.	"=0": no effect is assumed	"=0": no impact
TOTAL decrease	**-48.7%**	**-35.37%**	**-2.5%**

Figure 7: Effectiveness of levers of actions on the different causes of GHG emissions due to the exchange mobility.

From this table, different takeaways can be drawn. First, reducing by two the number of students going on mobilities would be effective for all five causes (assuming that net effect is positive, and that student and family & friends would travel less if no mobility) and would lead to a 48.7% decrease of total emissions. However, this would be the most harmful measure as students would lose mobility opportunities.

On the opposite side, alternative modes of transportation would be the least restrictive measures, but results show that they would lead to the least decrease in GHG emissions. Indeed, even when having all European mobilities go by train (which would be very hard to achieve in practice), the total GHG emissions would only decrease by 2.5 %. This is because alternative modes of transportation can only apply to European mobilities and that they do not reduce the impact of visiting family and friends and the student going back home during the mobility.

Finally, reducing distance of mobilities lies in between the two previous ones. Indeed, this would still allow students to have mobility experiences and it would lead to a total decrease of 35.37 %, which is much more than alternative modes of transportation. The detailed calculations can be found in Appendix 4.

One could now argue that measures should just consist in reducing the number of opportunities and the distance of mobilities but in order for a measure to be effective, it needs to be implemented in the first place. Measures need to be accepted by the university officials and also, to some extent, by the students who would not be happy if, for example, all mobilities were cancelled. If a measure is not accepted by students, there is a good chance that universities will not risk implementing it. Ideally, measures should be as acceptable as possible without compromising effectiveness but how to make a measure acceptable? The next few sections study the question of acceptability by first introducing some terminology for classifying measures before reviewing the literature about what types of measures are more acceptable.

3. Which measures are acceptable?

3.1. How can we classify measures?

A common way to classify policy measures in general is by splitting them into **high-coercive** (e.g., banning certain travels, reducing number of opportunities) vs **low-coercive** (e.g., awareness campaign) measures (Kreil & Stauffacher, 2021). Coercivity is according to Cambridge Dictionary (2022) "*using force to persuade people to do things they are unwilling to do*". There are different degrees of coercivity. The highest degree is ban but financial penalties are also viewed as high-coercive measures (Kreil & Stauffacher, 2021). In their recent study, these authors even regarded monitoring policies as high-coercive. On the other hand, low-coercive measures are measures like recommendations, promotion of alternatives and awareness-raising campaigns. These measures need students to be willing to change in order to be effective (Kreil & Stauffacher, 2021). High coercive measures are usually more effective than low coercive measures but are less acceptable.

A second way of separating policy measures is into **pull** and **push** policies. On the one hand, "*pull measures encourage the desired behavior (i.e., behaving environmentally friendly) and increase the benefits and opportunities of performing "correctly"; pull measures are generally regarded as non-coercive*" (Eriksson et al., 2006; Loukopoulos et al., 2005 as cited in de Groot

& Schuitema, 2012, p.101). An example of pull measure when trying to reduce public littering is to increase the number of bins. On the other hand, "*push measures incorporate discouraging the undesired behavior (i.e., not behaving environmentally friendly) or increase the disadvantages of this behavior; push measures are believed to be coercive in nature*" (Loukopoulos et al., 2005 as cited in de Groot & Schuitema, 2012, p.101). An example of a push measure are speed bumps (in the context of speeding). In our case, refunding train tickets could be seen as pull measures while push measures could consist in reducing grants for faraway destinations.

3.2. What types of measures are acceptable?

This master thesis consider that a measure is acceptable if it has a good chance of being implemented. As we live in democratic countries, public support is very important to implement policies. This is also the case for environmental policy measures in universities. A study of de Groot & Schuitema (2012) looked at factors determining support for environmental policy measures. This study aimed at confirming or rejecting general assumptions about public acceptability of environmental measures.

Which measures between push and pull are better accepted?

The paper of de Groot & Schuitema (2012) confirmed the difference between **push and pull** measures regarding acceptability. They found out that people were much more likely to approve of a pull measure than a push measure. Part of this is because little distinction was made between *push measures* and *high-coercive* measures and *pull measures* and *low-coercive measures* in the paper. The authors considered high-coercive measures to be push measures and it is easy to understand why people approve more of low-coercive measures.

But are high-coercive measures really the same as push measures? As expressed above in this section, the distinction between high-coercive and push measures is not very clear. Indeed, coercivity emphasizes people's willingness/unwillingness to do something while pull and push measures emphasize incentives/penalties or deprivation/opportunity schemes. For instance, subsidizing electric cars would be considered a noncoercive pull measure. However, can we really say that people buying electric cars are *willing to go electric*? Are they not *financially pushed* towards electric cars? We could argue that even if they are not really willing to buy an electric car, buying a combustion vehicle would not cost more money than previously and they would only gain money by going electric. However, when taking into account the fact that subsidies are coming from taxpayers' money, it turns out that they are forced to pay for electric cars through taxes and not going electric would then be a net loss. This example highlights the *psychology* of push vs pull measures and how people can be tricked into perceiving differently measures with the same effect. This is called the *framing effect* (Tversky & Kahneman, 1981). The **framing effect** is defined by Lavery (2017) as "*a cognitive bias in which the brain makes decisions about information depending upon how the information is presented*". In other words, depending on how a message is put forward, independently of its content, people will interpret it differently and adopt a different behavior. This psychological effect is crucial regarding the research question, and it will have to be considered when formulating any measure and can make a difference between a policy measure being accepted or rejected.

In the same paper, measures targeting **low-cost environmental behavior** were found to be more acceptable than **high-cost environmental behavior**. Low-cost and pull measures were even more approved while push and high-cost measures were even less approved. This is easily understandable as high-cost measures require more effort (de Groot & Schuitema, 2012). People seem to be more willing to act environmentally friendly when it does not require too much effort, this is known as the "*low-cost hypothesis".* According to Diekmann and Preisendörfer in 2003 (as cited in de Groot & Schuitema, 2012), this hypothesis "*predicts that the strength of effects of environmental concern on environmental behavior diminishes with increasing behavioral costs. Thus, environmental concern influences environmental behavior primarily in situations and under conditions connected with low costs and little inconvenience for individual actors*". This hypothesis seems to be valid in many situations, for example, academics have lately been criticized for their important use of air travel (Lassen, 2010) while they usually are highly educated and aware of environmental problems. When it comes to students, several studies, including the Green Erasmus study (2022), showed that 90% of students are aware of environmental issues and that the vast majority of students (almost 80%) are concerned about climate issues and believe that humans are responsible for taking action. However, this does not seem to be reflected in their practices during their mobility exchange as flying is the most common way to travel. On the one hand, this means that high-coercive measures requiring too much effort from students like cancelling mobilities or banning airplanes for certain destinations will not be well accepted among students even though they are aware of environmental issues. On the other hand, the low-cost hypothesis suggests that measures should not just rely on awareness raising, hoping that students will act responsibly. Measures will have to provide real incentives for students to change their behavior but as these incentives are most often financial incentives, it can get be quite expensive for universities to implement.

Additionally, de Groot & Schuitema also investigated how **social norms** affect perceived acceptability of environmental measures. According to Oxford Reference (Chandler & Munday, 2016), social norms are defined as "*common standards within a social group regarding socially acceptable or appropriate behavior in particular social situations, the breach of which has social consequences*". In other words, social norms define what is acceptable and what is not in a given society. These social norms shape our daily decisions and behaviors. de Groot & Schuitema (2012) found that "*when it was indicated that a minority instead of a majority of the public supported a policy, acceptability was lower".* As a way of explaining this phenomenon, the authors mention the "social dilemma" of individuals face an environmental policy where short-term individual interests deviate from long-term society interests. In this case the decision of the individual will depend on how much "social pressure" he/she feels to make the decision aligned with the interests of society. That is exactly the situation of taking the plane for a European exchange: flying contributes to the short-term individual interest as it is shorter and often cheaper than taking the train while this is harming society's long-term interests by accelerating global warming leading to negative consequences explained in the first part of this paper. In this case it is clear that flying is still socially very much accepted compared to public littering. This is probably because public littering is a low-cost environmental behavior and hence measures against it gained more popular support. However, this means that if air travelling becomes less socially tolerated in the future as it already is the case in some countries (like flight shaming in Sweden), measures that would not be accepted by students now could be accepted by students in the future.

Factors determinant in measure acceptability are not limited to those listed above, other studies showed that perceived effectiveness (Bamberg & Schmidt, 2003) and perceived fairness (Bamberg & Rölle, 2003) of measures are also determinant in acceptability.

Measures aiming at reducing student mobilities air travel will need to be designed in such a way that they are as acceptable as possible without compromising effectiveness. Unfortunately, there seems to be no magic solution as high coercive measures (banning air travel) are *very effective but not acceptable*, pull measures like refunding train tickets are *relatively effective but very costly* and cheap low-coercive measures like awareness raising are *acceptable but ineffective*. Finding the measures to fulfill this research question will thus consist in finding the right tradeoff between cost, effectiveness, and acceptability. Before designing new measures that could potentially fail, a good practice is to look at measures that have already been implemented, for these measures it is already known that they were accepted by some universities.

4. What measures have already been implemented to reduce the use of air travel in student mobilities?

We first look at what has been done by the Erasmus Programme, comprising most European mobilities. To promote sustainability, the European Commission (EC) allocated a limited budget intended to refund **50€** of the student's journey if he or she uses a sustainable means of transport. As sustainable means of transportation often take longer, the Erasmus Programme also offers daily **grant for every extra day** spent on the outward or return journey up to four days. This applies to all partner universities of the Erasmus + Programme. (ULB, 2022). While being a first step towards the right direction, this refund is definitely not high enough to offset the difference in costs between a train ticket and a plane ticket. Indeed, 50€ per student represents in fact 25€ to reach the Erasmus destination and 25€ to come back home. By taking an example, flying from Brussels to Madrid costs 51.48€ for a 2h20 flight while the same journey by using the train costs 129.99€ and takes 23h25 making the train still twice as expensive as the airplane besides being much longer. Even with one extra day of grant (e.g., 18€ for Spain), plane still is the cheapest besides being the fastest and most convenient for this country.

Additionally, refunds require a lot of paperwork and only take place several months after submitting the request. According to Natacha Buntinx (personal communication, January 18, 2023), working in international relations administration at UCLouvain, many students travelling by train do not ask for a refund. Besides the paperwork, this can also be explained by a lack of visibility of this refund. When asking students who went on a mobility experience whether or not they are aware about this refund in the quantitative survey (Appendix 3), 63% of them had not heard about it, 31% knew about the 50€ refund, and only 5% knew about the 50€ refund and about the additional days of grant discussed previously. These numbers suggest that most students do not know about this financial help, this might be due to the fact that universities are not incentivized to promote it as this would imply a lot of administrative work for them too.

We now look at what has been done at university level. Recently, UCLouvain allocated funds for supplementing the 50 euros granted by the Erasmus+ Programme when a student uses a sustainable mode of transport (i.e., train, bus, bike, or carpooling).

One way flight distance from Louvain-la-Neuve	Single contribution
Between 100 and 300km	50€
Between 301 and 600km	100€
Between 601 and 900km	150€
Between 901 and 1200km	200€
Between 1201 and 1500km	250€
Between 1501 and 3500km	300€

Figure 8: Amount funded by UCLouvain for mobility students using a sustainable means of transport to get to and from their destination according to the flight distance travelled (in euros).

This financial help is significantly greater than the 50 euros of the EC. Now, when going to Madrid by train (1300 km flight distance), the student would only need to pay 10 euros from his own pocket (2*129.99€ - 250€) for the round-trip travel compared to 102 euros when flying! This could be a game changer when students choose their mode of transportation as train is now generally cheaper than air travel. As this measure is very recent and will only be implemented for September 2023, data about how many students have requested the contribution is not available yet. As train is still much slower than the airplane, it is not straightforward how many students would find the train more interesting than the airplane. However, when asked about the most important factor when choosing their mode of transportation, of all students who had different options (for example students going to Australia only have the airplane as option), 44% said price was most important. In order to evaluate the effect of this measure, it is assumed that students who have different travel options correspond to student going on European mobility. If we assume that all students prioritizing price would take the train given the financial help, this measure would have 44% of the impact of the scenario where all students going in Europe have to go by train (scenario discussed previously in part 2, section 2). Because alternative modes of transportation were relatively ineffective, this would only lead to a 1.1 % of all air travel emissions of student mobilities.

Prior to the announcement of this measure, I interviewed Bart Stoffels (personal communication, January 18, 2023), head of mobility at the international relations administration of UCLouvain. At that time, Mr. Stoffels argued that the reason why UCLouvain was not refunding train or bus tickets was because of the high cost this would incur to the university. This turnaround shows how committed UCLouvain is to reduce GHG emissions of mobilities.

Several examples of measures currently implemented by European universities were highlighted in a recent report (De Pater et al., 2022) co-funded by the Erasmus + Programme of the European Union. This report looked at different ways to reduce transport-related carbon footprint of the Erasmus + Programme.

- Green Travel Grant: since 2021, Utrecht University refunds up to €185 of the outward journey using sustainable mode of transportation, if the journey costs more than that amount, students are encouraged to buy an Interrail ticket (currently at €174 for 4 days of travels over one month).
- Ghent University: "*subsidizes train and bus trips by 30 euros for tickets exceeding 100 euros, and by 100 euros for tickets exceeding 200 euros*" (De Pater et al., 2022, p.19)

Other measures taken by universities include monitoring and offsetting of GHG emissions, but those are of lower interest for this paper as it looks at ways to significantly reduce air travel (not offsetting emissions) and low-coercive measures such as awareness-raising. Interestingly, all these measures focus on *increasing the share of alternative modes of transportation* and are all pull measures. This confirms that pull measures are more acceptable than push measures as they are the only examples that could be found. No measure aiming at reducing Erasmus distances or number of opportunities was found although 74.6% of GHG emissions are caused by transcontinental mobilities. When asked about reducing distances of travels, Natacha Buntinx (personal communication, January 18, 2023) revealed that no measure was not taken mainly because faraway destinations tend to attract students the most and that UCLouvain wishes to increase the number of students going on mobility. When interviewing Vice-Dean of International Relations at UCLouvain, Ina Aust-Gronarz, she reported that there have been many internal discussions about reducing distance of mobility destinations and that UCLouvain will focus on European partnerships from 2021 onwards (personal communication, May 26, 2023). However, it is unclear what concrete measures have been taken for that purpose. When suggesting ways to reduce transcontinental travel mobilities like keeping certain destinations and removing others, Mrs. Gronarz pointed at different problems. Certain partnerships cannot be removed because they are part of a common alliance, this is the case for all CEMS destinations. Additionally, according to Mrs. Gronarz, certain partnerships have a diplomatic and societal role. This is the case for partnerships in China for it is essential to keep contact and to have good relationships.

5. What can we conclude from part 2?

In this section, three different levers of actions were identified: reducing numbers of opportunities, reducing distance of destinations, and increasing the use of alternative modes of transportation. Reducing number of opportunities and reducing distances were found to be much more effective than alternative modes of transportation because they are the only options that apply to transcontinental mobilities, which represent close to 75% of total emissions and also reduce emissions of side effects like visiting family and friends.

