

## Article

# A Win-Win Scheme for Improving the Environmental Sustainability of University Commuters' Mobility and Getting Environmental Credits

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**Abstract:** European Union Member States are called upon to meet internationally proposed environmental goals. This study is based, in particular, on the recommendation of the European Union (EU), which encourages Member States to pursue effective policies to reduce greenhouse gas (GHGs) emissions, including through appropriate changes in the behavioral habits of citizens. In this respect, among the main sectors involved, transport and mobility should certainly be mentioned. National institutions should be adequately involved in order to achieve the objectives set; in this regard, universities must certainly be considered for their educational value. These latter, for instance, could commit to improving the environmental performance of the mobility of their commuter students (to a not insignificant extent), since commuting modes are often the cause of high CO<sub>2</sub> emissions; indeed, they still largely involve the use of internal combustion engines based on fossil fuels. In this paper, the effectiveness of a smartphone-app-based method to encourage commuter students to adopt more sustainable transport modes is evaluated. In more detail, starting from a statistical analysis of the status quo of mobility habits of a sample of students at the University of Palermo (Italy), an improvement of current habits toward a more sustainable path is encouraged through a new application (specifically created for this purpose) installed on students' smartphones. Then, the daily and annual distances traveled by commuters with the new mobility modes are calculated, and the resulting savings in energy and CO<sub>2</sub> emissions are estimated. Finally, it is proposed that the reduced emissions could be converted into energy-efficiency credits that the University could use to enter the emission trading system (ETS), here contextualized within the Italian "TEE" ("Energy Efficiency Credits") scheme, while the benefits for students participating in the program could consist of reduced fees and free access to university services. The results obtained show the feasibility of the proposal. This approach can be considered a useful model that could be adopted by any other public institutions—not only universities—to facilitate their path toward decarbonization.

**Keywords:** sustainable mobility; universities; commuter students; efficiency credits; smartphone's social-game-based app; mobility behavior



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## 1. Introduction

Freight transportation and people mobility represent an important part of the tertiary sector (that aims to provide services to citizens) in advanced societies, not only from an economic point of view but also in relation to both the amount of energy required and the rate of associated pollutant emissions attributable to them [1]. According to a 2020 report of the International Energy Agency (IEA) (these figures refer to twenty-four countries—Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany,

Greece, Hungary, Italy, Japan, Korea, Luxembourg, the Netherlands, New Zealand, Poland, Portugal, Slovak Republic, Spain, Switzerland, the United Kingdom and the United States—of the IEA that account for about 92% of the total IEA final energy consumption of the considered year), the transport sector accounts for 36% of total energy consumption, of which 21% is ascribable to passenger cars and 15% to freight roads (i.e., cargo transport) and other transportations [2]. On the other hand, these two segments of the transport sector are also responsible for a significant amount of CO<sub>2</sub> emissions related to human activity; specifically, quotas of 20% and 10% have been indicated that affect passenger cars and freight roads [2], respectively. Referring to Italy, energy-consumption rates are comparable with those of other IEA countries. In fact, the most recent figures [3] show that energy consumption in the transportation sector accounts for 39.4 Mtoe, or for 33.8% of the total final energy consumption of the country (116 Mtoe).

This is the reason why, in recent years, the transport sector has been affected by interventions aimed at limiting its energy burden and the amount of fossil fuels required for its operations [4]. These limitations are imposed by the European Union (EU), with very stringent targets: in fact, greenhouse gases (GHGs) emissions are required to be reduced by 40% by 2030 compared to 1990 levels.

Unfortunately, EU Member States are missing their targets. In fact, national projections show that the EU emissions' reductions could actually achieve a reduction of only 30%, which is far from the 40% target and, more importantly, well below the potential target of 50% [5].

However, it should be noted that the COVID-19 pandemic emergency has been inducing major trend changes in energy demand and pollutant emissions from the transport sector. The consequences of such an unpredictable situation could lead to a twofold scenario [6]. On the one hand, the dramatic collapse of public and freight transportation during the lockdown (or semi-lockdown) period certainly resulted in a decrease in energy consumption and GHGs emissions from the sector [7]. On the other hand, it is hoped that measures taken by governments, aimed at modifying mobility modalities of people (pushing in the direction of electric and hybrid vehicles, among others) can trigger a faster transition of the sector toward more sustainable paths [8]. As already pointed out, the role of local governments and authorities in the implementation, governance and promotion of less impactful transport practices can facilitate the transition toward a more sustainable and smart urban mobility [9–11]. Moreover, attention to the changes imposed by the COVID-19 emergency in the transportation sector now seems to be of paramount importance for institutions and international organizations. The G7 group, for example, is deeply interested in this issue, particularly with regard to transportation safety and health-related aspects.

Several studies have been conducted [12,13] in order to make the operation of transport smoother from a structural point of view, thus making the whole sector more efficient and effective [14,15]. On the other hand, less attention has been paid to the behavioral patterns that characterize user mobility (that represent the focus of the present analysis), although some studies have focused on possible changes in mobility modalities in urban contexts. Indeed, the impacts related to a mixed use of different modes of mobility [16], such as single-occupant vehicles, transit and walking, and the so-called real-time human perception [17], have been questioned for a long time, in the belief that the people's awareness is a crucial element to improve the efficiency and the environmental performances of an urban mobility system. Moreover, it has been emphasized that the features of built environments and urban landscapes [18,19] should be properly considered as key elements that can deeply influence people's propensity to adopt less environmentally impactful and healthier modes of mobility [20]. Among these key elements, the physical characteristics of urban contexts, the role of structural configurations (such as the streets' network and width, connectivity and land-use mix), travel distances in relation to the travel task [21,22] and population density [23,24] have been considered important elements in both facilitating walking at neighborhood scale [25] and inducing a delay in traffic flow [26].

Clearly, commuters are an important part of urban mobility, and, at the same time, growing awareness of climatic threats, along with health considerations, have further oriented people toward more sustainable ways of commuting to and from cities in order to effectively counteract the general worsening of the environmental quality of cities and limit the congestion problems currently affecting urban areas [27]. Specifically, because urban design variables are recognized as crucial points in determining commuters' travel behavior, these characteristics have been associated with the active population traveling to/from work and educational facilities. Specifically, it has been shown how, once socioeconomic and demographic characteristics are suitably accounted for, improved roadway infrastructure would support the transport-related physical activities, regardless of the geographical area considered [28,29].

Students represent a relevant component among commuters worldwide. That is why learning about students' mobility behaviors and teaching about sustainable transportation (at different levels of education) by using new participatory educational solutions are key elements [30].

