



DELIVERABLES REPORT

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Impact of the use of electric vehicles for the environment

1. Introduction

This study explores the impact of electric vehicles on the environment and the environmental benefits of reduced CO₂ emissions and air quality improvements using a more sustainable mode of transportation (EEA, 2021a).

The report presents the findings from the Cycling Campus & City (3Cs) Project and shows the result from the initiative promoted as MUV Challenge, which occurred in the four European universities involved in the project (Université Paul Valéry – Montpellier; Universidade de Coimbra; Università di Torino; Universidad Camilo José Cela de Madrid) and calculated the CO₂ impact for each university as a result of their mobility model and commuting type most used.

2. State of art

The use of electric bicycles (e-bikes) is gaining traction as a sustainable mode of transport that promotes physical activity while reducing environmental harm. E-bikes enable individuals to travel greater distances with less physical strain compared to traditional bicycles, making them suitable for populations that might otherwise be less physically active. Studies have shown that e-bikes can encourage moderate physical activity and help reduce sedentary behaviors, which is critical in combating diseases such as cardiovascular disease, diabetes, and obesity (Bourne et al., 2018).

The transportation sector is a major contributor to global greenhouse gas emissions, accounting for approximately 24% of global emissions (IEE, 2021). Electric vehicles (EVs) offer a promising alternative to internal combustion engine (ICE) vehicles, potentially reducing emissions and improving air quality.

Electric vehicles (EVs) are increasingly seen as a key solution to reducing greenhouse gas emissions and combating climate change and one of the primary environmental benefits of EVs is their potential to reduce carbon emissions. Unlike internal combustion engine vehicles, EVs produce zero tailpipe emissions.

EVs are generally more energy-efficient than traditional vehicles. Electric motors convert a higher percentage of energy from the battery to power the wheels, whereas internal combustion engines lose a significant amount of energy as heat. Electric motors in EVs are highly efficient, converting over 77% of the electrical energy from the grid to power at the wheels, compared to only about 12-30% for conventional gasoline vehicles (US





Department of Energy, 2024). This higher efficiency means that even when the electricity used to charge EVs is generated from fossil fuels, the total emissions are still lower than those from traditional gasoline or diesel vehicles.

This efficiency translates to lower overall energy consumption and reduced environmental impact. Electric bicycles (e-bikes) offer additional environmental benefits. They provide a sustainable mode of transportation that reduces reliance on motor vehicles for short trips, thereby decreasing traffic congestion and emissions. E-bikes are particularly effective in urban and peri-urban settings, where they can replace car trips and reduce the overall carbon footprint.

Comparative studies show that EVs have a lower overall environmental impact than ICE vehicles. For instance, a study by the European Environment Agency (EEA) found that, across its lifecycle, a typical electric car in Europe produces less greenhouse gases and air pollutants compared with its petrol or diesel equivalent (EEA Report, 2018a). This is primarily due to the lower emissions during the use phase of EVs. The report confirms that the greenhouse gas emissions of electric vehicles, with the current EU energy mix and over the entire vehicle life cycle, are about 17-30 % lower than the emissions of petrol and diesel cars. However, as the carbon intensity of the EU energy mix is projected to decrease, the life-cycle emissions of a typical electric vehicle could be cut by at least 73 % by 2050.

For local air quality, electric vehicles also offer clear benefits, mainly due to zero exhaust emissions at street level. EVs contribute to improved air quality by eliminating tailpipe emissions, which are a major source of urban air pollution. Traditional vehicles emit pollutants such as nitrogen oxides (NO_x) and particulate matter (PM), which are harmful to human health. By contrast, EVs produce no tailpipe emissions, leading to cleaner air in urban areas. Shifting to electric vehicles could also reduce noise pollution, especially in cities where speeds are generally low, and traffic often stands still.

