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Contribution of University to Environmental Energy Sustainability in the City

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Abstract: The environmental energy sustainability of universities has aroused great interest in recent years. In this study, environmental impact assessment tools are used to analyse the environmental impacts of the University of the Basque Country (UPV/EHU) since 2015 and to identify reform scenarios to make the university more sustainable. University campuses can be considered to be small cities that impact the environment of the cities where they are located. The environmental impacts of the UPV/EHU Gipuzkoa campus and the impacts on the city of Donostia-San Sebastián in which the university is located are analysed. The environmental impacts are calculated using simulation tools based on three-dimensional models of the university campus and the city. These results are compared with actual impact results from monitoring. The simulation results differ from the monitoring results but provide a rapid determination of the best future scenarios for a more sustainable university by taking the impacts on the city into account. This study enables the university to align its efforts with the Covenant of Mayors for Climate and Energy.

Keywords: university environmental impact; urban planning; sustainability assessment; covenant of Mayors

1. Introduction

The environmental energy sustainability of universities cannot be separated from the large-scale overarching problem that affects the entire world. There is growing evidence that the situation of the global environment has become critical in several aspects. Thus, problems, such as the depletion of natural resources, global warming, or the depletion of the ozone layer, have received considerable media coverage and have significant social repercussions.

It is estimated that over 50% of the population lived in urban settlements, in 2016, which will increase to over 60% by 2030; that is, two out of every three persons in the world will live in cities [1–5]. This problem is magnified if this densification is considered in conjunction with recent assessments that two-thirds of the world's primary energy consumption can be attributed to urban areas, which in turn means that 71% of the world's direct greenhouse gas (GHG) emissions are energy-related [6]. In the European Community, in particular, buildings and the construction sector in general are responsible for 40% of energy consumption and 25% of CO_2 emissions. [7–9].

This situation presents a clear demand, both from the public and private sectors, to forecasters and urban planners for greater environmental awareness in project implementation. This new awareness must encompass many interrelated problems [10], such as the consumption of resources, waste production, water consumption, GHG emissions and the protection of biodiversity and air quality. Most of these problems cannot be addressed at the level of a building or a facility. The urban scale is an extremely relevant scale at both the city and university campus levels [11]. The environmental and energy impacts at the building scale are magnified at the urban scale [12]. For this reason, urban planners are more frequently employing environmental and energy efficiency parameters in the design of new urban development spaces and in the creation of regeneration projects for city districts [13]. Therefore, it is absolutely necessary to use tools in the simulation, measurement and evaluation of parameters that can facilitate the sustainable development of cities [14–19]. It is crucial to include these parameters at the design stage to be able to choose the most sustainable urban proposals among different projects. Different neighbourhood sustainability assessment (NSA) tools are available depending on the objective of an urban development project. Each tool has its own particularities and produces various forms of environmental assessments for different data.

Several studies have analysed different systems [20]. Lee presents an in-depth review of five representative qualitative assessment tools at the building scale: BREEAM, LEED, CASBEE, BEAM Plus, and ESGB [21]. Reith and Orova [22], compare different NSA tools at three levels of detail for different indicators. Sharifi and Murayama [23], analyse seven systems of sustainability assessment, showing a clear difference in focus among the tools. An in-depth case study in Spain is used to demonstrate substantial differences among thirteen assessment tools for sustainability at the urban scale at the international level [24]. Lastly, Xabat et al. conducts a study on different recent development tools for the energy assessment of cities at the district level [25]. Among the available options, the dynamic energy atlas can be used to solve energy problems in a geographical context, with some drawbacks [26]. Another tool analysed in the study is CitySim, which can be used to simulate energy scenarios at an urban scale, although considerable expertise in energy simulations is required [27].

