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Alain BOUSCAYROL[1*], Amandine LEPOUTRE[1*], Elodie CASTEX[2*]

[1] Univ. Lille, Arts et Metiers Paris Tech, Centrale Lille, JUNIA-Hauts-de-France, EA 2697- L2EP, F-59000 Lille, France

[2]Univ. Lille, UR 4477– TVES - Laboratoire Territoire Ville Environnement & Société, F-59000 Lille, France

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***Abstract* — The commuting home-work trips is an important contributor of the Greenhouses Gases (GHG) emissions of cities. In the campus "cité scientifique" of University of Lille, the commuting trips represent more than 50% of the total GHG emission. But during the pandemic, working at home change lead to significantly reduce these daily trips. At first sight, teleworking seems a valuable mean to cut these emissions by working at home and avoiding home-work trips. However, it requires new tools, such as videoconference, which also lead to indirect GHG emissions. In this paper, the GHG of a small research group on electro-mobility has been analyzed before and during the lockdown. From this case study, the GHG benefit depends on the daily commuting distance and the transport mean. For example, a person with 10-km daily trip using subway will increase its GHG emission by teleworking.**

Keywords — Teleworking, commuting trips, Green House Gases emissions.

I. Introduction

The mobility sector is one of the main Greenhouse Gases (GHG) contributor. International agencies show that the electrification of transport is of prime interest to face the global warming [1]. The University of Lille develops the CUMIN (Campus of University with Mobility based on Innovation and carbon Neutrality) as a demonstrator of electro-mobility transition [2]. Within this framework, it has been demonstrated that commuting (home-university) leads to more than 50% of the total GHG emissions of its "Cité scientifique" campus, a small city of 22 000 users, 80 buildings on 110 ha.

Teleworking seems a promising solution to reduce the GHG of the entities [3]. Since the COVID-19 crisis, teleworking has been strongly developed to face different local and sanitary constraints [4]. From the first experience of teleworking, it is of interest to estimate the GHG gain compared to on-site working and thus avoiding commuting GHG.

The objective of this paper is to compare the GHG emissions of a small research group for a pure teleworking organization and a classical on-site organization. Different types of transportation are considered for the commuting trips. Such a study does not aim to provide definitive conclusion. Rather, it aims to aware the campus users about teleworking considering the right issues.

II. Framework of the Study

The objective of this section is to define the limits of the case study. First, the CUMIN (Campus of University with Mobility based on Innovation and carbon Neutrality) programme of University of Lille is presented [2]. The proposed study is developed as an awareness tool for discussion on the campus transition. A target group has been defined to be representative of the L2EP (Laboratory of Electrical Engineering and Power electronics) research Lab of University of Lille. L2EP is composed of about 100 members, but only the 21 members working on electrified vehicles (EV) are considered. The panel is very limited and does not aim to be a representative case of the university. Anyway, it will enable to highlight some interesting facts that are obvious for some mobility specialists, but not so obvious for most of the students and the academic staff.

A. CUMIN programme

In 2014, a carbon assessment of the campus "Cité Scientifique" of University of Lille demonstrated that the commuting mobility leads to more than 50% of the greenhouse gases of this campus. This figure is mainly due to the 5 000 thermal cars that come daily to the campus for commuting (home-university trip).

From this starting point, the CUMIN programme has been developed since 2015 to propose a demonstrator campus based on electro-mobility with charging stations for electric vehicles supplied by renewable energy.

Several studies have been developed to encourage the electro-mobility but the COVID period leads to important questions for users. But what remains clear from these studies is that teleworking is seen as a "green" solution for most of users, as its ecological footprint is generally not considered.

B. *Description of the considered panel*

The target group is members involved in the EV topic of the control team of L2EP. This group is composed of 2 professors, 3 associated professors, 2 engineers, 1 technician, 1 secretary, 2 post-doctoral positions, 5 PhD students and 5 Master students. For the academic staff, it can be noted that some of them are not fully working on the EV topic, as they share activities with other parts of the L2EP. However, the selected distribution aims to have a representative set of the L2EP members and a realistic research group.

In normal time, all the members of this target group work on the campus "cité scientifique" of University of Lille, every day, all along the year, except Master students who are involved only during an internship of 6 months. The home-university distances and the commuting transport systems of the target group members are described in Table 1. Only their main transport types for commuting (daily home-work trip) are considered in this study. In terms of transport types, 9 commuters use subway while 5 commuters use thermal pollutant cars (Fig. 1). Only 1 member uses an electric vehicle. In the actual context of COVID-19, teleworking is encouraged and rotations are made between working at University and home. These rotations are not considered in this paper.