The adoption of electric vehicles (EVs), including electric cars and bicycles, has been recognized as a significant step towards reducing environmental pollution and mitigating climate change. By lowering greenhouse gas emissions, improving air quality, and enhancing energy efficiency, EVs play a crucial role in fostering a sustainable future.

In Europe, road transport is the largest source of air and noise pollution in most urban areas (EEA, 2018b). From a health perspective, PM, NO_x and ground-level ozone are considered the pollutants of most concern. The impacts of long-term and peak exposure to these pollutants range from impairing the respiratory system to premature death. A high percentage of people living in urban areas in Europe are exposed to pollutant concentrations above air quality standards, i.e. to levels deemed harmful to health (EEA, 2017).

Long-term exposure to road noise is linked to a wide range of health issues including sleep disturbance, annoyance and negative effects on the cardiovascular system and metabolism. In Europe, around one in four people are exposed to long-term average road noise levels of at least over 55 dB(A), sufficient to cause annoyance, and one in six to night-time road noise levels of at least over 50 dB, sufficient to cause sleep disturbance (Blanes et al., 2016).





At first sight, BEVs appear to be ideally suited to addressing both issues, having zero tailpipe emissions of air pollutants and reduced engine noise.

However, there are some key considerations that influence the net outcome for human health, such as:

- Local emissions of non-exhaust PM caused by all motor vehicles.
- Emissions of air pollutants elsewhere for electricity generation; and
- Road safety impacts of reduced engine noise.

Electric mobility is on the rise in many cities across the globe, underpinned by the urgent need to reduce critical levels of urban air pollution, greenhouse gas emissions, and noise pollution (UN-Habitat, 2022). Electrification of road transport vehicles was recognized as a powerful low-carbon transport strategy by the Intergovernmental Panel on Climate Change and the 2015 Paris Declaration on Electro-Mobility and Climate Change launched at the climate summit COP-21. A total of 54 Nationally Determined Contributions (NDCs) under the Paris Agreement on climate change and Long-Term Strategies have included measures promoting electric mobility so far, by countries located both in the Global North and South (TraCS and SLOCAT, 2021). Further to these environmental benefits, electric mobility has numerous economic and social multipliers. These include the opportunity to promote a more sustainable urban mobility stimulated by the renewal of public transport fleets and the introduction of innovative mobility options such as e-bikes, a new industry market and job opportunity, as well as the opportunity to proactively support gender-inclusive mobility.

Recognizing these opportunities, an increasing number of countries have enacted national and urban policies in recent years to support the roll-out of a variety of electric mobility options. Electric fleets range from lightweight two- and three-wheelers such as electric bikes, cargo bikes, scooters, mopeds, tuk-tuks – provider under private, shared or commercial forms –, over electric light duty vehicles including passenger cars and light commercial vehicles, to electric heavy-duty buses and trucks. In this global movement, cities can act as natural champions to foster a transition towards electric mobility. Cities are incubators of innovation, concentrating economic activities and the creativity of people. These strengths, coupled with the shorter distances between destinations and higher population and residential densities that characterize cities, place them in a unique position to complement national programs and steer electric mobility in the most sustainable direction.

2. Intervention Studies

2.1 Intervention 1: MUV Challenge

The MUV Game, developed by Italian startup MUV B-Corp, integrates digital gameplay into real-world mobility to encourage sustainable travel choices within the 3C's project. Through a mobile app, users can track their sustainable trips (walking, cycling, public transport, carpooling, electric vehicles), earning points for each verified journey (figure 1).





These points are used in game modes, including training, challenges, and team tournaments, rewarding the most eco-friendly participants. The app also aggregates mobility data, aiding organizations and cities in improving mobility policies. MUV Game, certified to calculate CO₂ savings at individual and community levels, is accessible in four languages and adaptable to each participating university.