In light of this, specific attention has long been paid to sustainable-transportation planning on large campuses [31,32] in order to identify best practices that could help students transition to more effective travel modes [33], while also taking into account the correlation between psychosocial and environmental issues [34,35]. In addition, other studies have investigated the positive effects of active commuting on physical activity and students' overweight [36], as well as comparisons of walking, biking and motorcycle riding [37].

Researchers' attention on students' attitude in assuming active mobility practices has been and still is quite active both in terms of analyzing mode's preferences [38] and the potential for active commuting [39,40], based on demographics, psychological and environmental variables [41]. Other factors could usefully enhance the effectiveness and the environmental performance of commuting. Some other actions seem, in fact, particularly promising, such as the adoption of appropriate student-housing policies and the improvement of bicycle networks [42]. In any case, the analysis of individual factors [43] and the structural elements [44,45] remains an important field of research currently investigated in order to provide exhaustive answers on what drives university students toward a sweeter sustainable mobility [46].

In fact, in relation to both the global-climate-change scenario [47] and the role that active travel has in mitigating mobility related CO<sub>2</sub> emissions [48], university campuses, being educational facilities that shape the minds and behaviors of present and future generations of students, represent crucial places where attention toward low-carbon development strategies that include greener and healthier lifestyles can be raised [49]. In this regard, student involvement has generally been considered within the evaluation of green strategies and initiatives implemented by higher education institutions on their path toward sustainability [50], fostering sustainable practices in curricula and research programs [51] and integrating different dimensions of the university system: education, research, governance and campus operation [52].

Therefore, the idea arises of enhancing these practices that improve mobility and its environmental performance by including them in the procedures that institutions, industrial plants, and companies can activate to receive benefits (credits) for the energy requalification actions implemented. These procedures have been recognized and formalized by the European Union—as part of the new policies and objectives aimed at the decarbonization of production systems—by including these benefits in a market of credits where the most virtuous institutions and production sites can sell them to companies whose practices are less sustainable. This exchange market is called Emission Trading System (ETS). Several documents have been released on this issue, i.e., “EU revision for the time period 2021–2030” (phase 4), [https://ec.europa.eu/clima/policies/ets/revision\\_en](https://ec.europa.eu/clima/policies/ets/revision_en), (accessed on 16 December 2021); “DIRECTIVE 2003/87/EC”; and “DIRECTIVE (EU) 2018/410 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL”, <https://eur-lex.europa.eu/eli/dir/2018/4>

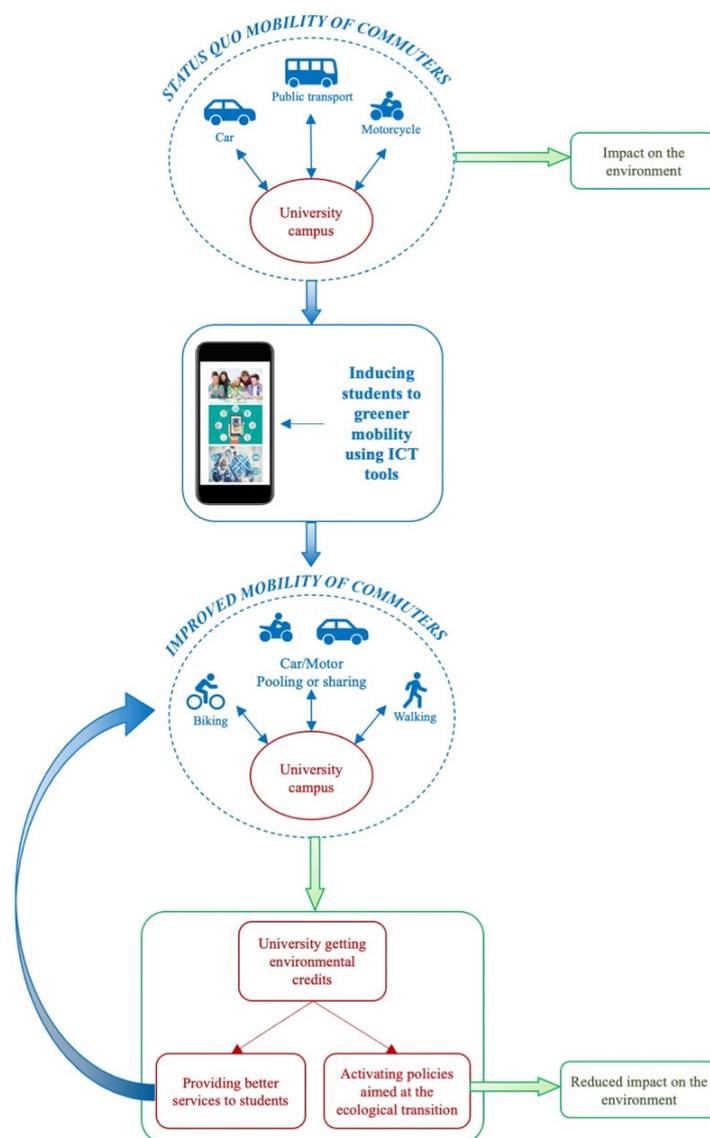
10/oj, (accessed on 16 December 2021). Specifically, according to this trading scheme, efficiency measures that can provide energy savings in terms of tons of oil equivalent (toe) would allow companies to obtain certificates that could be traded on the pertinent public platform through bi-lateral negotiations. The effectiveness of the market trading scheme is based on the commitment made by companies to obtain a number of credits corresponding to the amount of their annual emissions; on the other hand, virtuous companies can keep their credits in order to balance possible future emissions.

In this context, given that a more environmentally conscious mobility system could generally imply a reduction in the energy consumption of the involved transport means, it would then be reasonable for institutions pursuing such practices to be eligible for energy efficiency or environmental sustainability credits under the existing trading schemes. Referring to Italian institutions, this hypothesis would be further supported by the circumstance that the national trading system for energy-efficiency credits (whose acronym is “TEE”) contemplates the inclusion of behavioral patterns among the modalities and projects to which credits are awarded [53], the so-called white certificates. The question that arises here is whether, among the positive effects induced by a more sustainable mobility system, there are additional benefits for institutions that enable such sustainable practices.

A possible inclusion of these behavioral practices among those eligible for the white certificates would lead to a win-win scheme, such as the one described in Figure 1, where it is graphically depicted how an improvement in the environmental (and energy) performance of the commuter mobility could translate into a tangible benefit to the university through the acquisition of white certificates, which could be traded by the university governance in the existing credits market.

Figure 1 outlines the structure of this article and the steps through which the work was carried out. In detail, the study begins with a statistical analysis (based on a questionnaire) of the status quo of student mobility and the ways in which it is carried out (Step 1); it then continues with the direct involvement (of a sample) of students, who are encouraged to change their commuting habits toward more sustainable modes, which are detected through a new application (specifically created for this purpose) installed on their smartphones (Step 2). Following this, the daily and annual distances covered by commuters with the new modes of mobility are calculated, and the resulting savings in energy and CO<sub>2</sub> emissions are estimated (Step 3); finally, the energy efficiency credits resulting from these savings and attributable to the university are estimated, and some benefits for the students that have generated these improvements are suggested (Step 4).