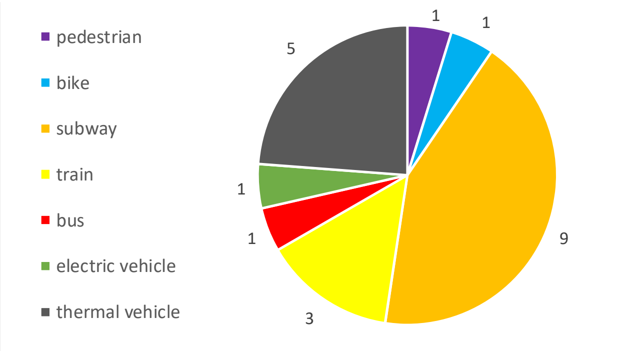

Fig. 1: Distribution of the transport types

Their total working days during one year are calculated from the average working day number of the University of Lille (see Table 1): 228 days. The number of working days of Master students are divided by 2 as their internships at L2EP is only during 6 months: 114 days.

C. *GHG of transport and ICT*

In order to compute the yearly GHG emissions of the target group, the emission factors of the different transport types are used from the ADEME French national database (Table 2) [5]. This database is regularly updated and used by national agencies and institutions for calculation of carbon footprints of various activities. These emission factors are expressed in CO_2 equivalent (CO_2e) per km. For example, the average value of a thermal car is 0.254 kCO_2e per km.

Table 1: Characteristics of the target group

Member ID	main transport type	home univeristy distance (km)	Anual working days
M1	electric vehicle	6	228
M2	subway	18	228
M3	subway	7	228
M4	thermal vehicle	22	228
M5	thermal vehicle	9	228
M6	subway	4	228
M7	regional train	26	228
M8	thermal vehicle	23	228
M9	thermal vehicle	20	228
M10	subway	19	114
M11	subway	9	228
M12	subway	10	114
M13	bus	8	228
M14	subway	9	228
M15	subway	2	114
M16	regional train	48	114
M17	pedestrian	1	228
M18	subway	2	114
M19	thermal vehicle	14	228
M20	bike	3	228
M21	regional train	20	228

Table 2: GHG emission factors for transport

main transport type	kgCO2e / km
pedestrian	0,0000
bike	0,0000
subway	0,0057
regional train	0,0089
bus	0,0154
electric vehicle	0,0950
thermal vehicle	0,2540

Figures for telework are quite difficult to obtain because there are great variations based on the perimeter and the computation methods for ICT (Information and Communication Technologies) [5] [7]. The reference for 1 hour of a Zoom connection is considered as this software is used by University of Lille as main videoconference tool. The GHG emissions of Zoom for 1h is estimated to 157 g CO_2e per connection by [8]. For example for a meeting of 1h between 10 persons, the total amount of GHG will be 1.57 kg CO_2e.

III. Different Working Scenarios

The objective of this section is to compute the GHG emission of different scenarios for the panel. The selected figures have been provided by the different users, including the number of hours of videoconference per day during the lockdown.

A. *Reference working scenario*

The reference scenario is computed on the pre-COVID period where all members of the target group where 100% in presence at work during the days. All travels (research meeting, conference attendance, etc.) are not considered. It is assumed that each group member has the same travels for all working day during the year. This scenario aims only to be a reference for the comparative analysis and does not claim to be fully representative of a real scenario.

The total annual amount of GHG emissions is 10.96 tons of CO_2e for the target group for a complete year (Table 3). It can be noted that if the thermal cars represent only 24% of the users, they produce 93% of the total GHG emissions of this small group.

Table 3: GHG emissions for the reference scenario

Member ID	main transport type	Annual commuting distance (km)	Emission factor	Annual emission (kg CO_2e)
M1	electric vehicle	2736	0,0950	260
M2	subway	8208	0,0057	47
M3	subway	3192	0,0057	18
M4	thermal vehicle	10032	0,2540	2 548
M5	thermal vehicle	4104	0,2540	1 042
M6	subway	1824	0,0057	10
M7	regional train	11856	0,0089	106
M8	thermal vehicle	10488	0,2540	2 664
M9	thermal vehicle	9120	0,2540	2 316
M10	subway	4332	0,0057	25
M11	subway	4104	0,0057	23
M12	subway	2280	0,0057	13
M13	bus	3648	0,0154	56
M14	subway	4104	0,0057	23
M15	subway	456	0,0057	3
M16	regional train	10944	0,0089	98
M17	pedestrian	456	0,0000	0
M18	subway	456	0,0057	3
M19	thermal vehicle	6384	0,2540	1 622
M20	bike	1368	0,0000	0
M21	regional train	9120	0,0089	81
TOTAL				**10 958**

B. *Pure teleworking scenario*

In this scenario, all the members of the target group work from home (teleworking) all the working day. If this scenario is quite unrealistic, it has been the case during the lockdown in France during 2 months in spring 2020. Only some hours of Zoom connections are considered and other communications are neglected based on their low carbon footprint [8]. An average hour-connection is considered for each category of the members in function of the past experience during the lockdown.