How MUV Game Works:

- **Tracking Features and Mechanism:** Users start tracking their sustainable trips by selecting their vehicle and pressing 'PLAY' in the app, which then provides live updates (distance, speed, time, points). At the destination, pressing 'STOP' automatically verifies the trip, displaying a summary and trip details like distance, time, calories, and points. If a trip is invalid, users can request verification, managed by customer support.
- **Supported Mobility Systems and Validation Algorithms:** MUV Game supports diverse sustainable mobility modes—walking, biking, public transport, and electric vehicles. Each system employs a custom validation algorithm, analyzing GPS data, speed, and user-entered information (e.g., vehicle plate or transport line). This ensures accurate tracking and reliable data for rewarding eco-friendly transportation choices.

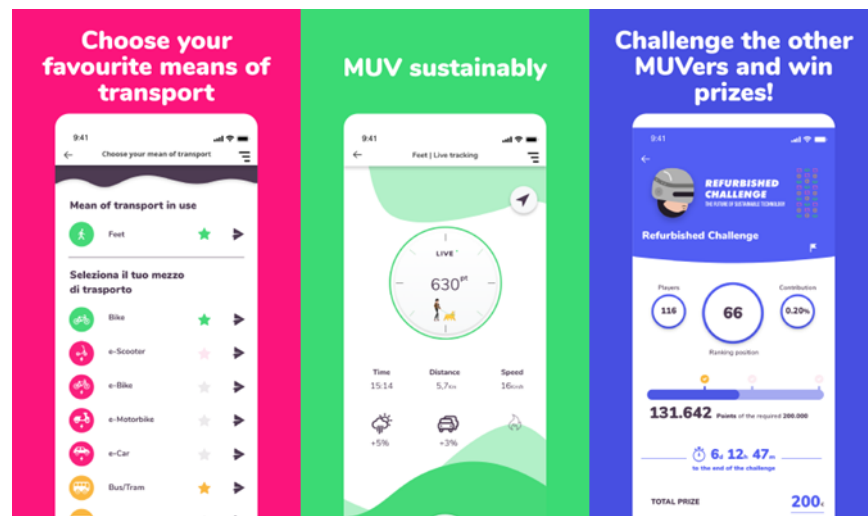


Figure 1. MUV App

2.1.1. Participants in the MUV Challenge

Four European universities that are part of the Cycling Campus & City (3Cs) Project participated in the study:

- Université Paul Válerý (Montpellier-France)
- Universidades de Coimbra (Coimbra-Portugal)
- Universidad Camilo José Cela (Madrid-Spain)





- Università di Torino (Torino-Italy)

Each university received instructions from MUV on how to carry out the challenge and received recommendations to encourage the use of the application in their respective university community. Each of the four universities have been able to choose whether and when to use MUV Game for 3C's project within their university. The MUV game for 3C's project had the necessary information of each institution (logo, email domain, faculty list, etc.), and a dedicated community was created and added to the app.

From that moment on, all students, professors and staff, after downloading the app and creating their account, were able to enter their university community where they were able to take part in dedicated game dynamics and know in real time the impact produced by the community in terms of CO2 saved. This phase had involved the university promoting the initiative by communicating that it has joined the MUV Game for 3C's project and inviting everyone to join the community and participate in the initiative.

All mobility data collected during experiments using the MUV app were anonymized and made available to the relevant universities for research purposes. Similarly, each university had access to a web dashboard where aggregated data showing MUV Game for 3C's project usage and impact can be accessed in real time. Finally, information on CO2 saved and modal split recorded by users was condensed into a report made available to universities.

2.1.2. Data Collection in the MUV Challenge

The following table summarizes the key characteristics of each university challenge.