In order to be effective, a measure should be implemented in the first place. Measures should be as accepted by university officials and students. The *low-cost hypothesis* tells us that the more effort is required for a sustainable action, the less willing people are to do it. Measures requiring more efforts than others will hence be less acceptable. This means that reducing the number of opportunities and reducing distances might not be accepted by universities or students because they limit mobility opportunities for students. In the literature, it was found that pull measures, like refunding train tickets, are generally more accepted than push measures (e.g forcing people to take the train). The previous assumptions were confirmed by UCLouvain officials. The university recently decided to give financial help to students travelling by train or bus. Although it indicated a will to focus on European mobilities, UCLouvain has yet to take concrete measures for that purpose. Reducing distance of mobilities would indeed cause several problems. On the one hand, the objective of UCLouvain is to increase the number of students having a mobility experience and long distance mobilities are the ones that attract students the most. This is a problem for reducing the number of opportunities. On the other hand, certain destinations cannot be removed because they are part of common alliances or because they play a diplomatic role for the university. Although this only reflects the case of UCLouvain, our research did not find any university that explicitly implemented measures aiming at reducing distance of mobilities or the number of mobilities. We only found measures that refund train tickets and other low-coercive measures like monitoring or awareness-raising. It then seems like universities are less willing to reduce distance of destinations than to promote the use of alternative modes of transportation. This means that reducing distance of destinations is less acceptable than promoting alternative modes of transportation.

This leads to a dilemma between effectiveness versus acceptability. On the one hand, reducing the number of mobilities was found to be the most effective but is the least acceptable as universities seek to increase the number of mobilities. On the other hand, universities seem to be willing to take measures to promote alternative modes of transportation, but it was shown to have limited effectiveness. Standing in the middle, reducing distance of mobilities is relatively effective and universities do not seem to be closed to these measures. In this master thesis, it was decided not to investigate reducing the number of mobilities as this is in complete opposition with universities objectives.

In the next parts, we first look at how to reduce distance of mobilities as this has the most GHG reduction potential. As the latter might not be accepted by universities, we then look at ways to increase alternative modes of transportation.

Part 3: How to reduce distances of international mobility destinations?

As seen in previous parts, reducing distances of mobilities can lead to significant gains in GHG emissions while still allowing students to have a mobility experience. For example, we saw in part 2 that by relocating all destinations further than 3000 km from Brussels to an average distance of 1500 km can already reduce by 35% GHG emissions of student mobilities for UCLouvain. While so far, no university has explicitly decided to reduce the distances of its mobility destinations, the covid health crisis of 2020 has proved that it is possible. During that period, UCLouvain had to replace many transcontinental mobilities by intra-European ones, leading to a decrease of 60% of emissions (but only considering emissions from student travels and not other causes like visiting family and friends, ...) while keeping almost the same number of total exchanges (UCLouvain, 2023). Unfortunately, as this was temporary, the situation went back to what it was prior to 2020 when restrictions were lifted (figures in Appendix 5).

This third part investigates how to voluntarily reduce distances of mobility destinations, using UCLouvain as a case study. Furthermore, it only looks at measures that can be implemented by universities. The first step is to define an objective. It should be determined "*by how much should GHG emissions of mobility air travel be reduced?*". Then, one would want to know what are the constraints faced by universities, what freedom do they have in relocating mobility destinations and what is not in their control. Finally, considering the different constraints faced by universities, different strategies for relocating mobilities will be considered in order to find the ones that best meet the reduction objectives.

1. Which emission reduction objective should this paper target?

At the highest level, the European Union has set as objective a 55% decrease of GHG emissions by 2030 (in less than 7 years) and net-zero emissions by 2050[7]. In order to reach these ambitious goals, all sectors will have to cut their share of emissions, including the aviation sector. As a

[7] According to IPCC, "*Net zero carbon dioxide (CO_2) emissions are achieved when anthropogenic CO_2 emissions are balanced globally by anthropogenic CO_2 removals over a specified period. Net zero CO_2 emissions are also referred to as carbon neutrality*" (Matthews, 2018). In other words, carbon neutrality means that emissions entering the atmosphere are balanced by the total removal of emissions from the atmosphere.

reminder from part 1, these reductions will not only come from technological innovation but will require people to fly less in the future.

At the university level, UCLouvain (2023) plans a reduction of 48% of its GHG emissions by 2035 (i.e., a reduction of about 32 880 tons of CO_2e compared to the year 2017). This objective is ambitious and will require important measures in all sectors, including for mobilities. As this research looks at measures that can be implemented at university level, the targets of UCLouvain university will be taken. Our reduction strategy will have to reduce GHG emissions of mobilities **by 48% by 2035**. It should be noted that the 48% decrease is a global decrease of GHG emissions of the university. As cutting emissions can be more difficult for certain sectors than others, the reduction needed from student mobilities could be less or more than 48%. For example, it is probably easier to reduce emissions from staff travels with video conferencing than reducing emissions from heating university buildings as the latter would require costly investments and would likely not lead to big gains. However, 48% is already a good benchmark and the methodology used in this paper would be the same for a different reduction target.

When it comes to the scope of emissions that should be reduced, part 1 concluded that the impact of European mobilities as well as transcontinental mobilities was equivalent to 4 times the round-trip travel of the student to his destination when factoring in all side effects. However, these side effects are not taken into account by UCLouvain when calculating emissions of student mobilities. Furthermore, 48% decrease would be very difficult to achieve if taking all side effects into account as relocating all destinations further than 3000km only led to a 35% decrease. This means that either we should take into account side effects with a reduced target, or we should keep the **48% objective but only looking at direct emissions of students** (one round trip travel). In order to make calculations easier, it was decided to only look at emissions for one round trip but knowing from part 2 that the impacts of side effects are also reduced when reducing distance.

It should be noted that these two hypotheses are conservative. On the one hand, it is safe to assume that in order to have a 48% decrease in global emissions, UCLouvain would probably need a greater decrease than 48% for student mobilities as this sector is relatively easier to decarbonize than others. On the other hand, a reduction of 48% of round-trip emissions will not lead to a 48% reduction of global emissions as some side effects like leisure trips will not be impacted by the distance reduction. This means that our scenarios will represent what is *at least* necessary for reaching reduction goals.

2. What is the degree of freedom of universities?

In order to be implementable by universities, distance reduction strategies should be compatible with constraints faced by universities. This leads to many questions: can all partnerships be ceased? How long are partnerships? How often are partnerships renewed? How are partners selected and how easy is it to set up partnerships? What destinations attract students most? To answer these questions, I interviewed Vice-Dean of International Relations at UCLouvain, Ina Aust-Gronarz.

2.1. How are partners selected?

First, Mrs. Aust-Gronarz (personal communication, May 26, 2023) drew our attention on the fact that mobility partnerships are reciprocal contracts, whereby two universities "exchange" a certain number of students that is first negotiated in the contract but can be progressively adapted. This has two implications: first, if a university wants to **increase the number of places** in the partner destination, there must also be an increase in the number of students from this university coming to Belgium to respect parity of exchanges. Secondly, not all incentive mechanisms are feasible. For example, incentivizing students through reduced/increased grants to go to certain destinations instead of others would not make sense as each destination has a fixed number of places negotiated in the contract with partners.

When it comes to **new partnerships**, there are no specific rules except that the potential partner university must have a similar level of education as UCLouvain. For evaluating teaching quality, different university rankings exist (Quacquarelli Symonds (QS), Times Higher Education, Shanghai Ranking Consultancy, …). Most top universities of those rankings are in North America and Western Europe. When reducing distance, all Western European universities would still be eligible for partnership, meaning that the pool of potential partners should stay quite large. Education level should hence not be too restrictive when trying to reduce the distance of mobilities in the case of UCLouvain.

Besides selecting new partners, rankings are also important for the university's standing. Indeed, if reducing the distance of mobilities causes a fall in university rankings, it would probably not be accepted by university officials. Taking QS ranking as example (QS Quacquarelli Symonds, 2023), the different criteria with their respective weight are the following: academic reputation (30%), citations per faculty (20%), employer reputation (15%), faculty student ratio (10%), international student ratio (5%), international faculty ratio (5%) and include since 2023 new criteria which are the international research network (5%), employment outcomes (5%) and sustainability (5%). The only criteria that could potentially be impacted by reducing distance of mobilities are international student ratio, international faculty ratio and international research network. On the one hand, international student ratio and international faculty ratio compute a score that only depends on the number of foreign students or faculties. It does not give more value if students/faculties are from other continents or from neighboring countries. This means that as long as relocated destinations are in different countries, the university score for these criteria will remain unchanged. Through a similar reasoning, reducing distance will not impact international research network as this criterion only gives importance to the number of partners and to the number of different locations represented by the partners. Other rankings have different criteria for internationalization such as "proportion of internationally co-authored research papers" but these criteria also make no distinction between European countries and countries from different continents (Times Higher Education, 2022). This means that reducing distance of mobilities will not impact the rankings of the university.

2.2. How long do partnerships last?

The duration of partnerships varies between one year, two years or a maximum of five years. After that time period, each university is free to look for other partners. This means that reduction strategies based on progressively looking for closer partners could be implementable.

2.3. How to cease partnerships?

When it comes to ceasing partnerships (or not renewing them), Mrs. Gronarz emphasized that some partnerships cannot be ceased because partner universities are part of common alliances. The university could not cease these partnerships without leaving the alliance. This is for example the case of CEMS and Circle-U partners. Additionally, some destinations, like Chinese destinations, have an "important diplomatic and social responsibility". Mrs. Gronarz did not elaborate on that topic.

2.4. What destinations attract students the most?

Ideally, when relocating destinations, the university should also take into account preferences of students. González et al. (2010) study about the determinants of international student mobility flows found that level of education, cost of living, distance, language, and climate are all important factors for student mobility choice. It should first be noted that level of education is already imposed by the university and so it is not a new constraint. Interestingly, the study found that students prefer short distances as it makes airplane tickets cheaper. This is somewhat different than what university officials said, i.e., that students are more attracted by transcontinental mobility. However, these two claims could very well be compatible, students with limited financial resources could be picking European destinations for financial reasons and wealthier students transcontinental mobilities as they are more exotic. In our case, as relocated destinations will be in Europe, it should not be a problem as European tickets are generally cheaper than transcontinental ones. Our data confirms that weather is an important factor as Spain, Italy and Portugal are respectively the top 2, 3 and 5 destinations for UCLouvain students (see Appendix 5). Finally, the study found that language was not a barrier to students and that improving a major foreign language was a main motivation for students to go on mobility. In short, destinations must have a good level of education and try to fulfill as many of the following criteria as possible: low expenses (low cost of living and cheap plane tickets), good weather, and major foreign language.

Thanks to the information brought by Mrs. Aust-Gronarz, it appears that the only implementable measures consist in progressively reducing the distance of destinations by looking for closer partners after exchange contracts come to an end. As contracts do not last more than five years with many of them lasting one or two years, this could be done effectively in a short period of time. In the next section, two scenarios are considered:

- The first one relocates destinations in decreasing order of distance until reaching the objective of 48% decrease by 2035. This very simple scenario aims at limiting the number of relocated destinations does not take any constraint into consideration.
- The second one does the same but keeps 1 place out of 3 in faraway destinations. The latter scenario allows to keep certain destinations and is therefore more in line with the constraints faced by universities but will probably be less effective.

It is assumed that the university is always able to find partners at closer distances. This assumption is reasonable in the case of UCLouvain given that a big part of top ranked universities is located in Western Europe.

3. What strategies to progressively reduce distance of mobility destinations?

As a reminder from previous sections, scenarios will take the year 2022 as reference for student flows. In that year, 974 students from UCLouvain had a mobility experience. Scenarios only look at emissions from round trip flights to student destinations with an objective of 48% reduction by 2035 with respect to the year 2022. In order to reach this quantitative objective, GHG emissions of 2022 should first be computed.

3.1. Computing round trip emissions for the year 2022.

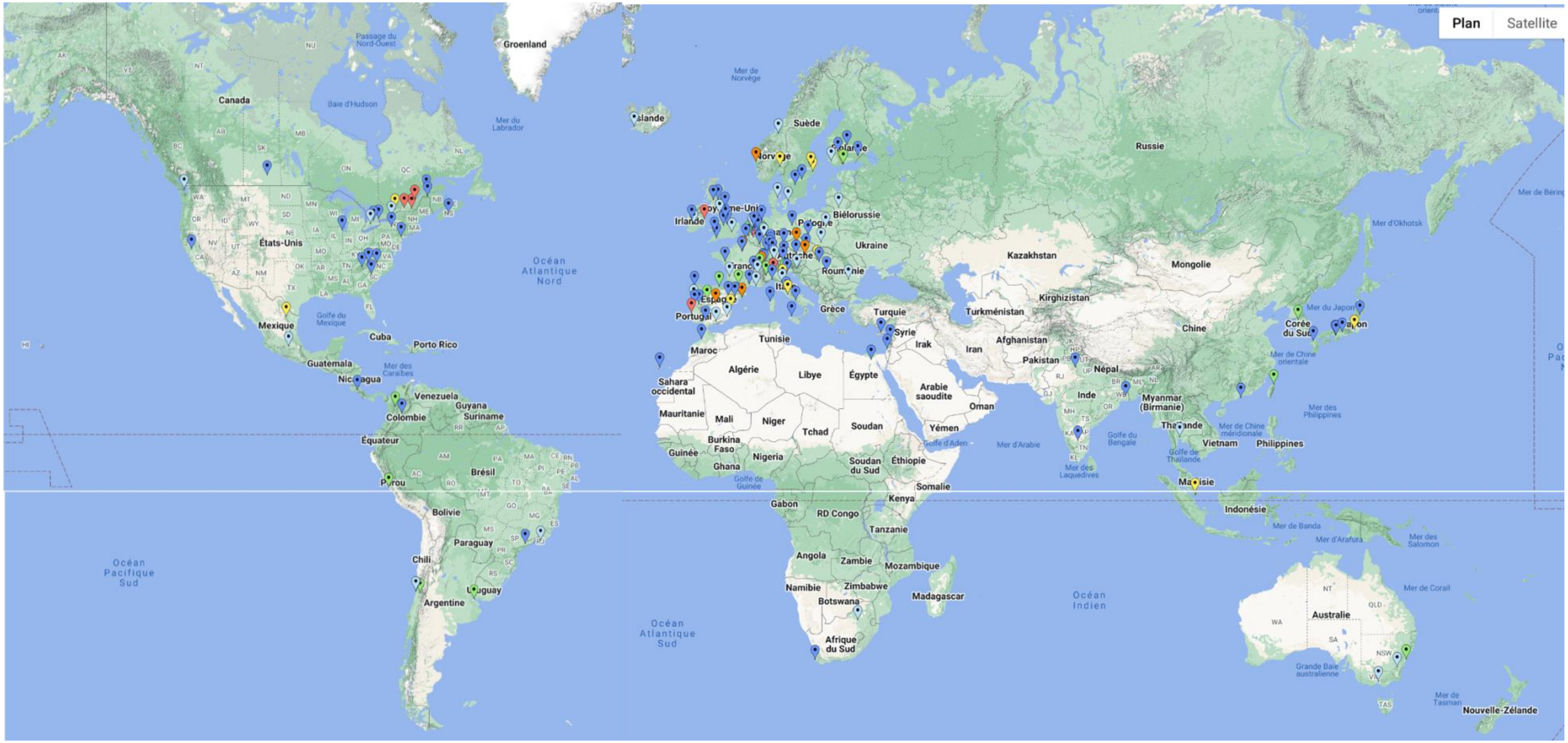
First, the distance separating each town from Brussels (not Louvain-la-Neuve, as most flights depart from Brussels airport) is computed using an online calculator (Distance calculator, 2023). Flying distance is used as most destinations are reached by airplane except for cities closer than 700 kilometers for which road distance was more adequate as these destinations are mostly reached by train or bus. GHG emissions for a flight is then computed by multiplying the distance by the proper emission factor: 0.195 kgCO_2e/km/passenger for long-haul flights; 0.254 kgCO_2e/km/passenger for short-haul flights and 0.04 kgCO_2e/km/passenger for train. These emission factors (EF) come from figure 4. It was also assumed that destinations less than 700 kilometers away by road are reached by train and that other destinations are reached by airplane. Finally, emissions are multiplied by two in order to consider the travel to the destination and the travel back in Belgium. The final formula to get the total round-trip emissions of students from UCLouvain in 2022 is the following:

$$\sum_{n}((Distance_n * EF_n * 2 * number\ of\ students\ in\ 2022 = 1190.16\ t\ CO_2 e$$

Where the sum goes over all mobilities of year 2022. We find total of 1190.16 t CO_2 equivalent; this means the 48% decrease by 2035 consists in a decrease of 571.3 tons of CO_2e.