In other words, a twofold goal is therefore pursued with this paper: on the one hand, to show the strong potential of an action regarding the change of students’ mobility habits (entailing the benefits previously described), and on the other hand, to propose to entitle universities to enter environmental credit markets. In particular, Section 2 addresses the application of a smartphone-app-based ICT method aimed at enhancing the sustainability of the commuter’s mobility, while Section 3 advances the hypothesis that the university could get environmental credits as a result of such a mobility-improvement initiative.



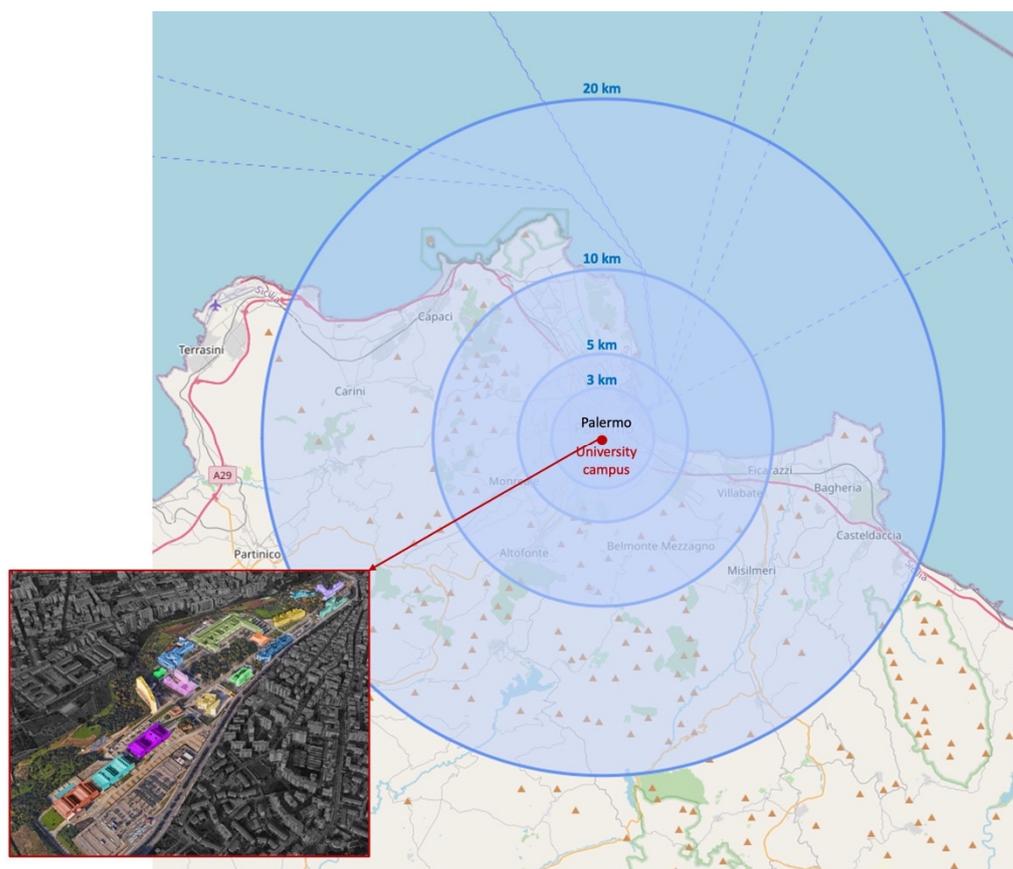
**Figure 1.** Visual sketch of the win-win proposal for the mobility of the commuter students.

## 2. Toward a More Sustainable Mobility of Commuter Students

The evaluation and promotion of a sustainable mobility related to university campuses, as a mean of transition toward more environmentally conscious and low carbon cities, has been a topic of interest within the scientific community in recent years [15,54,55].

Within this conceptual framework, a study and application involving commuter students who daily reach the campus of the University of Palermo in Southern Italy are presented here.

The Sicilian University of Palermo, encompassing 16 Departments, 134-degree courses and 23 Ph.D. courses, represents one of the largest Italian Universities, counting more than 42,000 enrolled students, with a rising trend in the last two years, and approximately 10,000 new freshmen in the 2020/2021 academic year only [56]. Most of the services offered by the University of Palermo take place on the campus sited in Viale delle Scienze, also known as “Cittadella” (meaning “small city”), given its large extension—about 37 hectares—characterized by the presence of large avenues and wide green areas and, in addition to that, various parking lots and buildings (Figure 2). Obviously, the circles in Figure 2 have the sole purpose of providing a draft visual representation of the distance between the different areas from which commuters originate and their target.



**Figure 2.** Campus and the circular distances from where commuters originate.

In order to reduce the use of carbon-related primary energy sources, and with the aim of contributing to the fulfillment of the target proposed by the EU [57,58] and the United Nations' Sustainable Development Goals (SDGs) [59], the University of Palermo has undertaken an effective path of energy saving since 2010. Specifically, SDGs numbers 7 [60] and 11 [61], regarding the promotion of concepts and technologies able to pursue energy efficiency, environmental sustainability, safety and resilience, were taken as a guide, as they seem to be of utmost relevance to the university sector. Among these actions, the mobility of students who reach the campus on a daily basis is considered by the university administration.

### 2.1. The Actual Structure of the Commuter Students' Mobility

Most students at the University of Palermo do not live near the campus (within walking distance); thus, they must travel daily to attend classes, and, usually, most of the commuting is accomplished by traditional polluting mobility modalities. Therefore, abandoning the use of private and highly polluting transportation in favor of more sustainable alternatives (i.e., walking, biking, public transport and vehicle pooling and/or sharing) would lead to a significant reduction in polluting emissions [62].

Clearly, the first step in any greener policy must start with an understanding of the actual structure of the commuters' mobility, pertinent to the modality of transportation, in relation to their distance from the campus. Approximately 25,000 daily commuters can be located in circular areas that are nearly 3, 5, 10 and 20 km far from the campus. The remaining part of them lives more than 20 km far from the university campus: for these students, a mean daily trip of 60 km has been found (students that live at greater distances are not commuters but usually stay in rented rooms that are relatively close to the university) [63].

We started with a survey conducted by the university on the origin of the paths of students arriving at the campus daily to attend classes (Table 1).