Table 1. MUV Challenge summary for each university

	University Paul-Válerý	Universidade de Coimbra	Universidad Camilo José Cela	Università di Torino	Total
Challenge	Montpellier	Coimbra	Madrid	Torino	
Launch Date	26/02/2024	10/04/2024	09/09/2024	09/09/2024	
Start Date	13/06/2024	13/05/2024	16/09/2024	16/09/2024	
End Date	10/04/2024	09/06/2024	14/10/2024	14/10/2024	
Users Section					
Total Users	117	94	163	132	506
Active Users	72	63	91	108	334
Gender (%)					
Male	75	50	40	18	
Female	25	50	60	82	
Modal Split recorded by active users (%)					
Feet	13,38	29,79	12,07	8,48	
Bike	13,92	5,13	0,51	11,40	
E-Bike	2,25	0,13	0,01	1,58	
E-Scooter	-	0,01	0,01	0,12	
E-Motorbike	-	-	-	0,53	
E-Car	1,94	0,03	0,98	2,52	
Bus	8,02	5,43	3,86	4,28	
Pullman	2,73	24,57	9,17	5,30	
Metro	0,32	-	7,51	5,05	
Train	57,43	34,50	52,88	54,27	
Carpooling	-	0,40	13,00	6,47	





2.1.3. Calculating CO2 Savings in the MUV Challenge

The MUV app's CO2 savings calculation follows an ISO 14064-2-certified methodology (validation carried out by RINA), allowing it to gauge CO2 reduction at both individual and community levels. Each user initially completes a survey to establish a baseline of typical emissions, then tracks changes in their transport choices. Weekly, the app calculates the CO2 savings achieved based on the modal shift toward sustainable transportation.

The table 2 below shows the data (total kilometers and CO2 saved) from the four university challenges with a duration of one month each.

Table 2. Kilometer and CO2 saved for each university and total

	University Paul-Válerý	Universidade de Coimbra	Universidad Camilo José Cela	Università di Torino	Total
Kilometer travelled	19.602	7.380	16.204	29.082	72.268
Total CO2 saved (kg)*	201	283	323	242	1.049

*CO saved by active users (kg CO) (compared to initial habits of active users/week)

MUV applies an emission reduction calculation methodology developed in-house and compliant with ISO 14064-2 (validation carried out by RINA)

According to the Table 1 it is important to highlight that the commuting type most used has been the train, followed by walking and cycling.

Considering the data from the four university challenges (Table 2) with a duration of one month each, the total kilometers travelled, and the CO2 savings are as follows

- Kilometers travelled: 72.268 km
- Total CO2 saved: 1.049 kg CO2

If we take into account the data obtained on CO2 emissions savings (1.049 kg CO2), and compare them with trips with combustion vehicles (taking into account that the values may vary depending on the vehicle model, driving style and road conditions), it's could indicate that they are equivalent to the following:

- Gasoline car: Approximately 143 grams of CO2 per kilometer
 - $1.049 \text{ kg CO}_2 / 143 \text{ grams CO}_2/\text{KM} \Rightarrow 7.335 \text{ km}$
- Diesel car: Around 171 grams of CO2 per kilometer
 - $1.049 \text{ kg CO}_2 / 171 \text{ grams CO}_2/\text{KM} \Rightarrow 6.134 \text{ km}$
- Large SUV: Can emit up to 295 grams of CO2 per kilometer
 - $1.049 \text{ kg CO}_2 / 295 \text{ grams CO}_2/\text{KM} \Rightarrow 3.555 \text{ km}$
- Liquefied petroleum gas (LPG) vehicle: Approximately 152 grams of CO2 per kilometer
 - $1.049 \text{ kg CO}_2 / 152 \text{ grams CO}_2/\text{KM} \Rightarrow 6.901 \text{ km}$

It is concluded that with sustainable transportation modalities, in addition to obtaining significant savings in CO2 emissions, it is equivalent to greater distances travelled.





2.2. Pilot Study: E-bike use

2.2.1. Participants in the pilot study

Sixteen participants were selected for the study, with ages ranging from 31 to 56 years old. Participants were equipped with e-bikes, and their physical activity levels and health metrics were monitored before and after the intervention. Each participant received training on how to use the e-bikes and was encouraged to incorporate e-bike travel into their daily routines.