3.2. Scenario 1: relocating most emissive mobilities.

In this first scenario, destinations are sorted in decreasing order of distance, the following figure shows the distribution of mobility destinations around the world:



Caption: 208-73 students 68-48 students 46-25 students 23-15 students

Figure 9: Distribution of UCLouvain mobility destinations around the world summed over the last five years.

Then, mobilities are relocated in that order until reaching the 48% decrease of GHG emissions. For the relocation of mobilities, it is assumed that students are relocated on average at 1500km and will reach their destination by airplane. All destinations in Australia and East Asian countries are the first ones to be relocated, the 48% reduction is reached for Montreal (5500 km). More precisely, it is reached when relocating 20 places out of the 67 places in Montreal. By removing all destinations >5500 km and 20 places in Montreal, 646.5 t CO_2e are saved. Relocating those students at 1500 km causes 71.8 tons of CO_2e *(=191*1500*0.254)*. The net gain is 573.7 t CO_2 which is very close to the 571 tons needed. In total, 191 students need to be relocated which is only 19.6% of students who go on mobility each year. This shows again that a minority of mobilities are responsible for a bigger part of GHG emissions. This strategy could be seen as imposing a maximum radius of 5500km for mobility destinations and relocating destinations outside of this radius at an average of 1500 km. This radius is illustrated on the next figure.

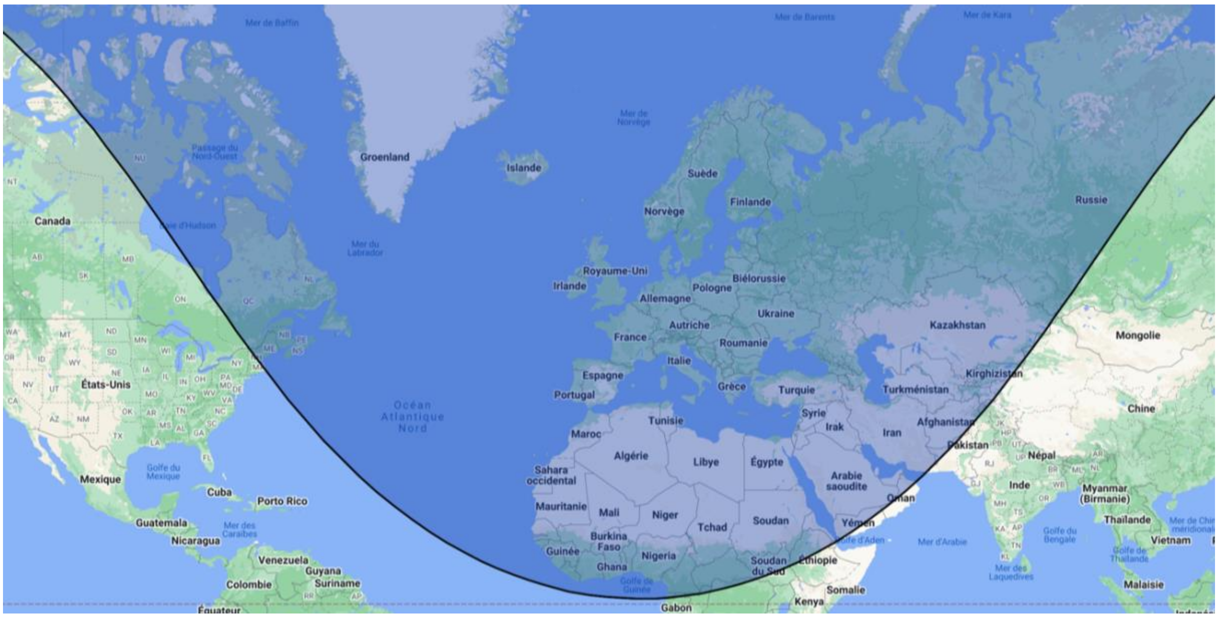


Figure 10: Radius to reach the 48%-reduction objective in 2035 based on the first scenario for UCLouvain (Map Developers, 2023)

As shown in the figure above, this 5550 km radius would reject all destinations in East-Asia, South-Asia, Oceania, South America, and all UCLouvain partners destinations in the USA. The remaining transcontinental mobilities are mostly in Canada (113 seats left out of the initial 167 places in Canada) and a few mobilities in Iceland, North-Africa, and the Middle East.

If instead of taking the airplane, the relocated students take the train, only 163 students would need to be relocated with Ottawa being at the limit (8 students out of 15 still able to go to Ottawa). This shows that the number of transcontinental mobilities that are maintained can be increased by increasing the use of the train on the European continent.

In the case where relocated students take the airplane, a total of 191 places in 47 destinations would need to find a new destination (representing 1/5 of total number of mobilities). As seen previously, exchange contracts usually last between 1 and 5 years. This means that more than a fifth of destinations are renegotiated every year. Starting in 2024, 4 or 5 of the destinations outside of the 5500 km radius would need to be relocated every year in order to reach the 48% decrease by 2035. This shows that if started soon enough, the 48% reduction is achievable for UCLouvain (and other universities that are in a similar situation). However, this measure will likely not be very acceptable as it does not take into account the destinations that the university wants to keep (like some CEMS destinations). For this reason, a second scenario is considered. In this second scenario, instead of relocating all places of all destinations, only 2 out of 3 places are relocated, allowing to keep approximately one third of places in distant destinations.

3.3. Scenario 2: keeping 1 place out of 3 in distant destinations.

The idea of this scenario is to simulate constraints faced by universities. Indeed, the previous section showed that some mobilities (like CEMS) cannot be relocated, meaning that a certain fraction of distant mobilities will have to be maintained. University might also want to keep some transcontinental mobilities for other reasons like attractiveness. For example, some partnerships could be necessary for research purposes. This will give some flexibility to the university but will force it to think carefully about long-distance partnerships and only keep the ones that bring the most value to the university and to students.

The fraction of 1/3 was chosen arbitrarily, according to results it could turn out that a greater fraction is needed or that a smaller fraction is enough in order reach the 48% reduction by 2035 objective. When it comes to how to decide which places are kept and which are relocated there are different ways. One easy way would be to completely cease some partnerships and to keep others such that in the end 1/3 of total places are kept. However, as discussed in previous section, this might be difficult to implement if more than 1/3 of partners are part of common alliances like CEMS. A second way would be to keep 1/3 of places in every single destination. For example, if 10 UCLouvain students go to Canberra among which 3 students are CEMS members, the 7 non-CEMS students would be relocated. In this case, the downside is that the university should renegotiate the terms of contracts with each partner university, the partner should then also agree to send less students which might not be the case. Either way, the results are similar: 2/3 of students of distant destinations are relocated, the way to do so is up to the university. In the following analysis, we keep 1/3 of places in each destination, alternatively rounding up and down if the number of places is not a multiple of 3.

The results are the following. Even when relocating all students from destinations distant of more than 1500 km (it is still assumed that students are relocated at an average of 1500km and still use the airplane), only 46% decrease is reached. In this case, 263 students are relocated, this is 27% of the total number of students going on mobility. It is clear that if UCLouvain wants to reach 48% decrease by 2035, it **should relocate at least 2/3 of transcontinental mobilities to Europe**. Small improvements could be attained by reducing the average distance of relocation (1500 km), but this would also reduce the number of potential partners and as 263 new places need to be found, it will be hard to make have achieve significant reduction.

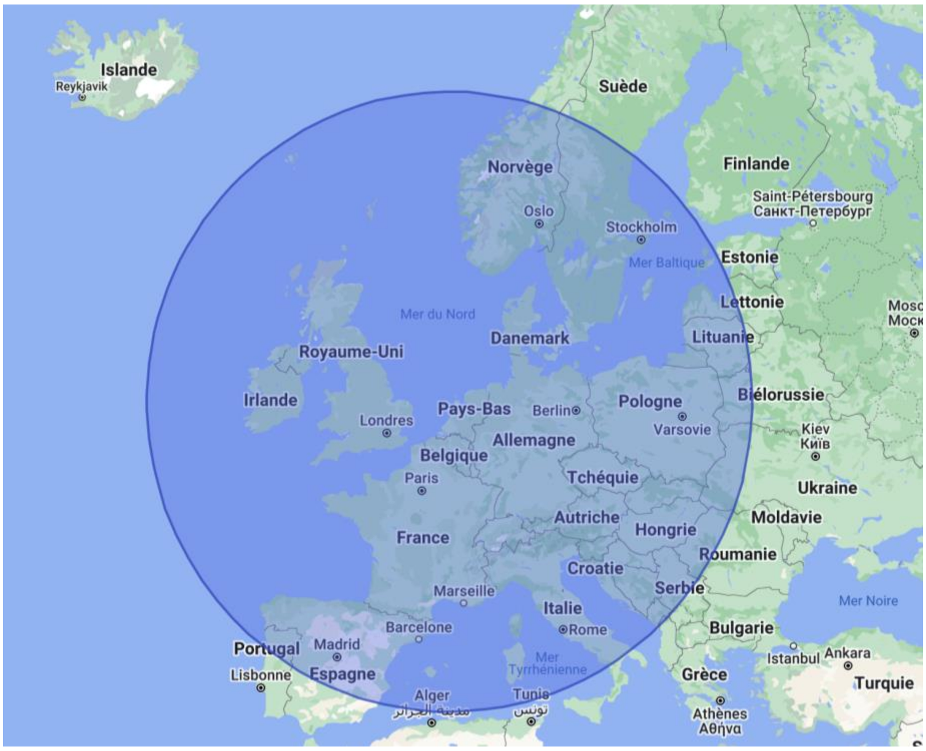


Figure 11: Radius to reach a 46%-reduction based on the second scenario for UCLouvain in 2035 while keeping one out of three seats in distance further than this radius (from Map Developers, 2023)

4. What can we conclude from part 3?

The two scenarios illustrate possible ways for UCLouvain to reduce the distance of their student mobilities. In these scenarios, only GHG emissions of the return-trip to destinations are taken into account, students are relocated at an average distance of 1500 km and use the airplane to reach their new destination. It was also assumed that the university had no problem finding closer partners.

Scenario 1 shows that if ignoring relative importance of partnerships, UCLouvain can achieve a 48% reduction of GHG emissions by 2035 while still sending 1/5 of students outside of Europe but to relatively close destinations like Canada or North Africa.

Scenario 2 shows that if the university wants to maintain some partnerships, it can keep at most 1/3 of places outside of Europe. 10% of students would still be able to travel outside of Europe but the number of places in some European destinations distant from more than 1500 km will also have to be reduced. Additionally, 263 students will have to be relocated in scenario 2 compared to 191 in scenario 1.

It should also be noted that as long as relocated destinations are in different countries than the host country, the university will keep the same internationalization score in university rankings. Of course, many more scenarios could be considered, but more generally, it appears that the same reduction can be attained by relocating fewer but more distant mobilities or more but closer mobilities. It would therefore be more effective to relocate mobilities in decreasing order of distance like in scenario 1. However, some mobilities are more important than others. When deciding whether to keep certain mobilities or not, each university should weigh its importance by its distance: if an important mobility is at 10.000 km, it should be less likely be kept than if it is at 3.000 km of distance.

Part 4: How can we increase the share of alternative means of transportation for Erasmus mobilities?

In part 2, it was computed that European mobilities were responsible for 25% of GHG emissions of student mobilities of UCLouvain in 2022 compared to 75% for transcontinental mobilities. This means that in order to achieve significant reductions in GHG emissions, a big part of transcontinental mobilities should be relocated to Europe (see part 3). This would then increase the carbon footprint of European mobilities and make the question of reducing this carbon footprint more relevant as carbon neutrality should be reached in the long run. For this purpose, we could, again, reduce the distance of European mobilities. However, when distance is reduced, the number of potential partners is also reduced, and it could become hard for universities to find enough partners when the distance becomes small. Additionally, we saw in part 2 that for European mobilities, promoting alternative modes of transportation could be used as already done by several universities through financial help (see part 2). This indicates that measures aiming at promoting the use of alternative modes of transportation have a greater chance to be accepted and implemented than measures aiming at reducing the distance of mobilities.

For these reasons, part 4 explores an alternative way of reducing the carbon footprint of student mobilities: increasing the share of alternative means of transportation. Indeed, a survey of Green Erasmus (2022) over 7776 Erasmus students found out that 7 out of 10 Erasmus students used the plane in order to go to and come back from their destination. Another survey with 1967 respondents (ESN & Eurail, 2020) found out that 83% of students used airplane as a way to go to their destination. This means that GHG reduction could be achieved by decreasing the number of students travelling by airplane. In section 1 of part 2, it was shown that train, coach, and carpooling are good alternatives to airplane (see figure 5). But we can wonder why do students prefer to travel by plane instead of train, coach, or car? Understanding this would allow us to design efficient measures for increasing the use of alternatives to the airplane.