**Table 1.** Distribution of the commuter students by distances from the campus.

Parameter	Distance (D) of Origins from the Campus					TOT
	$D \leq 3$ km	$3 < D \leq 5$ km	$5 < D \leq 10$ km	$10 < D \leq 20$ km	$D > 20$ km	
Average round-trip daily path, $L_{zc}$ (km/commuter)	3	8	15	30	60	
Sample share by distance, $MS_z$ (%)	30	26	27	9	8	100
Number of commuters by zone, $NC_z$ (-)	7500	6500	6750	2250	2000	25,000
Total distances by zones, $TL_z = NC_z \times L_{zc}$ (km)	22,500	52,000	101,250	67,500	120,000	363,250

Based on this distribution, a sample campaign was conducted [64] from May 2013 to June 2015, involving a total number of 311 university students who were distributed by distance, as reported in the survey provided. The purpose of this campaign was to single out, by distances class, the percentage share of students' preferred mobility modalities to reach the campus daily (columns  $MS_{zm}$  of Table 2).

**Table 2.** Share of commuters ( $MS_{zm}$ ) and related numbers ( $NC_{zm}$ ) per zone and per modality.

Modalities of Mobility	Distance (D) of Origins from the Campus									
	$D \leq 3$ km		$3 < D \leq 5$ km		$5 < D \leq 10$ km		$10 < D \leq 20$ km		$D > 20$ km	
	$MS_{zm}$ (%)	$NC_{zm}$	$MS_{zm}$ (%)	$NC_{zm}$	$MS_{zm}$ (%)	$NC_{zm}$	$MS_{zm}$ (%)	$NC_{zm}$	$MS_{zm}$ (%)	$NC_{zm}$
Walking	62	4,650	32	2080	0	0	0	0	0	0
Biking	12	900	20	1300	4	270	0	0	0	0
Public transportation	10	750	13	845	25	1688	19	428	34	680
Car	5	375	9	585	34	2295	35	788	35	700
Motorcycle	0	0	14	910	12	810	9	203	3	60
Carpooling	6	450	8	553	17	1148	25	574	25	500
Moto-pooling	5	375	4	228	8	540	12	259	3	60
Car sharing	0	0	0	0	0	0	0	0	0	0

Such a breakdown has been attributed to the total number of commuters (NC) in order to obtain the number of daily commuters ( $NC_{zm}$ ) by mode of transport and by travel distance to the campus, as reported in Table 2.

Subsequently, starting from the total distances by zones,  $TL_z$  (Table 1), using the pertinent  $MS_{zm}$  shares, the total daily trip lengths per zone and modality,  $TL_{zm}$ , can be calculated as follows:

$$TL_{zm} = TL_z \times MS_{zm} \quad (1)$$

At this point, it is easy to estimate the daily CO<sub>2</sub> emissions (tons of CO<sub>2</sub>),  $E_{zm}$ , by zone and modality (for the average vehicle occupation), as reported in Table 3:

$$E_{zm} = TL_{zm} \times E_m/OR_m \quad (2)$$

where  $OR_m$  represents the mean occupation rate (pass/vehicle) of the transportation means used to make the daily round-trips path from home to university and vice versa, and  $E_m$  refers to the emission rate (g CO<sub>2</sub>/km) for the carbon dioxide of the involved transportation means. Despite the fact that these parameters are available in recent technical reports [65], due to the average age of the Italian passenger mobility fleet, in the present application, we refer to the previously released values of CO<sub>2</sub> emission factors [66,67].

**Table 3.** SCENARIO 0—daily CO<sub>2</sub> emissions per zone and mobility modality and per vehicle occupation for all commuters,  $E_{zm}$  (tons of CO<sub>2</sub>).

Modalities of Mobility	CO <sub>2</sub> Emissions per Distance (D) of Origins from the Campus					Total (Tons of CO <sub>2</sub> )
	$D \leq 3$ km	$3 < D \leq 5$ km	$5 < D \leq 10$ km	$10 < D \leq 20$ km	$D > 20$ km	
Walking	0.0000	0.0000	0.0000	0.0000	0.0000	<b>0.0000</b>
Biking	0.0000	0.0000	0.0000	0.0000	0.0000	<b>0.0000</b>
Public transportation	0.0013	0.0038	0.0143	0.0072	0.0230	<b>0.0496</b>
Car	0.2240	0.9317	6.8534	4.7033	8.3615	<b>21.0740</b>
Motorcycle	0.0000	0.5882	0.9817	0.4909	0.2909	<b>2.3517</b>
Carpooling	0.0430	0.1407	0.5479	0.5479	0.9550	<b>2.2345</b>
Motor-pooling	0.0227	0.0368	0.1636	0.1568	0.0727	<b>0.4526</b>
Car sharing	0.0000	0.0000	0.0000	0.0000	0.0000	<b>0.0000</b>
<b>Total</b>	<b>0.2909</b>	<b>1.7012</b>	<b>8.5610</b>	<b>5.9062</b>	<b>9.7031</b>	<b>26.1624</b>

In Table 3, the high value of the total CO<sub>2</sub> emissions of the commuters coming from the 5 ÷ 10 km distance area is caused by their mobility preferences, which are mainly oriented toward the private cars, and by the number of students pertinent to this area.

Therefore, starting from the daily CO<sub>2</sub> emissions and using an energy factor,  $EF$  (toe/tCO<sub>2</sub>), that links these emissions with the fossil-fuel energy consumption (conversion and Emission factors, Italy; report associated to SiReNa 20 (in Italian), [http://www.energielombardia.eu/c/document\\_library/get\\_file?uuid=675ad6f1](http://www.energielombardia.eu/c/document_library/get_file?uuid=675ad6f1), 2019) (accessed on 18 September 2021) of car engines, it is now possible to determine the energy consumption  $C_{zm}$  per zone and mobility modality (toe), as reported in Table 4:

$$C_{zm} = E_{zm} * EF \quad (3)$$

These results represent the baseline scenario (Scenario 0) of the distribution of the mobility of the university commuter students. This scenario realized the amounts of CO<sub>2</sub> emissions and energy consumption shown in Tables 3 and 4, respectively. In the following, the actions taken by the University of Palermo in order to improve this impactful configuration are described. The new configuration represents Scenario 1.

**Table 4.** SCENARIO 0—daily energy consumption by zone and mobility modality and by vehicle occupation for all commuters,  $C_{zm}$  (toe).