2.2.2. Data Collection in the E-bike's study

The study focused on collecting both anthropometric and fitness data, which were measured at the start of the intervention and at follow-up points 8-week latter. The variables collected included weight, body fat composition and cardiovascular indicator, as well as the number of kilometers travelled by GPS tracking incorporated in the electrical bicycles. This GPS was only used to access the total amount of kilometer.

The following table summarizes the key characteristics of the study population:

Table 3. Baseline characteristics of participants

Variable	Mean	SD	Min	Max
Age (years)	40.7	10.1	31.0	56.0
Weight (kg)	82.6	13.6	62.7	110.1
Body Fat (%)	29.9	7.7	16.6	40.4
Ruffier-Dickson Index	10.1	4.4	2.7	19.0
Estimated VO2 Max (ml/kg/min)	25.4	5.0	17.5	33.7
Total Distance (m)	220,368	123,006	78,701	521,580

2.2.3. Calculating CO2 Savings in the E-bike's study

The shift from cars to sustainable transportation (walking, cycling, public transport, carpooling, electric vehicles) presents significant environmental benefits, particularly in terms of CO2 reduction. According to the European Environment Agency (2021b), passenger cars emit an average of 120 g of CO2 per kilometer. To estimate the CO2 savings resulting from the use of e-bikes, we used the following equation:

$$\Rightarrow \text{CO2 Savings (kg)} = \text{Distance Traveled (km)} \times 0.120 \text{ kg/km}$$

The total distance traveled by all participants was multiplied by this factor to determine the emissions avoided by not using conventional cars. The table 4 below indicate





the amount of kilometer done by each participant following their CO₂ savings calculate with the above equation.

Table 4. Km and CO₂ saving by participants in the intervention study

Participant	Total Distance (km)	CO ₂ Savings (kg)
Participant 1	200.92	24.11
Participant 2	78.70	9.44
Participant 3	301.43	36.17
Participant 4	351.16	42.14
Participant 5	82.88	9.95
Participant 6	234.12	28.09
Participant 7	78.70	9.44
Participant 8	346.89	41.63
Participant 9	489.07	58.69
Participant 10	146.91	17.63
Participant 11	199.87	23.98
Participant 12	238.76	28.65
Participant 13	407.65	48.92
Participant 14	329.20	39.50
Participant 15	355.60	42.67
Participant 16	521.58	62.59
Total	4,363.44 km	523.60

2.2.4. PM_{2.5} and PM₁₀ Savings Calculation in the intervention Study

In addition to reducing CO₂ emissions, e-bikes contribute to a significant reduction in other harmful pollutants that have direct effects on public health and the environment. Two key pollutants, Particulate Matter (PM_{2.5} and PM₁₀), are among the most harmful to human health, particularly in urban areas where vehicle traffic is dense.

PM_{2.5} refers to particulate matter with a diameter of less than 2.5 micrometers. Due to their small size, PM_{2.5} particles can penetrate deep into the lungs and even enter the bloodstream, posing serious health risks. Exposure to high levels of PM_{2.5} has been linked to cardiovascular diseases, respiratory problems, and an increased risk of premature death.

PM₁₀ refers to particulate matter with a diameter of less than 10 micrometers. While PM₁₀ particles are larger than PM_{2.5}, they can still be inhaled and cause health issues, particularly for individuals with asthma, chronic obstructive pulmonary disease (COPD), or other respiratory conditions.





Both PM_{2.5} and PM₁₀ are emitted by combustion engines in vehicles, especially from diesel-powered cars. Road traffic is a significant source of these pollutants in urban environments, where traffic congestion can lead to elevated levels of particulate matter. A study by Gojanovic et al. (2011) highlights that replacing car trips with e-bike trips can reduce PM emissions significantly, thereby improving urban air quality and public health.