1. Why do students prefer to travel by plane?

In the Green Erasmus survey (2022), students gave their main motivation for choosing what transportation mean they used, here are the results:

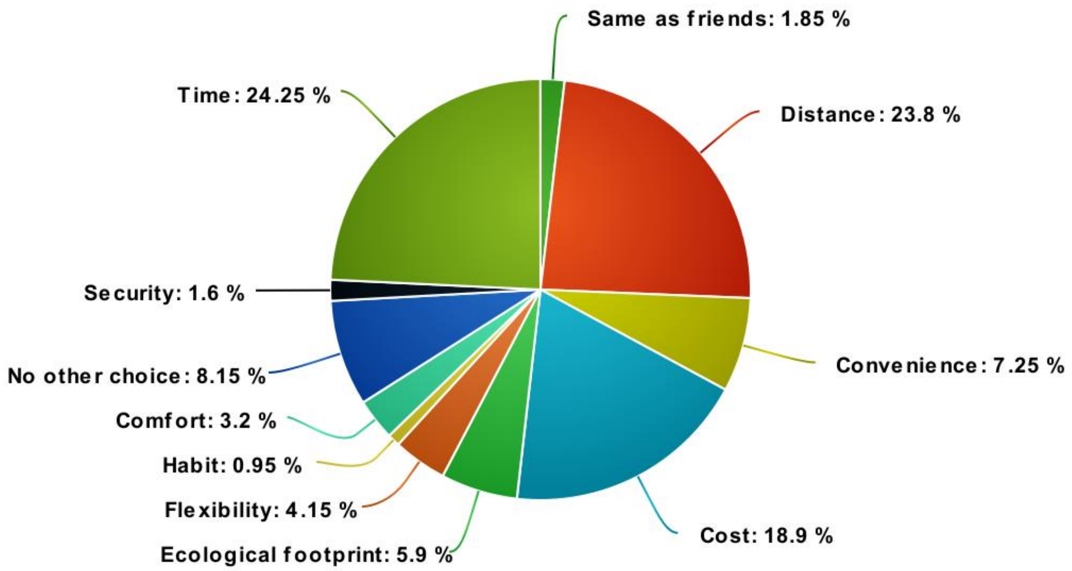


Figure 12: Major factor for choice of transportation mode for students going and coming back from Erasmus destination (Green Erasmus, 2022).

For 24.25% of students, **time** taken for the journey was the major factor, for 18.9% of them, cost of the ticket was the biggest factor. Only 7.25% of students choose their mode of transportation because of convenience. While this may not be a number one reason, it still can be an important factor when choosing transportation mode. For example, when travelling by train, having to take multiple trains can be exhausting due to the risk of missing connections because of delay and because of having to transport heavy luggage between trains. Another 23.8% responded "because of distance", which is not directly a real reason but rather underlies cost and/or time reasons. You could go anywhere in Europe with trains or buses with a lot of time, money, … and motivation.

In our survey (Appendix 2 and 3), we also asked students how they picked their mode of transportation. Some students had no choice but to take the airplane (i.e., students going to Australia). For students who had different options, 44% (39/89) considered price to be the most important factor when choosing their means of transport, 40% (35/89) considered journey time to be the most important factor and 16% (15/89) considered comfort to be the most important factor.

The previous results are in line with the Green Erasmus survey as time and money stand out as the two most important factors when choosing mode of transportation. This means that our solutions could either try to incentivize students by reducing travel time or travel cost or simply ban air travel for certain destinations.

In this paper, we decide to focus on incentives and not on bans for different reasons. First, as seen in part 2, bans are high-coercive push measures and have very low acceptance. Secondly, the ban could only apply to relatively close distance mobilities but these mobilities are also the least emissive ones. This means that it would have a limited impact. Lastly, the ban would make sense if students going to distant destinations had no choice. In that case, the only way to reduce GHG emissions would be to ask students who are able to travel by train to do it. In our case, students decide that they want to go on mobility and get to pick their destination. It would hence be unfair to target less emissive mobilities rather than the more emissive ones because students are responsible for the GHG emissions of their mobility.

Next, different alternatives to the airplane (train, coach, and carpooling) are compared based on travel time and travel costs to determine which alternative is best suited to replace airplane and how it could be made more attractive.

2. What transportation modes are best suited to replace airplane at low costs/ travel time?

In order to answer this question, the top 15 European destination countries for UCLouvain students are taken (for period 2018-2023). For each country, the travel time and travel cost to the capital city is estimated for airplane, train coach and car. Results are reported in the following table.

	Airplane		**Train**		**Coach**		**Car**	
	Cost	Time	Cost	Time	Cost	Time	Cost	Time
Brussels-Madrid	51.48€	2h20 + 3h	129.99€	23h25 2 conn[8]	53.98€	1d1h20m 1 conn	313.71€	15h26
Brussels-Zurich	137.14€	1h15 + 3h	46.9€	7h35 1 conn	38.98€	14h 1 conn	154.82€	6h35
Brussels-Rome	55.48€	1h55 + 3h	130.8€	15h26 3 conn	61.98€	1d 40m 1 conn	292.37€	14h41
Brussels-Toulouse	49.66€	1h40 + 3h	73€	7h15 1 conn	34.98€	14h05 1 conn	193.94€	9h43

[8] In this table, "conn" is the abbreviation of connection.

Brussels-Lisbon	55.48€	2h50 + 3h	/	/	69.98€	33h30 1 conn	380.78€	19h58
Brussels-Dublin	52.48€	1h40 + 3h	186.64€[9]	9h09	/	/	130.62€	12h50
Brussels-Oslo	131.14€	2h00 + 3h	/	/	79.98€	33h15 1 conn	254.78€	16h04
Brussels-London	101.14€	1h15 + 3h	57€	1h52 0 conn	29.99€	7h15 0 conn	88.39€	4h37
Brussels-Berlin	56.28€	1h25 + 3h	39.9€	6h49 1 conn	29.99€	12h10 1 conn	115.07€	7h43
Brussels-Vienna	41.98€	1h45 + 3h	56.9€	10h24 1 conn	37.98€	17h35 1 conn	162.16€	10h40
Brussels-Helsinki	90.83€	2h40 + 3h	/	/	/	/	277.53€	26h45
Brussels-Prague	54.98€	1h25 + 3h	57.9€	11h54 2 conn	39.9€	14h40 0 conn	144.86€	8h47

Figure 13: Comparison of travel time and cost according to the different mode of transports for some European destinations.

Hypotheses:

Several assumptions have been made in order to estimate travel time and costs as realistically as possible. A general assumption is that the tickets are booked three months in advance by the student, regardless of mode of transportation and that the student has no preference for the day of the trip. For this reason, the cheapest ticket was selected over a one-week period. However, some coach tickets are not bookable three months in advance and in this case, we selected the latest date.

For air travel, the following assumptions were made. When taking the plane, the student arrives two hours earlier at the airport and it takes one hour to get his/her luggage back and to reach the center of the town (as airports are often outside of the cities). As a result, three hours are added to the initial travel time. A 20kg luggage was added to the standard ticket, this seems

[9] Include a ferry.

realistic when going abroad for several months. Finally, as students want to minimize travel cost, prices mostly come from a low-cost company (Ryanair) except for destinations where it does not operate (such as in Switzerland).

For the train, prices and travel time were found on “the trainline” website which is one of the main websites used by travelers to book their train tickets.

For the coach, prices and travel time were also found on “the trainline” website, in the section “bus”. Trainline works with the company FlixBus, meaning that reported prices are the ones proposed by FlixBus. When different trips were proposed, the one having the best balance between travel time and travel cost was chosen.

For the car, travel cost and time estimations come from the website of “ViaMichelin”. This website automatically computes costs of tolls, freeway stickers (if needed) and gas consumption for a city car. It should be noted that the cost reported in the table should be divided by the number of passengers in the car.

Results:

Airplane is the fastest and coach is the slowest. For short distance journeys (<1000km), coach is the cheapest, train and airplane have similar costs except for destinations where Ryanair does not operate (e.g., Brussels-London, Brussels-Zurich). For longer travels (e.g., Brussels-Rome), airplane is the cheapest. For long travels (>1000km), it seems like students take the airplane because it is cheaper and/or it takes less time. For short distance journeys, students will prefer the airplane when cost is similar because it takes less time. It is clear that no mode of transportation will beat airplane when it comes to travel time. Solutions have to make trains/coaches more attractive by other ways than time.

One solution would be to refund train tickets but as seen in part 2 section 4, many measures have already been proposed in that direction and this paper would likely not bring any new idea.

On the other hand, coaches often stay in the shadow of trains and are rarely discussed in the literature. Coaches have the advantage of being cheaper than train and much lower environmental impact than the airplane. However, coach trips are very long. In many cases, waiting for connections is responsible for a significant part of the travel time. This means that travel time could be reduced by reducing the number of connections. One could argue that this also applies to trains but contrary to trains, coaches are much more flexible, and solutions could consist in operating specific coaches for Erasmus students. This could easily be implemented by universities, for example coaches are already booked for students who go skiing. Those coaches could operate on lines going through mobility destinations. Besides being faster than standard coach lines, students would have no connection and hence no stress of missing one and no need for moving around heavy luggage. In the next section the solution of operating coaches for Erasmus students is explored, this idea is named the “Erasmus bus” as it sounds better than “Erasmus coach”.

3. How to implement the Erasmus bus?

The “Erasmus bus” idea consists in operating coaches on routes going through Erasmus destinations. Students would not have to take any connection, hence gaining time and comfort compared to current coach lines. For example, if many UCLouvain students go to Munich, Vienna and Budapest, a bus could go through these destinations at the beginning and the end of the semester. The idea of buses for students was inspired by Belgian students who go skiing in the Alps or even in the Pyrenean mountains on a private coach. These students are willing to spend the night in the coach because of the great atmosphere and the low travelling cost. In order to make the Erasmus bus more cost-effective, they could travel from one city to another, dropping off some students and picking up others at every stop but this would require cooperating with other universities. In the previous example, our bus would pick up German students in Munich and Austrian students in Vienna. It would also bring back Hungarian, Austrian and German students to Belgium. The advantages of these coaches are the following:

- The coach is a low-carbon means of transportation (as a reminder from figure 5), coaches emit 27g of CO_2 per passenger per kilometer compared to 245g for short-haul plane).
- Coaches are cheaper to operate than trains (one could easily convince himself by comparing standard train and coach tickets).
- Coaches are very flexible, there is no need for big investments, all that is needed is a coach, drivers, and gas. Routes could very easily be adapted from year to year.
- The travel time will be reduced compared to a bus trip with a private operator which often features many connections and thus a higher travel time making the trip less attractive. For instance, going straight to Lausanne (Switzerland) takes 8h30 while with an operator such as FlixBus, the shortest trip goes through Paris and takes 13h30.

- Erasmus bus will stop in university cities, students will directly arrive in the center of the city (near to the university and accommodations). There will be no need to carry around heavy luggage between connections and no stress of missing connections because of delays.
- Students can already meet on the bus, they can chat with each other which makes it more fun, and time goes faster.

The only big drawback of coaches is the travel time. Even with no connection, coaches still are slower than direct trains and the different stops in cities increase the total travel time.

In order for this solution to be implementable and attractive, different questions must be answered. First, we need to determine "*what are the promising routes?*". Routes should go through destinations where enough students go to fill at least one coach. In this paper we will use UCLouvain as a case study and design promising routes for UCLouvain. Then, it should be determined "*how to operate the Erasmus bus?*". Should a private operator like FlixBus or BlaBlaCar operate the buses or should UCLouvain book coaches and directly organize the trips? Should UCLouvain cooperate with other universities? This will depend on costs and the costs reduction that would be achieved by including other universities. Costs in both cases need to be established and it should also be determined what students have to pay. Should it be entirely free, or should students pay part of it? The next few sections answer the previous questions.

3.1. What are the promising routes for the UCLouvain?

As for any new project, Erasmus bus should start with few but promising lines. This way, little investment is required, and routes can be expanded in the following years if it works well. It is therefore to start with the cities hosting the most students.

First, routes are identified based on fluxes of Erasmus students (see Appendix 6). The following map shows the distribution of European destination cities of UCLouvain students for years 2018-2023.

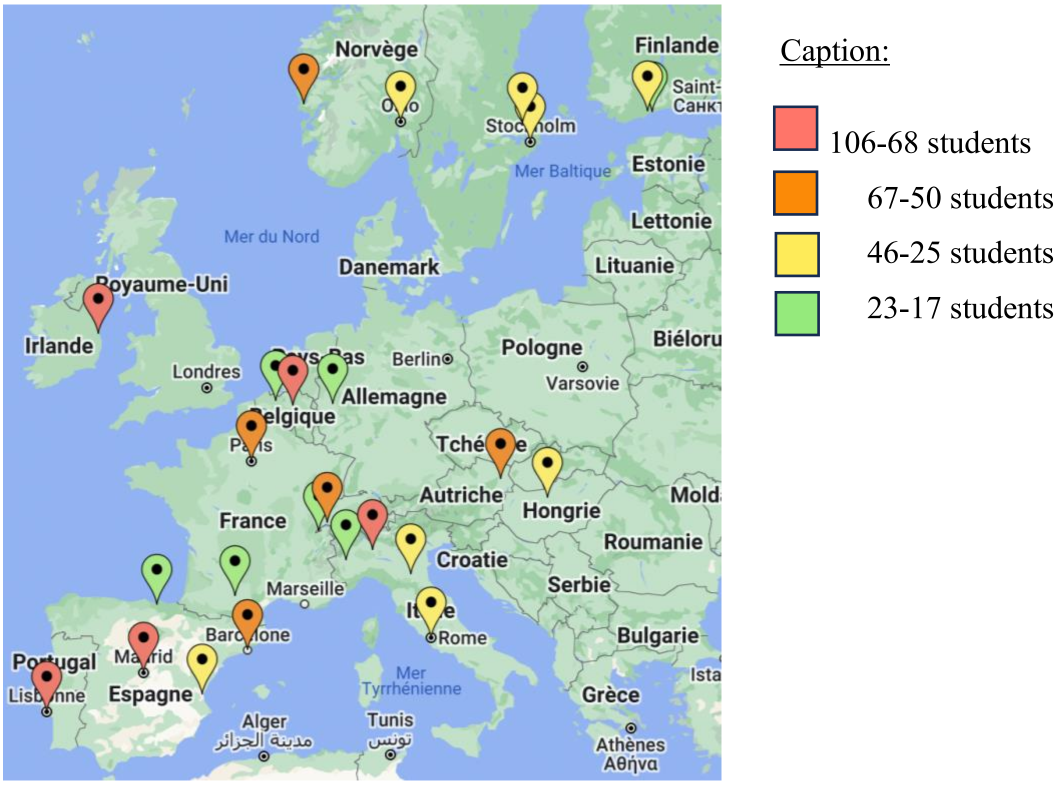
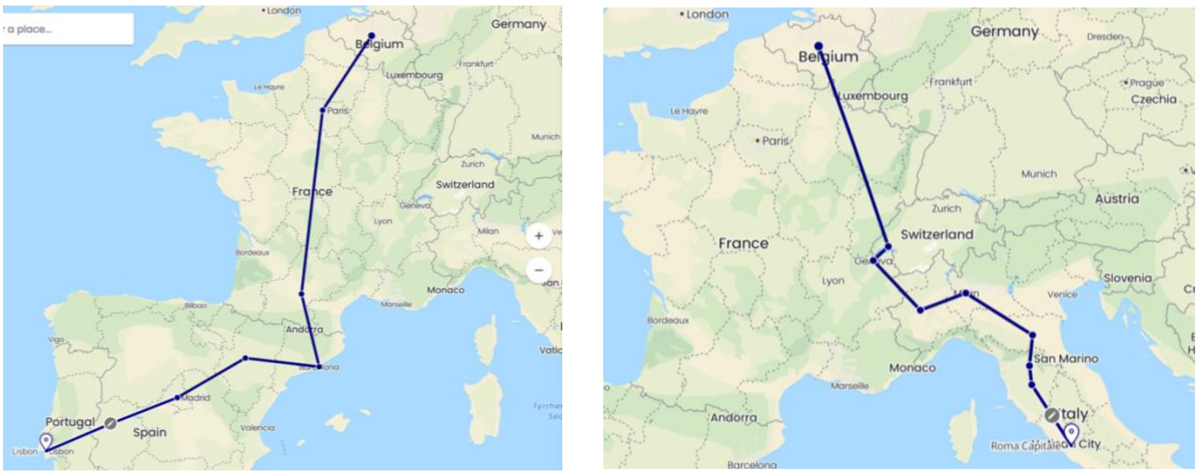


Figure 14: Distribution of UCLouvain students among most popular European destinations over the last five years (2018-2023).