Modalities of Mobility	CO <sub>2</sub> Emissions per Distance (D) of Origins from the Campus					Total (Tons of CO <sub>2</sub> )
	$D \leq 3$ km	$3 < D \leq 5$ km	$5 < D \leq 10$ km	$10 < D \leq 20$ km	$D > 20$ km	
Walking	0.00000	0.00000	0.00000	0.00000	0.00000	<b>0.00000</b>
Biking	0.00000	0.00000	0.00000	0.00000	0.00000	<b>0.00000</b>
Public transportation	0.00342	0.01027	0.03846	0.01949	0.06199	<b>0.13362</b>
Car	0.66743	2.77650	20.42326	14.01596	24.91727	<b>62.80042</b>
Motorcycle	0.00000	1.75291	2.92553	1.46276	0.86682	<b>7.00802</b>
Carpooling	0.12807	0.41930	1.63284	1.63284	2.84590	<b>6.65893</b>
Motor-pooling	0.06772	0.10956	0.48759	0.46727	0.21671	<b>1.34884</b>
Car sharing	0.00000	0.00000	0.00000	0.00000	0.00000	<b>0.00000</b>
<b>Total</b>	<b>0.86663</b>	<b>5.06853</b>	<b>25.50767</b>	<b>17.59832</b>	<b>28.90869</b>	<b>77.94983</b>

## 2.2. Implementing a Greener Mobility of the Commuter Students

As it is possible to see in Table 2, although part of the trips is made by biking or walking, a significant component of the mobility is made by typically polluting private means, such as cars and motorcycles. Therefore, there is large room for improving the environmental performances of the mobility pattern. Among possible strategies, encouraging students to assume a more sustainable commuting behavior can pursue this target.

To achieve this goal, an effective way to facilitate the communication between the university governance and the commuter students may consist of the use of new information and communication technologies, in the belief that a proper modeling of the relationship between environment and subject is becoming increasingly important in the governance of new smart cities [68], where users represent the central points of the technological applications. In particular, tools based on smartphone apps seem to be the most effective choice today, as also reported in some recent works of the literature [69–71]. With this intent, a smartphone app based on an info-mobility Decision Support System has been expressly developed [72].

Such Decision Support System, named TrafficO2 ([www.traffico2.com](http://www.traffico2.com)) (accessed on 18 September 2021), has been a social innovation project conducted by the PUSH design lab from 2013 to 2016 and co-financed by the Italian Ministry of University and Research.

The project intends to decrease private traffic intensity and limit pollution, not through policies promoted by city administrations, but simply by involving social applications supported by smart technological devices (smartphones and/or tablets). TrafficO2, the smartphone app here introduced [72,73], is an info-mobility Decision Support System whose main aim is to push people especially commuter students toward more sustainable mobility behaviors. This change in transport habits is being encouraged via incentives proportionate to responsible choices. In detail, participants obtain “environmental points” as a reward for their sustainable mobility choices. Being a Decision Support System [74] each user is asked to log in and take a survey based on which they will receive a personalized improvement Scenario. Specifically, based on personal route and mobility modality, the app provides some alternative route options to which some parameters are associated (i.e., travel time, emitted and saved CO<sub>2</sub> and burnt calories), along with related O2 points (i.e., a virtual currency), and cumulative score. This makes it possible for the commuter to immediately know his/her achievable improvement, thus being more stimulated in attaining it. Furthermore, with the aim of encouraging the use of the app (hence, promoting sustainable behaviors), users can challenge one another by using the app to increase their O2 points and also play with the provided information. The TrafficO2 platform is thus a sort of a citizens’ game [75] intended to encourage sustainable and environmentally friendly trips. Although the method is specifically designed to push people toward a soft mobility (i.e., walking and biking), the other transport modes between home and the university campus that are actually used are also considered, that is, public transportation, individual private transportation (cars and motorcycles) and shared mobility (car and motor sharing and carpooling).

The user’s travel lengths and modalities (i.e., the way the user moves) are recorded and managed by using GPSs and accelerometers, sensors that are commonly present in smartphones and are able to detect the motion system with a high level of accuracy. A dedicated algorithm-based software that was trained by using a Fast Fourier Transform [76] was specifically designed for this purpose. Figure 3 illustrates screenshots of the software interface that appear to the users.

Although commuters are thought to be less sensitive to weather conditions than non-commuters [77], weather conditions are also taken into account by TrafficO2 by means of proper additional factors added to the baseline O2 points per km, especially on cloudy and rainy days.

In order to verify the feasibility of the TrafficO2 app, the method was firstly field-tested by inviting a small number of testers to install the mobile app and participate in the challenge [72]. Subsequently, by June 2015, the in-field testing was extended to a sample of 357 students, where the length of the daily one-way home–university campus trip was estimated through the use of a specific questionnaire and a GoogleMaps<sup>®</sup> (<https://www.google.it/maps>) (accessed on 18 September 2021) analysis of the routes used by each member of the sample. The app was expressly designed to encourage the transition to walking, cycling, public transport and vehicle sharing, without completely excluding trips by car or motorcycle.

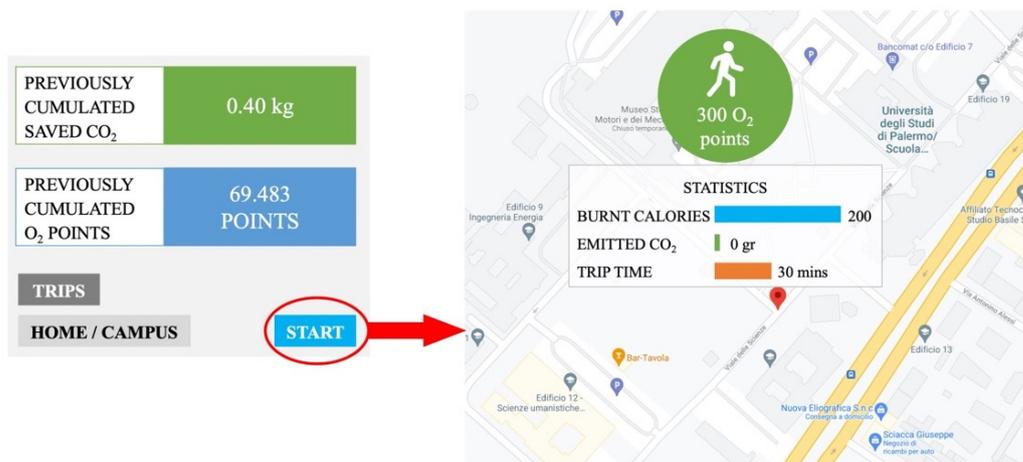


Figure 3. Mobile-phone screenshots of the app shown to the commuter users.