The NEST (neighbourhood evaluation for sustainable territories) tool is used in this study [28,29]. This recently developed and simply managed tool starts with a life cycle analysis at the building level to evaluate of the design of a district of a city and proposes improvement scenarios for a more sustainable evolution of the city [19]. Using NEST, three-dimensional (3D) models are used to evaluate a series of indicators to analyse the main environmental problems affecting sustainable design at an urban scale. This agile tool generates 3D graphical solutions that are very easy to interpret. The environmental energy sustainability of universities can be successfully studied at the university campus scale, and the impact of the university campus can be related to the city where it is located. This tool was initially developed to evaluate different sustainable scenarios for a city. However, present-day universities can be considered to be small cities because of their large size and population and the complexity of multiple campus activities, which directly or indirectly impact the environment [30,31]. These impacts are mainly related to the consumption of energy and materials related to operations and activities related to research, teaching, administration and services, and transportation to users' homes [32]. Thus, there is a growing demand for projects on sustainability in universities [33–37]. That is why the evaluation of the environmental impact of University of the Basque Country (UPV/EHU) has been carried out using the NEST tool [38].

A global evaluation can be performed using NEST at different scales of analysis, where the impacts of the university campus and the city are evaluated in an interrelated manner, and the links between impacts can be analysed. As a result, improvement scenarios can be proposed that do not focus on organisational or local policies but consider the best intentions of municipal policies in relation to university guidelines, thereby combining efforts to achieve common objectives for worldwide energy improvement.

2. Methods

The goals of this research project are as follows: (i) To compare the environmental impacts of the university in relation to the impacts of the city in which the university is located; (ii) to analyse the difference between scenarios simulated using the assessment tool and actual monitoring data to rapidly validate refurbishment scenarios; and (iii) to establish a scenario of joint reform between the university and the city in response to the city's environmental improvement plan to comply with international environmental commitments.

2.1. Study Case: The University Campus and the City

As discussed above, the aim of the project is to analyse the potential of the university to establish synergies with the city to meet environmental sustainability commitments at the international level, that is, the new Global Covenant of Mayors for Climate and Energy that was signed by the city of Donostia-San Sebastián in 2017. After separately evaluating the environmental impacts for the city and the university, a scenario for sustainable reform is proposed based on a joint plan, specific to the city, called the Sustainable Energy Action Plan (SEAP) of Donostia-San Sebastián. The environmental impacts for University of the Basque Country UPV/EHU are obtained by modelling and analysis of the Donostia-San Sebastián campus. The city of Donostia-San Sebastián is studied considering the main districts in relation to municipal plans and its pacts for sustainability at the international level. A 3D model of the university campus and the districts of the city is used to evaluate the environmental impact of the "building" and "transport" sectors, which have the most significant impacts. The "industry" and "waste" sectors are not considered. The industry that was located in what is now considered the centre of the Donostia-San Sebastián moved to the periphery and other places in the province in the 1980s and was replaced by the university campus, which did not maintain the industrial character. In terms of university waste management, different faculties have specific plans for the selective collection of waste (paper-cardboard, plastic-packaging, organic, batteries, toner, pens, computers, etc.), and the quantity of waste collected is monitored; however, there is no directive common to the entire university. In addition, in the comparison with the city there is a difference of criteria in the selection of conflicting waste to be monitored. The university and the city have different main activities: For example, the municipality is focused on reducing waste, such as baby diapers, whereas the university has begun to realise the significance of the impact of computers that have become obsolete increasingly quickly.

In summary, 3D modelling of the university campus and the main districts of the city is performed using the NEST tool to determine baseline scenarios of energy assessment. These results are compared with actual consumption to evaluate the accuracy of the simulation method relative to monitoring. Then, NEST is used to simulate scenarios of joint and interrelated energy improvement for both the university and the city and to analyse the feasibility of meeting the proposed goal of compliance with the Global Covenant of Mayors for Climate and Energy. To describe the characteristics and dimensions of the case study, we briefly present the two elements in the comparative analysis of the different phases of the proposed method.

2.1.1. City of Donostia-San Sebastián

The city of Donostia-San Sebastián can be mainly characterised by an approximate area of 60.89 km^2 and a population of 186,665 (year 2018) (Figure 1). According to the Köppen climate classification [39], the climate of Donostia-San Sebastián is an oceanic climate (Cfb), which is a climate with cool summers and cool (but not cold) winters and with a relatively narrow annual temperature range.