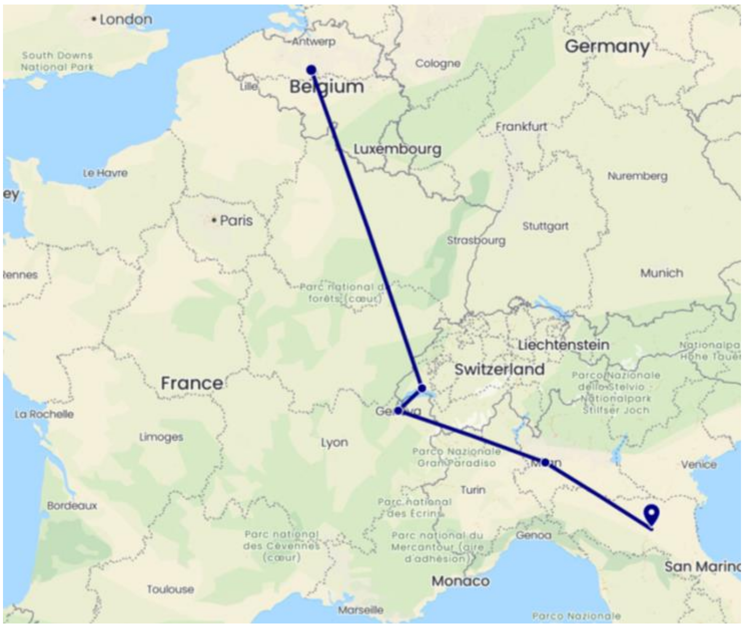
Red cities (i.e., Lisbon, Madrid, Milan, Leuven, and Dublin) are the ones hosting the most students, followed by orange ones (i.e., Barcelona, Lausanne, Paris, Wien, and Bergen), yellow ones and green ones. The exact numbers can be found in Appendix 6. From this map, two routes stand out. First, the "Iberian route", going from Brussels to Lisbon through Paris, Toulouse, Barcelona, Saragossa, Madrid, and Lisbon. Second, the "Italian route" going from Brussels to Roma, stopping in Lausanne, Genova, Torino, Milan, Bologna, Florence, and Sienna.



Figures 15 & 16: Promising routes based on UCLouvain data.

When calculating the travel time, it turns out that these routes are quite long: 31h bus journey to Lisbon (2641 km) and 24 hours 50 minutes bus journey to Roma (1726 km) without taking into account the time to get on and off the bus at each stop. Although Lisbon and Roma both host many UCLouvain students, these students will likely find the trip too long and prefer the 3-hour flight. For this reason, routes were shortened to Brussels-Madrid (23 hours without stops) and Brussels-Bologna (17h without stops). Unfortunately, Brussels-Madrid is still too long. Indeed, a coach driver has a maximum daily driving time of 9h (up to 10h twice a week) (Voyages Léonard, 2023). This means that 2 drivers would be needed for a duration (without stops) inferior to 20 hours. For this reason, the "Iberian route" ends in Barcelona. The final routes are the following:

First promising route: the Italian route.



Bus stops

1. Brussels
2. Lausanne
3. Geneva
4. Milan
5. Bologna

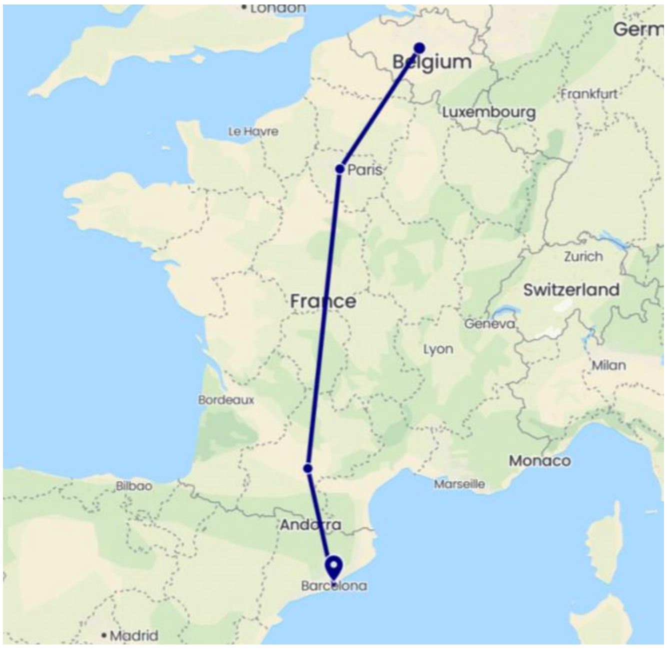
Figure 17: Designed route between Brussels and Bologna based on UCLouvain data.

Each year, there are on average 19.33 students from UCLouvain going in Lausanne, 6 in Geneva, 27 students in Milano and 15.33 students in Bologna. In the ideal case, i.e., if all students took the Erasmus bus to these destinations, there would be more or less 67 interested students per year, so 33 UCLouvain students per semester.

According to the website Bookabus (2023) a standard coach has 65 seats. Given that there could be a maximum of 33 students from UCLouvain, this would not be enough to fill the one coach. In order to be cost-effective, it would be necessary to bring together students from various Belgian universities (ULB, Uliège, KULeuven, etc.). Gaël Vandenbroucke, Head of Student

Mobility Office at "Université libre de Bruxelles" (ULB) provided the mobility data of ULB. The top three destination countries for ULB students are respectively Spain, France, and Italy. This is very similar to UCLouvain for which Spain, France and Italy are part of the top 4 with Canada. This confirms the preference of students for Mediterranean countries. It should be noted that our routes could easily be adapted to specific needs of partner universities by adding one or two stops. Surprisingly, no ULB student go to Switzerland. However, an average of 13 students go to Milano and 7 to Bologna per semester. This would allow us to fill the bus up to 53 places with 12 places left. It is hence reasonable to assume that the bus could be completely filled with a third partner university like KU Leuven.

Second promising route: the Iberian route.



Bus stops

1. Brussels
2. Paris
3. Toulouse
4. Barcelona

Figure 18: Designed route between Brussels and Madrid based on UCLouvain data.

Each year, there are on average 18.33 students going to Paris, 6 in Toulouse and 22.33 students in Barcelona. In the ideal case, i.e., if all UCLouvain students took the Erasmus bus to these destinations, there would be 46 interested students a year, so 23 students per semester. For the same reason as the first route, in order to be cost-effective, other Belgian universities should join effort with UCLouvain. Based on ULB data, 36 students go to Paris, 8 to Toulouse and 16 to Barcelona each year. In total, this adds 30 students each semester and brings the total number of places in the bus to 53 students. Similarly, to the Italian route, it is safe to assume that a third partner universities could allow to fill the bus if sufficiently promoted among students.

3.2. What will be the timetable for these bus routes?

Schedules of the routes have to guarantee that students do not arrive at their destination in the middle of the night and can easily take public transport to reach their accommodation. The bus journey time is calculated using the time indicated by car on Google Maps. Assuming that the speed of a coach is 100 km/h and that the speed of a car is 120 km/h, the duration of travel time is obtained by multiplying the duration for a car by 1.2. Additionally, the coaches have to find a place to park that is close to public transportation and close to highways in order to minimize travel time. After some research, we found the following schedules.

Italian route

1. 10:00 pm in Brussels-Central station.
2. 6:20 am in Lausanne (parking Dorigny close to universities)
3. 8:00 am in Geneva (parking Rive-Centre close to universities)
4. 0:50 pm in Milano (parking of the B&B hotel La Spezia)
5. 3:50 pm in front of the university of Bologna

Iberian route

1. 7:00 pm in Brussels-Midi station.
2. 10:35 pm in Paris (parking Indigo Paris Bercy cars close to universities)
3. 6:15 am in Toulouse (parking pating close to universities)
4. 10:50 am in Barcelona (parking bus at the center of the town)

In both cases, at each stop, 20 minutes were added for dropping off and picking up students. These timetables fit with the maximum 20h trips allowed for two drivers. No schedule was established for the return trip but places for stops could be reused. One could also easily find a feasible schedule, the idea being that the longest time between 2 stops should occur during the night. for the "Italian route", the bus would arrive in Geneva late in the evening in order to arrive in Brussels in the morning.

Lastly, the dates of the trips should be determined. Usually, students wish to arrive between 2 days and one week before the beginning of the classes in order to adapt to the city. In practice, universities have different kickoff dates, and the departure date should satisfy as many students as possible. In order to have an idea of kickoff dates, a large sample of partner universities was taken.

For the Italian route, in the first semester, most partner universities start mid-September, ending in the beginning of February, it is therefore possible to find dates satisfying most students, for example around 10/09 and 07/02. This also allows Italian students coming in Belgium to arrive a couple of days before the start of classes in Belgium which occurs mid-September. For the second semester, most universities start mid-February and end at the of June. It is again possible to find dates satisfying most students, for example, 07/02 and 30/06. For travels between semesters, it would even be possible to combine students coming back from mobility and students going on mobility.

For the Iberian route, for the first semester, starts range between the end of August and the beginning of October while ends range between beginning to end of January. If the Erasmus bus is run at the end of August, students for which classes start in the second part of September will probably find it too early. However, if it is run mid-September, all students starting before will be unable to take it. As students pay their rent on a monthly basis, it is decided to depart at the beginning of September and to come back mid-January. For the second semester, starts range between the beginning of January to the beginning of February and end between the end of May to the end of June. Again, it is difficult to satisfy most students and a solution would be to depart at the beginning of January and come back mid-June.

For both routes, feasible schedules were found. However, when trying to determine dates when running the buses, the first route is much better than the second as start and end time of semesters are much more homogeneous. Added to the fact that less students go to destinations of the Iberian route, this means that the Italian route has more potential than the Iberian route.

3.3. How to operate the Erasmus bus?

When it comes to operating the coaches, two options are possible. The first one consists in setting up a partnership with a bus service provider such as “BlaBlaCar” and “FlixBus”. These companies would operate the buses on the routes indicated by universities. The second option consists in using a coach rental company such as “Voyages Léonard” or “Bookabus”, these companies would only provide a coach and drivers.

Working with a bus service provider would be more convenient for a group of universities. Indeed, if students from other universities than UCLouvain take the Erasmus bus, they would just need to buy their ticket on the website of the service provider which would be much easier than if one university had to rent the bus for the whole group in the case of rental company. In that case, no university would want to take the financial risk of booking the bus or dealing with all of the coordination and negotiating ticket prices with others. Additionally, a bus service provider could also fill the Erasmus bus with its own customers in the case where students do not entirely fill the bus. One possible solution would be to reserve places for students up until a certain date, after which places are available for other customers. For these reasons, working with a bus service provider seems like the best solution.

After sending multiple emails to BlaBlaCar and FlixBus, the answer was negative. FlixBus responded that they do not privatize their buses in any way while BlaBlaCar did not respond. This could be because this idea is not backed by the university itself or maybe these companies are really not interested in it.

In the case where UCLouvain decides not to include other universities, renting a bus seems like the easier solution. If it wants to rent a bus and share it with other universities, one reasonable solution would be for UCLouvain to seek external funding for the project. For example, the LIFE program of the EU delivers subsidies to private and public organizations implementing sustainable projects. If money is put aside, cooperation between universities would be much easier.

3.4. How much would this cost to students and to university?

In the case of the rental company, a quote from Bookabus asked 7765 euros for the Iberian route and 7255 euros for the Italian route (quotes are in Appendix 7). In the case where a bus service provider operates the buses, the Erasmus bus would be operated the same way as other buses from operators (round trips with stops). The only difference would be that instead of being run on a regular basis, these buses would only operate at specific dates. We can hence expect prices to end up being similar to the ones of standard ticket on other lines.

In order to compare prices of bus rental with prices of bus service provider and train tickets, we computed prices per capita for bus rental. To do so, we imposed that ticket prices are proportional to the road distance to the destination. We also assumed that the bus is full and the distribution of destinations of students respects the distribution of UCLouvain data. The following prices were determined:

Italian route:

Italian route	**Price of bus rental ticket <u>without</u> cooperation of Italian & Swiss universities**	**Price of bus rental ticket <u>with</u> cooperation of Italian universities**	**Price of a <u>FlixBus</u> ticket**	**Price of a standard <u>train</u> ticket[10]**
Brussels-Lausanne	84.34€	42.17€	44.98€	145.9€
Brussels-Geneva	93.9€	46.95€	49.99€	98€
Brussels-Milan	116.01€	58€	51.98€	161€
Brussels-Bologna	145.35€	72.67€	44.98€	178.9€

Figure 19: Comparison of prices (in euros) of bus rental, FlixBus and standard train tickets for the Italian route.

In the case of bus rental without cooperating with Swiss and Italian universities, the bus costs less than the train but is much more expensive than FlixBus. As the bus is already slower than the train, prices should be reduced as much as possible to be valuable. For computing prices in the case of cooperation with Italian universities, we assumed that the bus on the return trip is full and that this would lead to the division of prices per capita by two. In that case, bus becomes much cheaper than train but is still less attractive than prices proposed by FlixBus. More precisely, prices are similar for Lausanne and Geneva but are more expensive in the case of rental for Milan and Bologna. This could be explained by two reasons. First, FlixBus is able to drive prices down by picking up passengers in Lausanne and Geneva. This could certainly also be done in the case of bus rental but would require cooperating with Swiss universities too. Secondly, FlixBus could be charging more to people going to Switzerland because plane tickets are expensive (as discussed in part 4, section 2) but could not do that for Italian destinations where plane tickets are cheaper. In conclusion, prices with cooperation with Italian universities

[10] Prices are established through the website of "Trainline", booked for the first week of September 2023. Hypothesis: the departure date can vary on a one-week period. We picked the less expensive train ticket of the week for each destination. This is only an indication as prices fluctuate a lot across time.

are already acceptable but prices could be driven further down by cooperating with Swiss universities depending on how easy it is to cooperate.