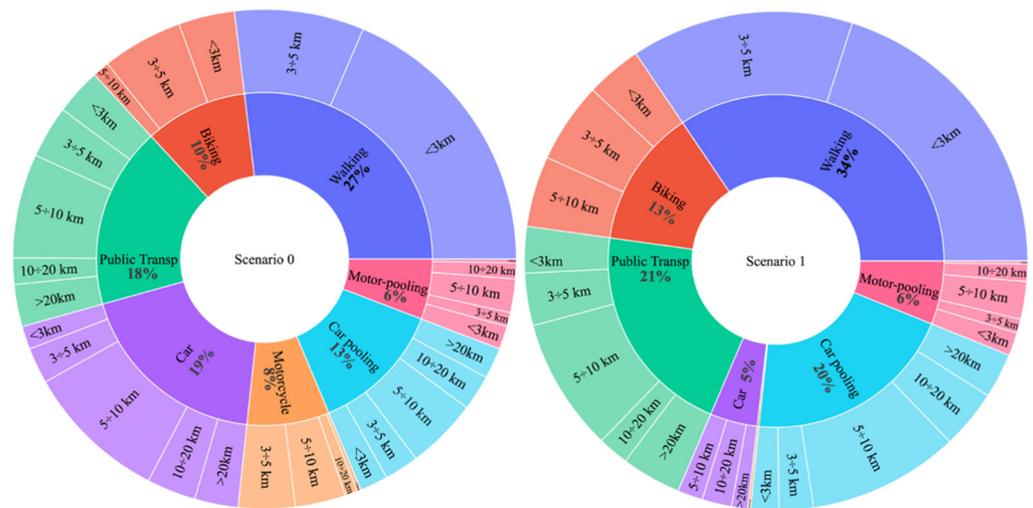
The proposed reward scheme was field-tested by using a sample of commuter students. The new mobility percentages,  $MS'$ , by distances and transportation modalities that emerged from testing the selected sample of students (Table 5) were attributed to the totality of the commuters gravitating around the campus in order to assess the whole energy and environmental benefits if they all chose to apply to the program.

Table 5. SCENARIO 1—share of commuters by zone and modality ( $MS'_{zm}$ ) and related numbers ( $NC'_{zm}$ ) per zone and per modality.

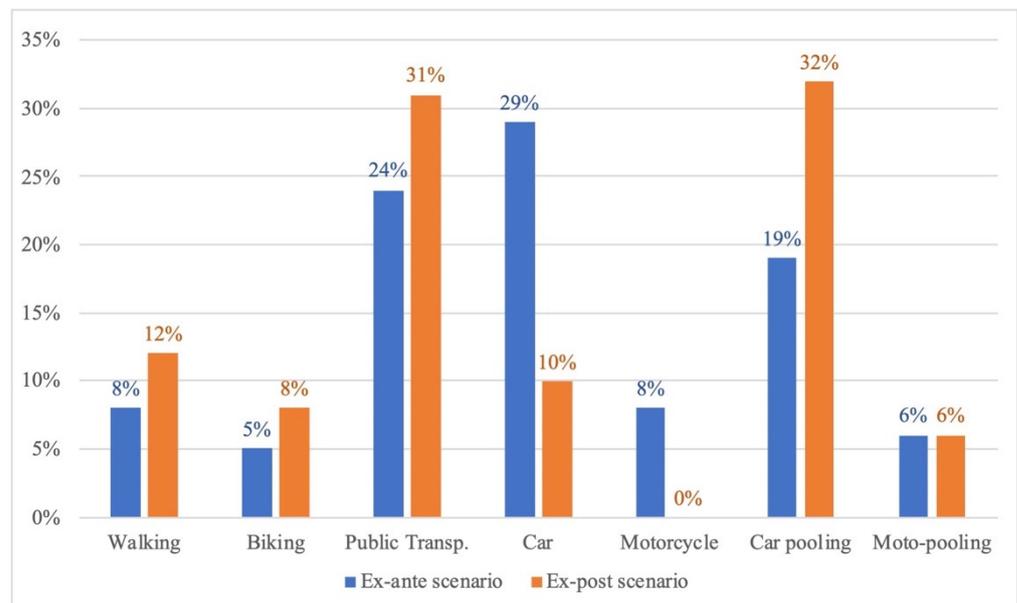
Modalities of Mobility	Shares and Related Numbers of Commuters per Distance (D) of Origins from the Campus									
	$D \leq 3$ km		$3 < D \leq 5$ km		$5 < D \leq 10$ km		$10 < D \leq 20$ km		$D > 20$ km	
	$MS_{zm}$ (%)	$NC_{zm}$	$MS_{zm}$ (%)	$NC_{zm}$	$MS_{zm}$ (%)	$NC_{zm}$	$MS_{zm}$ (%)	$NC_{zm}$	$MS_{zm}$ (%)	$NC_{zm}$
Walking	67	5025	55	3575	0	0	0	0	0	0
Biking	12	900	20	1300	17	1148	0	0	0	0
Public transportation	10	750	13	845	32	2160	22	500	48	960
Car	0	0	0	0	6	405	21	473	13	260
Motorcycle	0	0	0	0	0	0	2	45	0	0
Carpooling	6	450	9	553	36	2430	42	954	37	730
Moto-pooling	5	375	4	228	9	608	12	279	3	50
Car sharing	0	0	0	0	0	0	0	0	0	0

The comparison of Table 5 with Table 2 indicates a significant change in the modes of students' travel to the campus as a result of the solicitations proposed by the app scheme. In addition, the aggregate percentage values, related to the modes of travel, indicate a considerable change in the performance of the mobility structure (see Figures 4 and 5), which tends to favor the less impactful methods.

This modified mobility implies a reduction in the amount of CO<sub>2</sub> released by commuters on their way from home to campus, assuming 200 working days in a year for students, as reported in Figure 6.

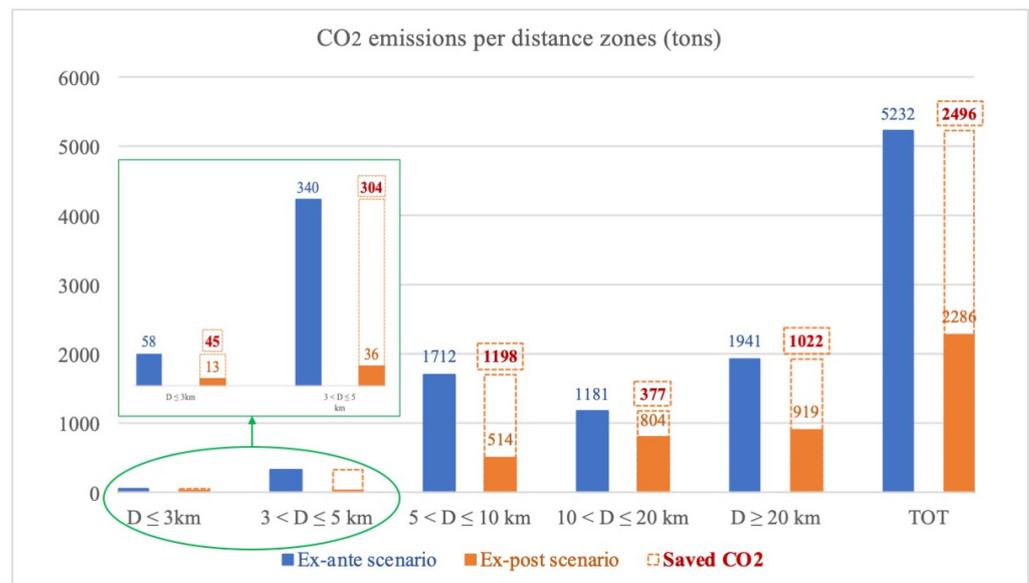


**Figure 4.** Percentages breakdown of the mobility means in the ex-ante (0) and improved ex-post (1) scenarios by origin distances, in reference to the total number (25,000) of commuters.