This second scenario leads to reduce the total amount of GHG emission to 1.86 tons of CO_2e for the complete year (Table 4). However, if some members significantly reduce their commuting footprints (green cells), half of the members increase their environmental impact (red cells) due to their usual low-carbon transport types. Other members have globally an equivalent amount of GHG emissions.

The reduced panel do not aim to be representative of the campus users but offers realistic cases. Based on this small case study, it is worth noting that teleworking is not a zero-carbon practice and that its GHG emissions should be considered. Of course, the results depend on transport types and connection hours, but one sees here that teleworking is not always better than *in situ* working.

Table 4: GHG emission for the teleworking scenario

Member ID	Annual working days	Daily zoom connection (h)	Emission factor (kg CO2 /h)	Annual emission (kg CO_2e)
M1	228	6	0,157	215
M2	228	4	0,157	143
M3	228	6	0,157	215
M4	228	3	0,157	107
M5	228	3	0,157	107
M6	228	4	0,157	143
M7	228	3	0,157	107
M8	228	3	0,157	107
M9	228	1	0,157	36
M10	114	1	0,157	18
M11	228	2	0,157	72
M12	114	2	0,157	36
M13	228	2	0,157	72
M14	228	2	0,157	72
M15	114	1	0,157	18
M16	114	1	0,157	18
M17	228	2	0,157	72
M18	114	1	0,157	18
M19	228	3	0,157	107
M20	228	2	0,157	72
M21	228	3	0,157	107
TOTAL	21			**1 861**

C. *Alternative scenarios*

Scenario 3, starts like scenario 1 (all the members of the target group work at the university all the working days). But their commuting trips are subway, except for pedestrian and bike. Of course, as some locations have no subway connection this scenario is quite unrealistic, but it will be the theoretical minimal value of the on-site working. This scenario leads to a global GHG emissions amount of 456 kg CO_2e (Table 5) for the complete year. It can be noted that this figure is largely lower than the teleworking scenario.

In scenario 4, all the members of the target group work at the university all the working day as well. Their commuting trips are thermal vehicles only to order to describe the worse scenario in terms of GHG. In this case, the GHG emissions leads to 20.33 tons of CO_2e (Table 5) for the complete year. Fortunately, the reference case (actual situation) is lower than this worse case.

In scenario 5, all the members of the target group work at the university all the working days again. Their commuting trips are electric vehicles only to describe an alternative scenario in terms of GHG. Once again, this scenario is unrealistic but it will enable a comparison between thermal and electric vehicles. In this case, the GHG emissions lead to 6.60 tons of CO_2e (Table 5) for the complete year. It can be noted that this case leads to reduce the GHG emissions by 3 compared to scenario 4 with only thermal vehicles.

All these scenarios are unrealistic but they demonstrate the impact of the transport type in terms of CO_2 emissions. A pure teleworking scenario is not the best case in terms of global warming for our studied reduced panel. It is the subject of a future work of the CUMIN group, with study based on a more representative panel.

Table 5: GHG emission (kg CO_2e) of the different scenarios

reference scenario (1)	pure teleworking scenario (2)	Subway scenario (3)	Thermal vehicle scenario (4)	Electric Vehicle scenario (5)
10 958	1 861	456	20 327	7 603

IV. Conclusion

The CUMIN programme has been developed by the University of Lille to propose solutions to significantly reduce greenhouse gases emissions of its “Cité Scientifique campus”. These GHG emissions are mainly due to the commuting trips of students and academic staff. But, the COVID-19 lockdown, and the heavy use of videoconference that it produced, was the opportunity to question oneself on the impact of teleworking. According to a CUMIN survey, most of the campus users consider that teleworking does not have any environmental impact.

Based on this result, a reduced panel of a research group has been considered for the analysis of the GHG emissions of the daily commuting and teleworking. Of course this study is only valid for this very limited study case and the considered emission factors. The aims of the different scenarios of such limited study are not to be representative at the university scale, but they allow to aware the campus users on the real impact of teleworking.

It is true that teleworking generally reduces the GHG emissions but for not all group members. Some members increase their footprints by teleworking when their transport types have low-carbon impact. For the campus users, a study on their usual commuting trip is thus necessary before considering teleworking as the best solution in terms of CO_2 emissions.

The replacement of thermal car by EV or common transport is of high interest for reducing the GHG emissions. The best solution is a combination of low-carbon transport type and teleworking considering the different location and user’s constraints. A more general study with an important number of campus users should be developed for a fair analysis.

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