Iberian route:

Iberian route	**Price of bus rental ticket without cooperation of Spanish universities**	**Price of bus rental ticket with cooperation of Spanish universities**	**Price of a FlixBus ticket**	**Price of a standard train ticket**[11]
Brussels-Paris	42.22€	21.11€	12.99€	121€
Brussels-Toulouse	131.78€	65.89€	37.98€	174€
Brussels-Barcelona	179.53€	89.77€	52.98€	190€

Figure 20: Comparison of prices (in euros) of bus rental, FlixBus and standard train tickets for the Iberian route.

Similarly as for the Italian route, if Belgian universities do not cooperate with Spanish ones, the bus rental costs less than train tickets but is double the price than FlixBus. When cooperating with Spanish universities, bus rental becomes much cheaper than train but it is still more expensive than FlixBus, especially for students going to Toulouse and Barcelona. Part of this is because Paris is much closer to Brussels than Toulouse and Barcelona (322 km for Paris, 990 km for Toulouse, 1355 km for Barcelona). The bus is hence empty a great part of the journey. For this route, it seems critical to pick up students going to Toulouse and Barcelona in Paris. This should not be difficult as Paris is a very large city with many universities, and this would greatly reduce ticket prices. When picking up students in Paris, new ticket prices are the following:

[11] Prices are established through the website of "Trainline", booked for the first week of September 2023. Hypothesis: the departure date can vary on a one-week period. We picked the less expensive train ticket of the week for each destination. This is only an indication as prices fluctuate a lot across time.

Iberian route	**Price of bus rental ticket with cooperation of Spanish universities**	**Price of bus rental ticket with cooperation of Spanish and Paris universities**	**Price of a FlixBus ticket**	**Price of a standard train ticket[12]**
Brussels-Paris	21.11€	14.81€	12.99€	121€
Brussels-Toulouse	65.89€	46.22€	37.98€	174€
Brussels-Barcelona	89.77€	62.96€	52.98€	190€
Paris-Toulouse	/	32.07€	24.99€	49€
Paris-Barcelona	/	49.01€	42.98€	89€

Figure 21: Comparison of prices (in euros) of bus rental with and without cooperation of Paris universities for the Italian route.

Here, we assumed that all students stopping in Paris are replaced by French students. Students picked up in Paris go to Toulouse and Barcelona with the same proportions as UCLouvain students. This leads to a 30% drop in prices for UCLouvain students. New prices are closer to FlixBus prices and become much cheaper than train. These prices could be even more decreased by picking up students in Toulouse but again, this would require new partners to join the Erasmus bus project.

It is clear that prices proposed by a bus service provider are very competitive and could only be matched by a rented bus if the bus picks up students in every stop. However, picking up students in every stop would require many different universities to cooperate which would make things more complex. Bus rental should therefore only be considered if BlaBlaCar and FlixBus both refuse to operate the buses.

[12] Prices are established through the website of "Trainline", booked for the first week of September 2023. Hypothesis: the departure date can vary on a one-week period. We picked the less expensive train ticket of the week for each destination. This is only an indication as prices fluctuate a lot across time.

The last question that should be answered is whether students should pay for the Erasmus bus and how much? Despite all of the advantages of the Erasmus bus over standard buses, the travel time is still very long, and many students would probably still prefer the airplane in the case of no refund. It is hence clear that in order to attract students, universities should refund at least part of the tickets. In the case of bus rental, the goal is to fill the bus to make it cost-effective. It then makes sense to make it free for students, this way we maximize the number of students taking the bus and we limit the number of universities needed to occupy all seats. In the case of bus service company, universities should be careful about completely refunding the tickets. Indeed, if the universities let the operator set the prices, the operator will take advantage of the refund to ask higher prices. Indeed, in case of complete refund, students will take the bus regardless of the price and the operator knows it. Universities could hence end up paying much more than what they *should be*. The university could either directly negotiate prices with the service provider or refund only part of the tickets. While the first option is more complicated, the second one does not maximize the number of students taking the Erasmus bus as some of them might only take it in the case where it is free.

Finally, it should be noted that based on the following UCLouvain refund for sustainable means of transportation:

- Paris: 50€
- Lausanne and Genova: 100€
- Toulouse, Milano, and Bologna: 150€
- Barcelona: 200€

Both bus service provider and bus rental with cooperation with other universities would cost less to UCLouvain than the current refund policy. For other universities, Erasmus bus would be cheaper than refunding train tickets.

4. What can we conclude from part 4?

The Erasmus bus can help reduce the impact of European mobilities. It is an improved version of standard bus services in the sense that it is also cheap but additionally, students have no connection which makes it faster and more convenient. However, it is still much slower than the airplane, meaning that the number of cities reachable by the Erasmus bus in a reasonable time is limited. We identified two routes going to Italy and to Spain from Brussels.

In order to operate the Erasmus bus, there are two options. The first one consists in a bus service operator operating the lines, universities then just need to promote the idea and refund tickets of students. This option is the easiest for universities and the cheapest too. However, after exchanges of emails with the two major bus service operators (FlixBus and BlaBlaCar), the answer was negative. It is unclear whether it is a definitive no or if they could consider the idea if the universities made the request themselves. The second option would consist in one university renting a coach from a rental company like “Voyages Léonard”. In order to make it cost-effective, Belgian universities should cooperate with other universities to pick up students at stops and fill the bus for the return trip. The problem is then for the different universities to cooperate (who pays and how much?), one solution would be to fund the project with EU green subsidies like the LIFE program.

In both cases there remains uncertainty, would a bus service operator agree to run the lines if requested by universities? Would EU deliver green subsidies for running the Erasmus bus? As the environmental transition will not rely on one single solution, the “Erasmus bus” could be part of the solution for reducing the carbon footprint of Erasmus students and are therefore worth being considered by universities.

Conclusion

In order to reduce air travel in student mobilities, we first determined all causes of air travel. While all students going on transcontinental mobilities have no other alternative to the airplane, 70 to 77% of students going on European mobility also use the airplane to reach their destination. Besides the round-trip to the destination, our survey shows that several side effects caused by the mobility also induce air travel use. These numbers varied according to the type of mobility. We found that students on European mobility get visited by 4.2 relatives on average versus 1.3 relatives for transcontinental mobilities. Students also travel for leisure purposes while on mobility with 0.9 flights for European mobilities and 3.3 flights for transcontinental mobilities. Additionally, students sometimes come back home during the mobility with an average of 0.6 return for European mobilities and 0.4 for transcontinental mobilities. After their mobility, many students plan to meet again with their mobility friends. In our survey, 55% of students responded that they already planned a travel for that purpose. Because we are looking for the effect of the mobilities, we had to determine the additional effect of the mobility rather than the raw numbers. Indeed, if a student would have travelled for leisure purposes regardless of being on mobility or not, we cannot say that the mobility caused leisure travel. After making different reasonable hypotheses, it was found that the real impact of a student mobility is equal to 4 times the impact of the round-trip to the destination. Side effects have a huge impact, they cannot be neglected and make our research question even more relevant.

In a second time, this master thesis highlighted the difference between European mobilities and transcontinental mobilities. While transcontinental mobilities only represented 32% of mobilities in 2022 at UCLouvain, they were responsible for 75% of aviation GHG emissions. This is because distance of European mobilities is much smaller than distance of transcontinental mobilities. For example, Brussels-Singapore is 9 times the distance to Rome. Transcontinental mobilities should hence be the first target of measures aiming at reducing the environmental impact of student mobilities. As these mobilities could not be reached by train or bus, this master thesis looked at ways to reduce the distance of mobilities. Two scenarios were investigated in order to reduce the emissions of the roundtrips to the destinations by 48%. In both cases, we assumed that students are relocated at an average of 1500km and still use the airplane to reach their destination. The first scenario relocated mobilities in decreasing order of distance. We found that 19.6% of mobilities were relocated, there remains 12.4% of mobilities outside of Europe mainly in regions like Canada and North-Africa. However, this scenario does not take into account the constraints faced by universities. Indeed, UCLouvain officials reported that certain mobilities are necessary for the university to stay in alliances like CEMS or Circle-U and that others have a diplomatic role for the university. Other reasons could be academic research and valuable teaching in specific fields. For these reasons, we investigated a second scenario where the university only relocates 2/3 of mobilities. We found even when relocated all mobilities distant from more than 1500 km, we only reached a 46% decrease. This means that UCLouvain should relocate at least 2/3 of transcontinental mobilities (if done independently from distance) in order to reach the 48% decrease objective. However, when discussing about reducing distances with UCLouvain officials, they revealed that these measures are facing resistance because transcontinental mobilities are the ones that attract students the most and that UCLouvain seeks to increase the number of students going on mobility. According to Mrs. Gronarz, Vice-Dean of International Relations at UCLouvain, the university turned its focus to European mobilities, but she did not mention any concrete measure that UCLouvain implemented to increase the share of European mobilities. Outside of UCLouvain, no university explicitly passed measures aiming at reducing distances of mobilities. However, as reducing distance of mobilities is inevitable for university's carbon neutrality on the long run, it should only be a matter of time before universities take steps towards reducing distance of mobilities.

Meanwhile, it is also interesting to look at ways to decarbonize European mobilities. Although these mobilities only represent 25% of GHG emissions, this share should increase once distant mobilities start being relocated closer. In this master thesis, we developed the idea of the "Erasmus bus". These buses would consist in special coaches operated on routes going through Erasmus destinations on dates of departure and return of Erasmus students. Although faster and more convenient than regular coaches, the Erasmus bus are still much slower than the airplane, restricting the number of cities that can be reached. In order to make it cost-effective, the buses would need to be shared by multiple universities in the departure and arrival cities/countries. Picking up students at the different stops would also help decreasing the costs per student. One convenient way to operate these buses would be to find a bus service provider (FlixBus or BlaBlaCar) operating buses on those lines. However, it is uncertain whether one of these companies would be willing to do it or not. An alternative way would be for one university to rent one coach and to share it with other higher institutions. As financial issues could compromise cooperation between universities, funding the bus with EU green subsidies seems necessary for this solution to succeed.

As human societies are striving for carbon neutrality, universities will have to rethink student mobilities. This master thesis showed that transcontinental mobilities are deeply unsustainable and should be relocated to Europe as much as much as possible. For decarbonizing European mobilities, this master thesis proposed an original and relatively cheap solution. Although we should not expect the “Erasmus bus” to take over the whole European continent it could definitely be part of a future sustainable higher education.

Limitations and beyond this master thesis

For any research, there are limitations and room for future improvement.

In this master thesis, we tried to estimate to additional effect of student mobility: what air travel was caused by the student mobility and would not have occurred if the student had stayed home. As we did not have any data about students staying home, we assumed that students would not have travelled during the semester if they stayed home. Although this hypothesis seems reasonable, another survey designed for these students could have provided a reliable estimation of how much students staying home travel during the semester. It should be noted that as travelling costs money, maybe students going on mobility would have travelled less prior to their mobility and even after it in order to save money. Travels of students going on mobility and students staying home would then have to be compared on a period of time spanning from before to after the mobility. This would provide a reliable estimation on the additional effect of the mobility on the travel of the student but would need more data and a deeper analysis. For visiting family and friends, we assumed that 1 in 2 relatives would have travelled elsewhere if not visiting the student on mobility. Data could confirm or reject this hypothesis. However, this data would be much harder to get as we would need to survey all relatives and all friends of each student staying home and going on mobility. Finally, it should also be noted that respondents to our survey were exclusively Belgian students and do not represent all international students. Although the additional effect (4 round-trip flights) could be better estimated, the conclusion would stay the same if it was 3 or 5 round-trip flights: side effects have a great impact and universities should try to decarbonize student mobilities.

Regarding reducing distances, it is still unclear what is the willingness of universities to implement these measures. UCLouvain did not seem close to these measures but enumerated certain barriers such as international alliances. It would be interesting to better understand these barriers in their full extent order to make reducing distances easier for universities. This would also allow to evaluate the objective of 48% reduction and whether it is attainable considered the barriers to reducing distance of mobilities. It should also be noted that no other university than UCLouvain was reached for information but when researching online, we could not find universities that explicitly took measures to reduce distance of mobilities.

Finally, although this master thesis explored the “Erasmus bus” idea in details, a few questions remain. What do universities think about? Would UCLouvain be willing to launch the project? Would cooperation with other universities be easy? As cooperation with other universities seems inevitable for financial reasons, our routes might need to be redesigned to suit all partner universities. It is also still unclear whether FlixBus and BlaBlaCar would still not be interested in the project if a group of universities was contacting them with a practical plan. In the case where no bus service provider is willing to operate the buses, the solution of green subsidies should be deeper investigated. Would the “Erasmus bus” project be eligible for green subsidies?

In conclusion, as little research has been done on “how to reduce student mobility air travel”, this master thesis provided an exploratory analysis and possible solutions to answer this urgent question. It is now up to future research and universities to answer the remaining questions and to adapt our solutions to their needs in order to make student mobilities greener!