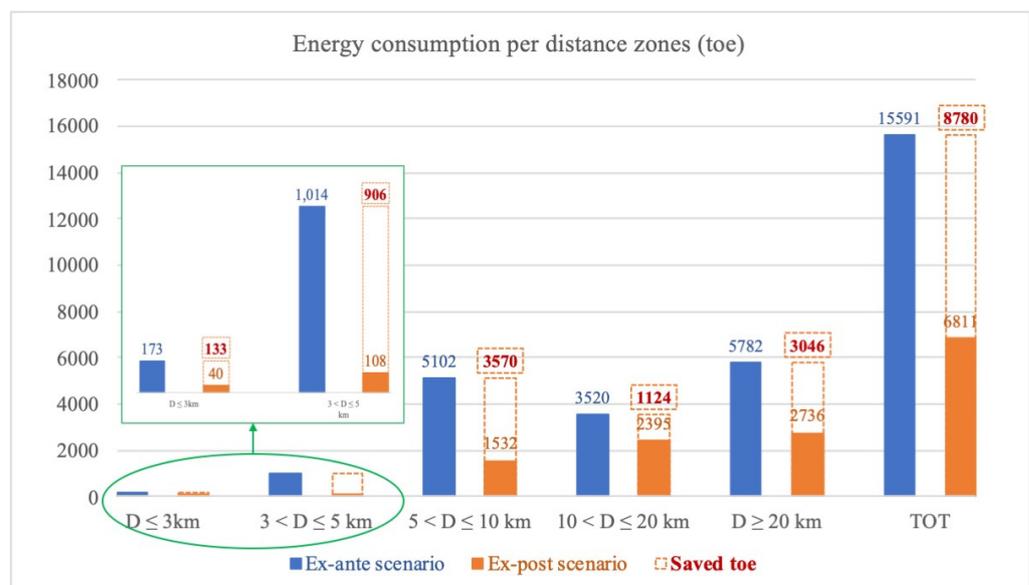


**Figure 5.** Aggregate percentages of kilometers covered by the mobility means in the actual ex-ante (0) and improved ex-post (1) scenarios, in reference to the total distance traveled by all commuters.

On the other hand, for the 25,000 students commuting to the campus from the periphery of Palermo (and its provincial territory), the pertinent energy required is equal to 15,591 and 6811 toe for the actual (ex-ante) and new improved (ex-post) scenarios, respectively. Such a significant enhancement, which consists in a reduction of up to 8780 toe, is highlighted in the graph shown in Figure 7. Data assumed for energy conversions through this study are 1 toe = 11,628 kWh for primary fuels (that is, 1 toe = 41.860 GJ) and 1 toe = 5347.59 kWh for electric energy (1 kWh = 0.187 \* 10<sup>-3</sup> toe).



**Figure 6.** Yearly CO<sub>2</sub> (tons) releases and saved in the actual ex-ante (0) and improved ex-post (1) scenarios.



**Figure 7.** Yearly fossil fuels energy amounts (toe) involved in the actual ex-ante (0) and improved ex-post (1) scenarios.

The significant reduction in CO<sub>2</sub> emissions and energy use associated with the new hypothesized commuters’ mobility configuration is certainly an important contribution that signals how a greener mobility (adopted by this category of students) could be effective for sustainability purposes.

The question now arises whether the universities (or any other Public Administrations that adopts similar incentive policies) may be entitled to receive tangible benefits due to the adoption of such more sustainable practices, for instance, by acquiring credits corresponding to the avoided carbon emissions and to the energy savings achieved (in this case, related to the new student-mobility configuration).

### 3. A Hypothesis of Acquisition of Certificates by the University

The following explores the potential of applying to a credits system for a university that adopts effective policies concerning the mobility modalities of its commuter students.

The Italian system, specifically designed for the access to the environmental market, the so-called “white certificates” or “Titoli di Efficienza Energetica” (TEE), was introduced in January 2017 [78] by a decree of the Italian Ministry of the Economic Development and further modified by a Ministry Decree released in May 2018 [79]. Finally, in May 2019, an operative guide was published [80] that introduced relevant changes concerning algorithms used for computing energy savings in the climatization of buildings.

The TEE scheme indicates the primary energy savings to be mandatorily achieved (after the implementation of energy efficiency actions) by the distributors of electric energy and natural gas with more than 50,000 customers. Entrusted entities may fulfill their energy-saving obligations by directly carrying out energy-efficiency interventions or by purchasing credits corresponding to the exceeding of their emission limits from another voluntary subject admitted to the TEE mechanism.

For each ton of oil equivalent (toe) of energy saving achieved through the adoption of energy-efficiency measures, a credit is recognized for a period (from three to ten years), depending on the type to which each project belongs. The targets indicated for Italy for the years 2017, 2018, 2019 and 2020 were 7.14, 8.32, 9.71 and 11.19 Mtoe, respectively.

Public administrations can also benefit from credits to be used for the refurbishment of highly energy-intensive public services, such as public lighting and urban mobility. The projects eligible to receive white certificates by the public administrations are those shown in Table 6 [53].

**Table 6.** Projects eligible for the efficiency transfer system in the public administrations.

Sectors	Allowable Projects
Industry	Plants of thermal energy; power quality systems; electric engines; energy recovery in the re-gasifying plants.
Networks, services and transportation	Energy efficiency of existing district heating and cooling; new fleets of transportation means fed by natural gas, liquefied natural gas, liquefied gas petroleum and hydrogen; efficiency of electric, gas and hydraulic networks; energy efficiency of data computing centers.
Civil	Installation of heating systems and warm-air generators; thermal insulation interventions; retrofit and realization of zero energy buildings.
Behavioral	Adoption of efficient systems for signaling and management; adoption of data analysis systems for single plants; adoption of action aimed at the utilization of low emission vehicles.

These projects are awarded white certificates if they generate additional energy savings, i.e., primary energy savings calculated as the difference between baseline consumption and post-operam energy consumption.