To calculate the savings in emissions of pollutants such as PM₁₀ and PM_{2.5} by using an electric bicycle instead of a motorized vehicle, we use the following steps and formulas:

$PM_x = \text{Distance} \times \text{Emission Factor of } PM_x$
Where:

- PM_x = avoided emissions (g) of specific pollutants (PM₁₀ or PM_{2.5})
- Distance = distance traveled (km)
- Emission Factor of PM_x = average emissions of PM₁₀ or PM_{2.5} per kilometer for the replaced vehicle (g/km)

Assumed Emission Factors:

- Average emission factor for PM₁₀ ≈ 0.01 g/km
- Average emission factor for PM_{2.5} ≈ 0.008 g/km

* Based on European Environment Agency (2019) reports and World Health Organization (2021) data:

These values are approximations for typical passenger vehicles and may vary with engine type, fuel quality, and local conditions (EEA, 2019; WHO, 2021).

Calculation for 4,363.44 km:

$$PM_{10} = 4,363.44 \text{ km} \times 0.01 \text{ g/km} = 43.63 \text{ g}$$

$$PM_{2.5} = 4,363.44 \text{ km} \times 0.008 \text{ g/km} = 34.91 \text{ g}$$

PM₁₀ and PM_{2.5} final results:

- PM₁₀ avoided = 43.63 g*
- PM_{2.5} avoided = 34.91 g*

*These values represent the amount of particulate matter emissions avoided by using an electric bicycle instead of a combustion engine vehicle to cover this distance.

3. General Discussion

The findings of the MUV challenge and the pilot study of 3Cs project underscore the potential of CO₂ (and others pollutants) savings that promote both individual health improvements and environmental sustainability.





Moreover, the environmental impact is evident in the significant total CO₂ savings of 1,049 kg achieved by the 4 universities through the monthly challenges plus the 523kg of the pilot study. These savings highlight the potential to contribute meaningfully to reducing greenhouse gas emissions, particularly in urban environments where transportation is a major source of air pollution (European Environment Agency, 2021). Beyond CO₂, the reduced emissions of harmful pollutants such as particulate matter (PM_{2.5} and PM₁₀) further emphasize the role in improving air quality and public health, particularly in urban areas where vehicle traffic is dense.

Reducing PM_{2.5} and PM₁₀ levels leads to substantial public health benefits. Lower levels of particulate matter in the air are associated with decreased incidences of:

- Respiratory diseases (e.g., asthma, bronchitis, COPD),
- Cardiovascular diseases (e.g., heart attacks, strokes),
- Premature mortality, especially among vulnerable populations such as children, the elderly, and individuals with pre-existing health conditions.

According to MacArthur et al. (2017), reducing vehicular emissions, including particulate matter, through the increased use of e-bikes not only helps alleviate the environmental burden of pollution but also improves quality of life by reducing medical costs and improving public health outcomes.

In addition to health and environmental benefits, using more sustainable modes of transport can alleviate urban traffic congestion, reduce noise pollution, and decrease the demand for parking space, offering broader urban sustainability solutions. As cities face growing populations and environmental challenges, widespread adoption of more sustainable modes of transport can be part of a comprehensive strategy to promote healthier lifestyles while addressing the climate crisis.

4. CONCLUSION

In conclusion, using more sustainable modes of transport presents a powerful tool to achieve both personal health and environmental goals. Future research should explore long-term adoption patterns, examining how more sustainable modes of transport can be integrated into daily routines and transportation systems

Cities seek innovative solutions for sustainable mobility and environmentally friendly alternative for addressing both health and environmental challenges and universities can significantly contribute to the promotion and adoption of sustainable mobility practices leveraging their educational, research, and community resources.

MUV Game had been one of the solutions implemented in the context of the Cycling Campus & City (3Cs) Project to actively involve students, professors and staff of the four partner universities and guide them towards more conscious and sustainable mobility choices by creating dedicated competitions while measuring the impact produced.





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