Bibliography

Ademe. (2021). *Base Empreinte®*. Agence De La Transition Écologique. Retrieved July 31, 2023, from https://base-empreinte.ademe.fr/donnees/jeu-donnees

Alves, H., & Terzieva, V. (2023). HANDBOOK for sustainable internationalisation. *Green Erasmus*, 2020-1-BE01-KA203-074971. Retrieved July 6, 2023, from https://project.greenerasmus.org/documents/GE-handbook-HEIs.pdf

Bamberg, S., & Rölle, D. (2003). Determinants of People's Acceptability of Pricing Measures : Replication and Extension of a Causal Model. *Acceptability of Transport Pricing Strategies*, 235248. https://doi.org/10.1108/9781786359506-015

Bamberg, S., & Schmidt, P. (2003). Incentives, Morality, Or Habit ? Predicting Students' Car Use for University Routes With the Models of Ajzen, Schwartz, and Triandis. *Environment and Behavior*, *35*(2), 264285. https://doi.org/10.1177/0013916502250134

BBC News. (2019, August 24). *Climate change: Should you fly, drive or take the train?* Retrieved February 5, 2023, from https://www.bbc.com/news/science-environment-49349566

Bongardt, D., Stiller, L., Swart, A. & Wagner, A. (2019). Sustainable Urban Transport: Avoid-Shift-Improve (A-S-I): iNUA # 9: Implementing the New Urban Agenda. *Transformative Mobility*. https://www.transformative-mobility.org/assets/publications/ASI_TUMI_SUTP_iNUA_No-9_April-2019.pdf

Bookabus. (2023). *Besoin de louer un bus avec chauffeur? Bookabus a la plus grande variété de bus.* https://www.bookabus.be

Bourguignon, F., & Darpeix, P. (2016). *Air Traffic and Economic Growth: The Case of Developing Countries*. HAL open science. https://shs.hal.science/halshs-01332085

Cambridge Dictionary. (2022). Meaning of coercive in English. In *Cambridge Dictionary*. https://dictionary.cambridge.org/dictionary/english/coercive

Carbone4. (2020). *Trainées de condensation : quel impact sur le climat ?* Retrieved 15 July 2022, from https://www.carbone4.com/trainees-de-condensation-impact-climat

Chandler & Munday. (2016). social norms. In *Oxford Reference*. https://www.oxfordreference.com/view/10.1093/acref/9780191800986.001.0001/acref-9780191800986-e-2542

Chancel, L., & Piketty, T. (2015, November 3). Carbon and inequality: from Kyoto to Paris: Trends in the global inequality of carbon emissions (1998-2013) & prospects for an equitable adaptation fund. *Paris School of Economics*. Retrieved January 23, 2023, from http://piketty.pse.ens.fr/files/ChancelPiketty2015.pdf

Connaissance des Énergies. (2013, October 2). *Biomasse*. Connaissance Des Énergies. Retrieved February 1, 2023, from https://www.connaissancedesenergies.org/fiche-pedagogique/biomasse

CO2Logic. (2023). *CALCULER ET COMPENSER VOTRE IMPACT*. Greentripper. Retrieved February 11, 2023, from https://www.greentripper.org/fr

De Pater, M., Gabrielczak, P., Kokko, S., Omar, M., & Saarela, H. (2022). *MEASURES TO REDUCE THE TRANSPORT-RELATED CARBON FOOTPRINT OF THE ERASMUS+ PROGRAMME* (No. 2020-1-FR01-KA203-080260). Retrieved March 5, 2023, from https://uni-foundation.eu/uploads/2022_EGG_IO3%20report_final.pdf

de Groot, J. I. & Schuitema, G. (2012). How to make the unpopular popular? Policy characteristics, social norms and the acceptability of environmental policies. *Environmental Science & Policy*, *19–20*, 100-107. https://doi.org/10.1016/j.envsci.2012.03.004

Distance calculator. (2023). *Calculez la distance entre deux villes*. Distance Calculator. Retrieved May 30, 2023, from https://fr.distance.to/

Dugast, C., & Soyeux, A. (2019, June). *Faire sa part ?* Carbone4. Retrieved 8 July 2022, from https://www.carbone4.com/publication-faire-sa-part

Durovic, M., & Lovrentjev, S. (2015). ERASMUS STUDENTS – The New Tourism Force. *The Macrotheme Review*, *5*(4). https://macrotheme.com/yahoo_site_admin/assets/docs/1MR45Lov.14833252.pdf

Eriksson, L., Garvill, J., & Nordlund, A. M. (2006). Acceptability of travel demand management measures: The importance of problem awareness, personal norm, freedom, and fairness. *Journal of Environmental Psychology*, *26*(1), 15–26. https://doi.org/10.1016/j.jenvp.2006.05.003

ESN & Eurail. (2020). *Student's mobility needs: Snapshots of a Eurail survey on participants in Erasmus+ Mobility Programmes*. Retrieved March 3, 2023, from https://esn.org/sites/default/files/news/erasmus_mobility_survey_report_-_final_0.pdf.

European Commission. (2019). What is the European Green Deal? *European Commission*. https://ec.europa.eu/commission/presscorner/detail/en/fs_19_6714

European Commission. (2022). Erasmus+ Programme Guide. *European Commission*. https://erasmus-plus.ec.europa.eu/sites/default/files/2022-01/2022-erasmusplus-programme-guide-v2_en_0.pdf

Electricity Maps. (2022). *Live 24/7 CO2 emissions of electricity consumption*. Retrieved June 29, 2022, from https://app.electricitymaps.com/map

González, C. R., Mesanza, R. B., & Mariel, P. (2010). The determinants of international student mobility flows: an empirical study on the Erasmus programme. *Higher Education*, *62*(4), 413–430. https://doi.org/10.1007/s10734-010-9396-5

Gössling, S., & Humpe, A. (2020). The global scale, distribution and growth of aviation: Implications for climate change. *Global Environmental Change*, *65*, 102194. https://doi.org/10.1016/j.gloenvcha.2020.102194

Grébonval, C. (2023, May 4). *Coûts de Production Électricité en France en 2023 : Répartition et Analyse*. Prix-Elec.com by Selectra. Retrieved August 1, 2023, from https://prix-elec.com/energie/production#:~:text=L

Green Erasmus. (2022). Research on the habits of Erasmus students: consumer, daily life, and travel habits of Erasmus students from the perspective of their environmental attitudes and beliefs. *Green Eramsus*. https://project.greenerasmus.org/documents/GE-report.pdf

Hamamoto, M. (2019). An empirical study on the behavior of hybrid-electric vehicle purchasers. *Energy Policy*, *125*, 286–292. https://doi.org/10.1016/j.enpol.2018.10.042

Haberl, H., Wiedenhofer, D., Virág, D., Kalt, G., Plank, B., Brockway, P. E., Fishman, T., Hausknost, D., Krausmann, F., Leon-Gruchalski, B., Mayer, A., Pichler, M., Schaffartzik, A., Sousa, T., Streeck, J., & Creutzig, F. (2020). A systematic review of the evidence on decoupling of GDP, resource use and GHG emissions, part II: synthesizing the insights. *Environmental Research Letters*, *15*(6), 065003. https://doi.org/10.1088/1748-9326/ab842a

IEA. (2019). *Renewables – Global Energy Review 2019 – Analysis*. Retrieved 29 June 2022, from https://www.iea.org/reports/global-energy-review-2019/renewables

IEA. (2020). *World air passenger traffic evolution, 1980-2020 – Charts – Data & Statistics*. Retrieved 20 August 2022, from https://www.iea.org/data-and-statistics/charts/world-air-passenger-traffic-evolution-1980-2020

IEA. (2021, June). *Executive summary – Hydropower Special Market Report – Analysis - IEA*. International Energy Agency. Retrieved August 1, 2023, from https://www.iea.org/reports/hydropower-special-market-report/executive-summary

IEA. (2022a). *Belgium - Countries & Regions - IEA*. International Energy Agency. Retrieved July 24, 2023, from https://www.iea.org/countries/belgium

IEA. (2022b). *Global Energy Review: CO2 Emissions in 2021 – Analysis*. International Energy Agency. Retrieved June 29, 2022 from https://www.iea.org/reports/global-energy-review-co2-emissions-in-2021-2

IEA. (2023, March). *CO2 Emissions in 2022 – Analysis - IEA*. International Energy Agency. Retrieved July 5, 2023, from https://www.iea.org/reports/co2-emissions-in-2022

IPCC. (2022a). *Climate Change 2022: Impacts, Adaptation and Vulnerability. Working Group II Contribution to the IPCC Sixth Assessment Report.* Retrieved July 09, 2022 from https://www.ipcc.ch/report/ar6/wg2/

IPCC. (2022b). Climate Change 2022 Mitigation of Climate Change: Summary for Policymakers. In *Intergovernmental Panel on Climate Change* (doi: 10.1017/9781009157926.001). Cambridge University Press, Cambridge, UK and New York, NY, USA. Retrieved May 14, 2023, from https://www.ipcc.ch/report/ar6/wg3/resources/spm-headline-statements/

Jancovici. (2019). 2 - Les énergies fossiles - Cours des Mines 2019. Retrieved July 06, 2022 from https://www.youtube.com/watch?v=1NHPgrH5lcQ&list=PLMDQXkItOZ4LPwWJkVQf_PWnYHfC5xGFO&index=2

Kreil, A., & Stauffacher, M. (2021). Reducing air travel related greenhouse gas emissions in academia: An empirical policy overview. 10.31235/osf.io/bzrfq.

Krzaklewska, E., & Krupnik, S. (2008). The Role of the Erasmus Programme in Enhancing Intercultural Dialogue. Presentation of the Results from the Erasmus Student Network Survey 2007. *Higher*

Education for Intercultural Dialogue and Multiculturalism, *6*. https://upcommons.upc.edu/bitstream/handle/2099/5767/l6_pap_Krupnik_Krazlewska.pdf?sequence=1&isAllowed=y

Lassen, C. (2010). Environmentalist in Business Class: An Analysis of Air Travel and Environmental Attitude. *Transport Reviews*, *30*(6), 733-751. https://doi.org/10.1080/01441641003736556

Lavery, T. (2017). *Framing effect*. Teach Target. Retrieved 11 October, 2022, from https://www.techtarget.com/whatis/definition/framing-effect

Lee, C. F., & King, B. (2015). International Students in Asia: Travel Behaviors and Destination Perceptions. *Asia Pacific Journal of Tourism Research*, *21*(4), 457–476. https://doi.org/10.1080/10941665.2015.1062786

Louis, C. A., Bouvet, C., Martin, G., & Boucherand, S. (2020). Analyse et modélisation de l'impact climatique du transport aérien actuel et à venir en France. *BL Évolution*. https://www.bl-evolution.com/Docs/200721_Etude-BLevolution_Climat-Aviation.pdf

Map Developers. (2023). *Draw a circle with a radius on a map*. Retrieved June 6, 2023, from https://www.mapdevelopers.com/draw-circle-tool.php

Matthews, J. B. R. (2018). *Glossary — Global Warming of 1.5 ºC*. IPCC. Retrieved June 20, 2023, from https://www.ipcc.ch/sr15/chapter/glossary/

Moerman, J. (2020). *Combien de CO2 émettons-nous en Belgique ?* Écoconso. Retrieved 8 July 2022, from https://www.ecoconso.be/fr/content/combien-de-co2-emettons-nous-en-belgique

Mulhern, O. (2022). *EO Indexes: Energy Storage*. Earth.Org. Retrieved 25 July 2022, from https://earth.org/data_visualization/eo-indexes-energy-storage/

Overton, J. (2022, June 9). *Issue Brief | The Growth in Greenhouse Gas Emissions from Commercial Aviation (2019, revised 2022) | White Papers | EESI*. Environmental and Energy Study Institute

(EESI). Retrieved May 10, 2023, from https://www.eesi.org/papers/view/fact-sheet-the-growth-in-greenhouse-gas-emissions-from-commercial-aviation#2

Parlement européen. (2022, June 27). *Ajustement à l'objectif 55: des carburants plus durables pour l'aviation | Actualité | Parlement Européen*. Parlement Européen. Retrieved February 1, 2023, from https://www.europarl.europa.eu/news/fr/press-room/20220627IPR33913/ajustement-a-l-objectif-55-des-carburants-plus-durables-pour-l-aviation

QS Quacquarelli Symonds. (2023, July). *QS World University Rankings*. Retrieved July 30, 2023, from https://support.qs.com/hc/en-gb/articles/4405955370898-QS-World-University-Rankings-

Ritchie, H. (2020). *Climate change and flying: what share of global CO2 emissions come from aviation?* Our World in Data. Retrieved 10 July 2022, from https://ourworldindata.org/co2-emissions-from-aviation

Ritchie, H., Roser, M. & Rosado, P. (2020). *CO2 and Greenhouse Gas Emissions Country Profiles*. OurWorldInData. https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions

RTE. (2020, January). *La transition vers un hydrogène bas carbone : Atouts et enjeux pour le système électrique à l'horizon 2030-2035*. Réseau de transport d'électricité. Retrieved July 4, 2022, from https://www.connaissancedesenergies.org/sites/default/files/pdf-actualites/Rapport_hydrogene-pdf.pdf

Service Public Fédéral Mobilité et Transport. (2023, February 6). *Les déplacements domicile-travail : le vélo continue son ascension avec +80 % en 16 ans | mobility*. SPF Mobilité Et Transport. Retrieved July 27, 2023, from https://mobilit.belgium.be/fr/news/les-deplacements-domicile-travail-le-velo-continue-son-ascension-avec-80-en-16-ans

The Shift Project. (2021). Pouvoir voler en 2050: Quelle aviation dans un monde contraint ? *The Shift Project*. https://theshiftproject.org/wp-content/uploads/2021/12/TSP_AVIATION_RAPPORT_211116.pdf

Times Higher Education. (2022, October 5). World University Rankings 2023: methodology. *Times Higher Education (THE)*. Retrieved August 1, 2023, from https://www.timeshighereducation.com/world-university-rankings/world-university-rankings-2023-methodology

Tversky, A., & Kahneman, D. (1981). The Framing of Decisions and the Psychology of Choice. *Science, 211*(4481), 453–458. http://www.jstor.org/stable/1685855

UCLouvain. (2023). *Évolution du bilan carbone de l'Université*. Retrieved May 19, 2023, from https://uclouvain.be/fr/decouvrir/universite-transition/bilan-carbone-evaluer-pour-mieux-agir.html

ULB. (2022, October 20). *Voyages durables*. Retrieved January 20, 2023, from https://www.ulb.be/fr/partir-en-echange/erasmus-goes-green

United Nations. (n. d.). *The Paris Agreement*. United Nations - Climate Change. Retrieved November 16, 2022, from https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement

Université Paris Cité. (2022, October 13). *La biomasse* [Video]. YouTube. Retrieved February 1, 2023, from https://www.youtube.com/watch?v=pK2uVygoQzs

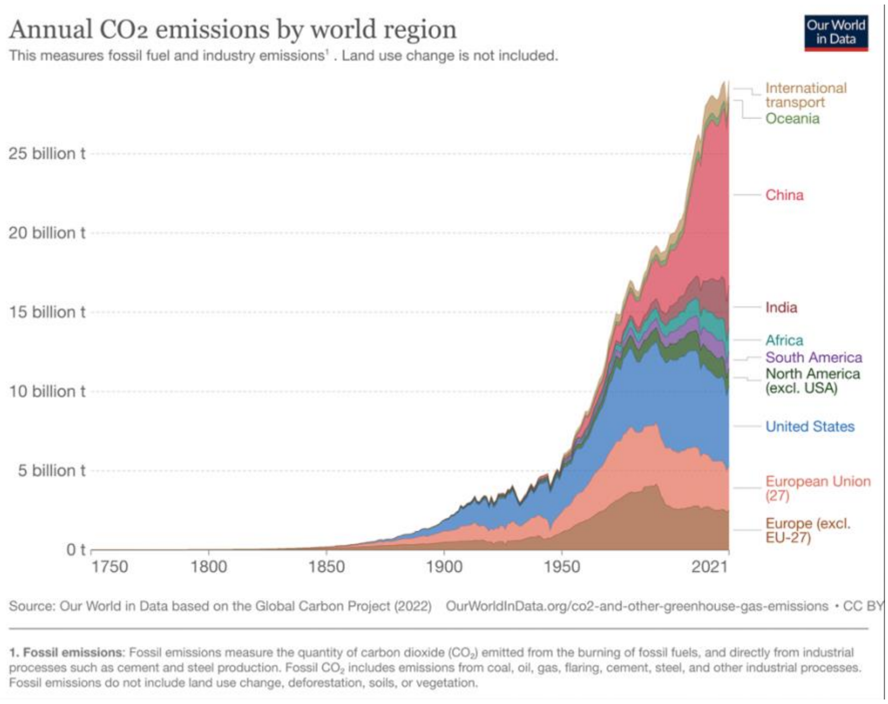
Voyages Léonard. (2023). *Temps de conduite des chauffeurs*. Retrieved July 3, 2023, from https://www.voyages-leonard.com/groupes-location-autocar/legislation/legislation-des-temps-conduite

World Tourism Organization. (2016). Affiliate Members Global Reports: Volume 13 - The Power of Youth Travel, UNWTO, Madrid, DOI: https://doi.org/10.18111/9789284417162

Wei, T., & Liu, Y. (2017). Estimation of global rebound effect caused by energy efficiency improvement. *Energy Economics*, *66*, 27-34. https://doi.org/10.1016/j.eneco.2017.05.030

Appendixes

Appendix 1 - Evolution of annual CO_2 emissions by world region.