It is interesting to note that, among the sectors included in the TEE scheme, behavioral interventions are also covered, although it should be noted that a relevant sector from the point of view of the CO<sub>2</sub> emissions, such as transportation/mobility, it is not yet directly included among the actions eligible for the assignment of such credits.

However, it might be reasonable to propose to include—with minor changes to the structure of the scheme—sustainable mobility practices among the behavioral and virtuous actions that result in a reduction of the GHG emissions of the sector and, therefore, as candidate measures for the nomination of credits to be traded in the trading platforms.

From another perspective, it should be noted that the energy consumption and corresponding pollutant emission associated with commuter mobility pattern cannot be directly attributed to the campus area itself. However, the more environmentally sustainable and energy efficient habits adopted by campus users (mainly students) could be indirectly attributed to the university administration, due to the new low-carbon governance policies [81].

Hence, assigning to the University of Palermo the TEE certificates related to the environmental benefits, deriving from the choice of a more sustainable mobility pattern adopted by the commuter students, appears to be a sensible proposal. In fact, since this

behavior would contribute to improve, at the same time, the air quality of a certain area of the city, the related energy savings could be included among the measures implemented by the university toward its sustainable low-carbon path.

The combination of the above-cited considerations—i.e., (1) the fact that the transportation sector has, to date, been scarcely considered in the TEE scheme and (2) the possibility that behavioral models could be promoted among the eligible actions for environmental and energy credits—suggests that special attention should be paid to commuter mobility if affected by new and greener sustainable behavioral models.

The application presented here showed how the use of ICT based technology allows us to restructure the commuters' mobility, resulting in an energy saving of 8780 toe/y. In exchange for approximately 128 €/toe, which represents the average of the TEE value in Italy, the University of Palermo might easily count on an interesting budget that could be used both to offer additional services to students and to implement further energy-saving policies, which, with a flywheel effect, could then produce other positive effects in terms of climatic impacts. This would place the universities (but also other institutions that decide to adhere to such policies) at the center of the scheme proposed by the European directives. In fact, the Clean Energy Package proposed a set of fundamental Standards aimed at achieving a climate-neutral economy by 2050, involving seven strategic areas, including energy efficiency and the use of energy from renewable sources, as well as eight European Directives, including the "Renewable Energy Directive (RED II)" 2018/2001/EU [82] and the "Electricity Market Directive (EMD)" 2019/944/EU [83].

#### 4. Discussion

The proposal presented here starts from the consideration that a very important sector from the CO<sub>2</sub> emissions standpoint, such as mobility, is not yet fully included among the actions eligible for the acquisition of energy efficiency credits, while the white certificates scheme takes into account behavioral patterns. On the other hand, the European Parliament encourages citizens to participate in the European Union's energy efficiency process. The combination of these aspects leads to propose the sustainability of commuter students' mobility practices among the eligible actions for universities to obtain such credits.

However, a number of limitations emerge from the work presented here that should be appropriately highlighted in order to allow its application to other contexts and situations. First of all, the study is applied to a sample of students at the University of Palermo, while its results are extended to the entire audience of campus commuters. Although the sample is statistically representative of this audience, a study extended to all commuters would allow for more robust conclusions to be drawn from the results. In addition, considerations of the magnitude of GHGs emission savings (and energy consumption) from changing student mobility mode should be tested on other categories of commuters in order to estimate their true effectiveness.

On the other hand, it must be stressed that this proposal is very well contextualized in the current debate on sustainable development. In fact, this scheme seems to be very much in line with the desirable involvement of the citizens, as requested by the European Commission. Indeed, according to guidelines established by the European Parliament [84,85], the new concept of "community of renewable energy" is introduced. This means that citizens are encouraged to take part in the EU energy-efficiency process, paying cheaper energy bills and, much more importantly, self-consuming the energy produced by renewable energy plants.

In addition, these guidelines introduce and regulate a new energy system, no longer centralized or hierarchical, but distributed and collaborative: energy communities and self-consumption, in which citizens take an active role in the process of decarbonization of the energy system, no longer acting only as consumers but also as producers and managers of clean energy (prosumer), thus limiting barriers and promoting and fostering the development of renewable energies. These new legislative and technical tools, operating

in the direction of an active involvement of citizens toward the decarbonization of the energy production and consumption sectors, are in line with the proposal made here.

Moreover, considering that the Italian system of the white certificates explicitly considers the role of citizens involvement and that the mobility sector does not appear to be fully exploited at the moment, it can be deduced that there is a favorable situation at the regulatory level (both European and Italian) for the promotion of policies aimed at enhancing the behavior of specific groups of users toward more sustainable choices, by rewarding, at the same time, the institutions and administrations that adopt such choices.

Of course, when universities access the economic benefits of acquiring these credits, they could transform part of these extra earnings into services for student. Some of these services could be benefits that have, in turn, a flywheel effect on students' propensity to make more sustainable mobility choices. Advantages include substantial reductions in university fees, awarding of formative university credits (CFU)—analogous to those students usually get from laboratory/field activities—and the provision of smartphones and/or tablets (by means of which further promoting the use of the mobility app game). This would likely induce a large amount of commuting students to adopt more sustainable behaviors.

Among the practical implications of this study is that, if institutions were extensively involved in the scheme proposed here and could enter the current energy trading and exchange markets, the process of facilitating countries' sustainability paths would receive a major boost forward.

However, it is clear that a change/revolution of the normative context of white certificates is highly desirable.

## 5. Conclusions

The field test, which involved a sample of students, showed a first feasibility of the proposal, which can be included among the practical results of the study.

The advantages for the University of Palermo in facilitating a more sustainable mobility of its students, which daily commute to and from the campus and the practical benefits for commuters applying to the campaign, through the rewards that the university provides them, are well evident.

Among the findings of the present analysis, it is noteworthy that the proposed student participation scheme has a strong educational value, as it involves young EU citizens who can acquire sustainability practices that will be part of their life background over the years.

The novelty of the proposal mainly relies on the possibility of directly engaging the educational institutions in the countries' path toward the environmental sustainability.

The study certainly opens to future works, aimed at testing its feasibility and effectiveness to different categories of commuters, in addition to university students. In this sense, an analogous application of the method to another class of commuters, for example, public employees that daily reach their working sites, would be highly recommended.

Although the proposed method for the acquisition of efficient credits by the universities cannot be directly included in the funding mechanisms currently operating, its implementation would require non-substantial changes to some of the current schemes (for example, the Italian so-called white certificates).

Certainly, such an implementation would be an effective way to involve institutions and local administrations in the path toward the greenhouse-gases-emission abatement and the decarbonization of the anthropogenic activities, with particular regard to those related to the mobility sector.

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