From Ritchie, Roser & Rosado, 2020

Appendix 2 - Student mobility survey: questions.

Dear students,

I'm a second-year master’s student at the Louvain School of Management. As part of my dissertation on student mobility, I'm carrying out a survey to find out more about the direct and indirect effects of European and international mobility.

Completing this 13-question questionnaire will take you 2 minutes, and the information collected will remain completely anonymous. Your invaluable help will contribute to a better understanding of the direct and indirect effects of exchanges and, I hope, to the success of this dissertation.

Thank you in advance!

Q1: Where did you go on exchange?

- Europe
- Outside Europe

Q2: In which country did you go?

- Free answer

Q3: In which year did your exchange take place?

- 2023
- 2022
- 2021
- 2020
- 2019
- 2018
- Before 2018

Q4: What was the main means of transport you used to get there?

- Airplane
- Train
- Coach
- Car
- Other

Q5: Which of the following factors was most important when you chose your means of transport?

- The ticket price.
- The travel time.
- The comfort.
- I didn't have a choice, there was only one possibility.
- Other

Q6: Apart from the round-trip flight to your destination and back to your home country at the end of your exchange, how many times did you fly (round-trip) during your exchange? (From 0 to 6 and more)

	0	1	2	3	4	5	6 and more
Coming back to your home country during the exchange	○	○	○	○	○	○	○
Visit the exchange country	○	○	○	○	○	○	○
Visiting neighboring countries close to your exchange destination	○	○	○	○	○	○	○

Q7: How many **friends** came to visit you during your exchange?

- 0
- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8
- 9
- 10 or more

Q8: How many **members of your family** came to visit you during the exchange?

- 0
- 1
- 2
- 3
- 4

- 5
- 6
- 7
- 8
- 9
- 10 or more

Q9: How many family members or friends have taken the **train or bus to visit you**?

- 0
- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8
- 9
- 10 or more

Q10: How many times did you fly (round trip) in the **6 months prior to your exchange**?

- 0
- 1
- 2
- 3
- 4
- 5 or more

Q11: Has this exchange made you want to **travel more often?**

- Yes, it gave me a taste for travel and adventure.
- Yes, I plan to travel a little more often.
- No, not particularly.

- Other

Q12: Have you met people of other nationalities whom you **plan to see again** in the future?

- Yes, we're already planning to meet again.
- Yes, if I'm visiting their country.
- No, not particularly.
- Other

Q13: For European students only

Did you know that the European Commission (EC) **reimburses part of your transportation costs** if you use an alternative to air travel (train, bus, etc.)?

- Yes, I knew that the EC reimburses 50€ of the train/bus ticket.
- Yes, I knew that the EC reimburses 50€ of the train/bus ticket and up to 4 additional days of scholarship.
- No, I hadn't heard about it.
- Other

Appendix 3 - Student mobility survey: results.

Flights	**Europe (80 students)**	**Outside of Europe (55 students)**
To reach his/her destination	62/80 = 0.775	55/55 = 1
Come back in Belgium during the exchange	48/80 = 0.6	22/55 = 0.4
To visit the host country	30/80 = 0.375	108/55 = 1.96
To visit neighboring countries of the host country	41/80= 0.5125	74/55 = 1.345
Visit from friends	155/80 = 1.9374	24/55 = 0.436
Visit from family	179/80 = 2.2375	50/55 = 0.91
Friends of family members that take the bus/train/car	47/80 = 0.5875	0/55 = 0

The previous table reports the average number of flights/person for the different causes of air travel. This number is obtained by dividing the total number of flights by the number of people. In order to estimate the carbon footprint of mobilities, we compute a multiplicative factor to the round-trip flight to the destination. For example, for a factor 3 and New-York as destination, the carbon footprint of the mobility is equivalent to 3 round-trip flights to New-York. In order to study differences between European and transcontinental mobilities, numbers were computed separately for both types of mobilities.

Here are the assumptions:

- "10 or more" and "5 or more" answers were respectively counted as 10 and 5.
- As domestic flights are shorter than flights from home country to host country, the number of domestic flights (for leisure travels) was divided by 2 for European mobilities and by 3 for transcontinental mobilities. This is equivalent to dividing distance by 2 and 3.
- For flights to neighboring countries, distances are again assumed to be smaller, and the number of flights is divided by 2 for European mobilities and by 2 for transcontinental mobilities.

- For visiting family and friends, it was assumed that 1 in 2 people would still have taken the plane even if the student had not gone on exchange. Before this division by 2, we subtracted the number of relatives who took sustainable means of transportation as these people did not fly.

Here are the formulas used for computing the different multiplicative for respectively European and transcontinental mobilities.

$$0.775 + 0.6 + \frac{0.375}{2} + \frac{0.5125}{2} + \frac{(1.93+2.23-0.58)}{2} = 3.6$$

$$1 + 0.4 + \frac{1.96}{3} + \frac{1.345}{2} + \frac{(0.463+0.91-0)}{2} = 3.4$$

For indirect effects, we added 1 flight for people who responded that they already planned to meet again with people that they met during their mobility (55% of respondents). We therefore added +0.5 to the previously calculated multiplicative factors. meaning that at least 0.5 flight should be added to direct effects. Although the majority of respondents (more than 8/10) reported that their mobility gave them a taste for travel, as this is complex to quantify, it will not be taken into account in our multiplier factor. It should be noted that we tried to make conservative assumptions in order to give lower bounds. Here total multiplication factor:

European mobilities: *3.6 + 0.5 =* ***4.1***

Transcontinental mobilities: 3.4 + 0.5 = **3.9**

Finally, as the difference between both factors is very small, we consider that side effects are the same for European and transcontinental mobilities and only keep a multiplicative factor of 4 for both.

Appendix 4 – Comparing potential of different levers of actions.

In order to compare the potential of different levers of action, different scenarios were considered:

- **Removing half of mobility opportunities**. Destinations are sorted by decreasing order of distance, one spot out of two is removed in that order. For example, if the first destination is Sydney with seven spots and the second is Canberra with three spots, then four spots are removed in Sidney and one spot is removed in Canberra.
- **Relocating all distances of more than 3000km to 1500km**. It is assumed that students still take the plane to go to their new destinations.
- **Forcing all students going on a European mobility to take the train**.

For removing half of mobility opportunities, computations are easy: GHG emissions for all causes of air travel are divided by 50% leading to a total decrease of 50% (in practice it was not a perfect cut and 48.7% was found). For relocating destinations, if **long-distance destinations** (cities further than 3000 kilometers from Brussels) were removed, it would represent a gain of 885.89 tons of CO_2e (based on 2022 figures).

$\sum_{n=3000}^{dist\ max}((Distance_n * EF_n * 2 * number\ of\ students\ in\ 2022)$ = 885.89 tons of CO_2e[13]

However, all students in those removed destinations (310 students) would have to be relocated in closer European destinations. We assume that they are relocated at an average distance of 1500 km and still take the airplane to reach their new destination. This would represent 118.11 tons of CO_2e (=310*1500*0.254). The **total GHG gain of reducing mobility distance would be 767,78 tons of CO_2e** (885.89 tons of CO_2e - 118.11 tons of CO_2e), which would represent a reduction in GHG emissions of more than **64.5%** (= 767,78/1188,66). This reduction would affect the travels of the student and of visiting family and friends but not leisure travels and taste for travel. For long-distance relationships, we assumed that closer destinations are evenly favorable for students to develop long-distance relationships and as they can meet students from

[13] In the formula, EF corresponds to the emission factor of the transportation mean, in this case long-haul flight (i.e., 0.195g CO_2e/km/cap). We multiplied by two to take into account round trip and we multiplied this number by the totaling number of students that went to that destination in 2022 to get the final number of emissions.

all over the world, the mobility destination does not influence where they will meet again with their mobility friends.

On the other side, if all European flights (cities below than 3000 kilometers from Brussels) were replaced by **trains** for the year 2022, it would represent a CO_2 gain of 226.47 tons of CO_2e (i.e., 19% of total emissions for the UCLouvain students mobilities). For computations, we assumed that destinations below 700 km of route distance were already reached by trains and are hence not taken into account in the calculations.

Computation: (Distance vol* CO_2 avion* 2 * student number) – (Distance route * CO_2 train* 2 * student number) = 290.34 tons of CO_2e – 63.86 tons of CO_2e = 226.47 tons of CO_2e

If all European flights (cities below than 3000 kilometers from Brussels) were replaced by **buses** for the year 2022, it would represent a CO_2 gain of 248.07 tons of CO_2e (i.e., almost 21 % of total emissions for the UCLouvain students mobilities).

Computation: (Distance vol* CO_2 avion* 2 * student number) – (Distance route * CO_2 bus* 2 * student number) = 290.34 tons of CO_2e – 42.06 tons of CO_2e = 248.07 tons of CO_2e

We see that buses actually lead to a greater decrease than trains, however we still assume that students would take the train and keep the reduction number of -19%. This reduction only applies for the travel to and back from his destination of the student and not for other side effects.

Appendix 5 - Data of UCLouvain student mobilities between 2018 and 2023.

UCLouvain STUDENTS IN MOBILITY	2018 - 2019	2019-2020	2020-2021	2021-2022	2022-2023	TOTAL	Global evolution
Total of students OUT	**903**	**824**	**577**	**903**	**974**	**4181**	**-**
Canada	159	148	15	120	165	**607**	**-**
Spain	81	73	75	86	96	**411**	**-**
Italy	75	64	55	97	104	**395**	**-**
France	39	32	53	77	74	**275**	**-**
Portugal	41	43	44	55	37	**220**	–
Belgium	45	34	49	37	21	**186**	–
Ireland	37	33	25	35	40	**170**	=
Switzerland	31	25	34	31	41	**162**	**-**
Sweden	20	34	31	45	31	**161**	**-**
Norway	23	26	20	38	38	**145**	**-**
UK	35	27	27	30	21	**140**	–
Germany	22	20	24	26	24	**116**	=
Austria	32	16	24	22	17	**111**	–
Finland	18	23	17	19	29	**106**	**-**
Czech Republic	13	17	11	16	23	**80**	**-**
Percentage of European mobilities	**82.28%**	**81.92%**	**97.23%**	**86.71%**	**82.96%**	**85.39%**	=

Appendix 6 - Most popular European cities for UCLouvain students' mobilities.

Country	Locality	2018	2019	2022	Mean	Sum
Portugal	Lisboa	37	37	32	35,33	**106**
Ireland	Dublin	33	27	33	31,00	**93**
Italy	Milano	27	23	31	27,00	**81**
Belgium	Leuven	33	28	13	24,67	**74**
Spain	Madrid	27	18	23	22,67	**68**
Spain	Barcelona	19	17	31	22,33	**67**
Austria	Wien	29	15	15	19,67	**59**
Switzerland	Lausanne	18	15	25	19,33	**58**
France	Paris	18	16	21	18,33	**55**
Norway	Bergen	17	18	15	16,67	**50**
Italy	Bologna	13	14	19	15,33	**46**
Spain	Valencia	12	12	16	13,33	**40**
Italy	Roma	10	8	20	12,67	**38**

To ensure confident and accurate results, years 2020 and 2021 were not given and analyzed due to covid restrictions.

Appendix 7 – Quotes from Bookabus for Erasmus bus routes.

Iberian route: quote.

Votre citation

Résumé des prix

prix	€7765
T.V.A.	0%
Total	**€7765**

Information additionnelle

Cette offre est valable à un bus et un chauffeur pour au moins 65 les passagers.

Toutes les citations comprennent tous les frais liés à votre itinéraire qui est le bus avec chauffeur, taxe sur la valeur ajoutée locale (TVA), d'autres taxes et frais mais à l'exclusion des frais d'hébergement du pilote.

votre itinéraire

Mardi 10/09/2024

heure de départ

12:00

De:
Brussels, Belgium

Par:
Paris, France

Par:
Toulouse, France

À:
Barcelona, Spain

Mercredi 11/09/2024

heure de départ

12:00

De:
Barcelona, Spain

Par:
Toulouse, France

Par:
Paris, France

À:
Brussels, Belgium

passagers:

65

Italian route: quote.

Votre citation

Résumé des prix

prix	€7255
T.V.A.	0%
Total	**€7255**

Toutes les citations comprennent tous les frais liés à votre itinéraire qui est le bus avec chauffeur, taxe sur la valeur ajoutée locale (TVA), d'autres taxes et frais mais à l'exclusion des frais d'hébergement du pilote.

Information additionnelle

Cette offre est valable à un bus et un chauffeur pour au moins 65 les passagers.

votre itinéraire

Mardi 10/09/2024

heure de départ
22:00

De:
Brussels, Belgium

Par:
Lausanne, Switzerland

Par:
Geneva, Switzerland

Par:
Milan, Metropolitan City of Milan, Italy

À:
Bologna, Metropolitan City of Bologna, Italy

Mercredi 11/09/2024

heure de départ
12:00

De:
Bologna, Metropolitan City of Bologna, Italy

Par:
Milan, Metropolitan City of Milan, Italy

Par:
Geneva, Switzerland

Par:
Lausanne, Switzerland

À:
Brussels, Belgium

passagers:
65

Abstract: While scientists have been warning us about climate change for over 30 years, GHG emissions have yet to start decreasing. While so far, most governments have focused their efforts on renewable energies and energy sufficiency technologies, it appears that energy sufficiency measures, meaning restricting energy consumption will be inevitable to limit global warming under 2°C. In the aviation sector, energy sufficiency consists in reducing the number of passengers. This master thesis looks at ways to reconcile climate objectives with air travel-intensive student mobilities by looking at the case of UCLouvain. First, this master thesis evaluates the environmental impact of student mobility. Through a quantitative survey, we found that the impact of a mobility is equivalent to 4 round-trip flights to the destination. While currently implemented measures mainly focus on incentivizing students going on European mobility to take alternative modes of transportation, these measures miss the elephant in the room: transcontinental mobilities are responsible for 75% of UCLouvain student mobility emissions while only accounting for 32% of the total number of mobilities.

We found that in order to reach its 48% GHG emissions reduction objectives, UCLouvain should relocate to Europe at least 2/3 of transcontinental mobilities. For decarbonizing European mobilities, this master thesis developed the promising idea of the "Erasmus bus". Routes would connect university campuses and directly bring students to their mobility destination. These buses would be operated exclusively for students and at low price, which makes it interesting for universities with limited budget.

UNIVERSITÉ CATHOLIQUE DE LOUVAIN
Louvain School of Management
Place des Doyens, 1 bte L2.01.01, 1348 Louvain-la-Neuve
Boulevard Emile Devreux 6, 6000 Charleroi, Belgique
Chaussée de Binche 151, 7000 Mons, Belgique
www.uclouvain.be/lsm