Figure 1. Aerial image of the city of Donostia-San Sebastián. The University campus is represented to the northwest of the city. Source: Google Earth.

Donostia-San Sebastián has been consistently committed to climate change over the past 20 years. The city has made the following significant commitments, among others: The Carta de Aalborg (Aalborg Letter) (1998); the First Local Plan to Combat Climate Change 2008–2013 (2008); the Safe and Sustainable Mobility Plan 2008–2024 (2008); a municipal ordinance on energy efficiency in buildings (2009); signature of the Covenant of Mayors (2011); Sustainable Energy Action Plan (2011); the environmental strategy Hiri Berdea 2030 (2014); Mayors for Adaptation to Climate Change (2014); a Plan of Action III of Local Agenda 21 2015–2022 (2015); the Adaptation to Climate Change Plan (2017); Plan de Accion Clima 2050 DSS (2017); and adherence to the new Global Covenant of Mayors for Climate and Energy (2017).

2.1.2. Campus of the University of the Basque Country in Donostia-San Sebastián

The University of the Basque Country is located in the three provinces of the autonomous community: Gipuzkoa (1997 km^2), Bizkaia (2217 km^2), and Álava (3030 km^2) [38]. The major university campuses are located in the three provincial capitals, Donostia-San Sebastián, Bilbao, and Vitoria-Gasteiz. The chosen campus for this study is the campus located in Donostia-San Sebastián (Figure 2), which will be evaluated and compared with the city that contains it.

The university campus in Donostia-San Sebastián can be considered to be an urban campus. The various faculties are located amidst pleasant green areas on a total area of 170,000 m^2 (Figure 1; Figure 3). The different university faculties and schools were originally scattered around different parts of the city, until Donostia-San Sebastián urban planning created a common campus for the development of new faculties and obtaining university degrees. Approximately 25% of the students of the entire university pursue higher education and the administration and services staff (PAS) and teaching and research lecturers (PDI) are located on this campus. This area is located northwest of the city and is crossed by an urban avenue with broad tracts of trees that allow access and exit of vehicles between the city and other towns in the province. There is a well-maintained public transportation network of trains and buses, as well as a network of cycling roads that connect practically the entire city.

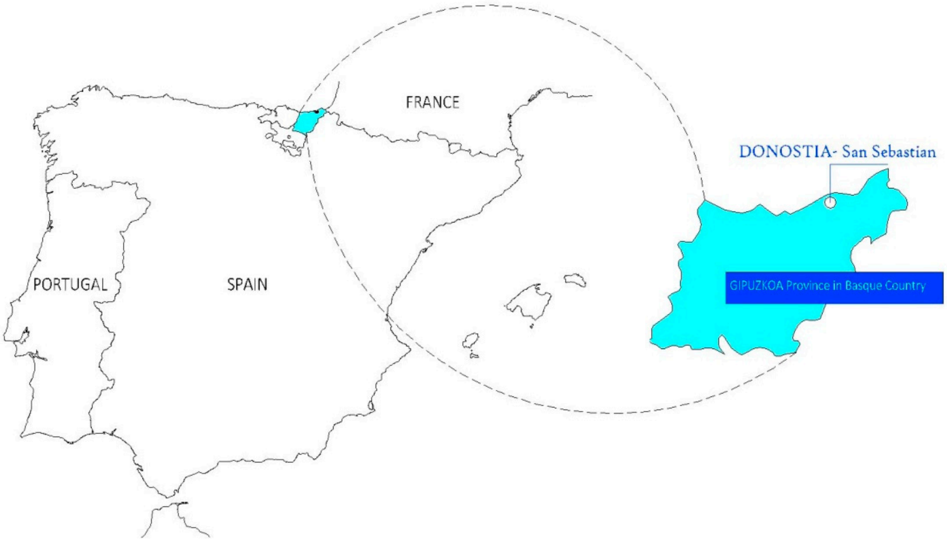

Figure 2. Location of the Basque Country and the city of Donostia-San Sebastián.

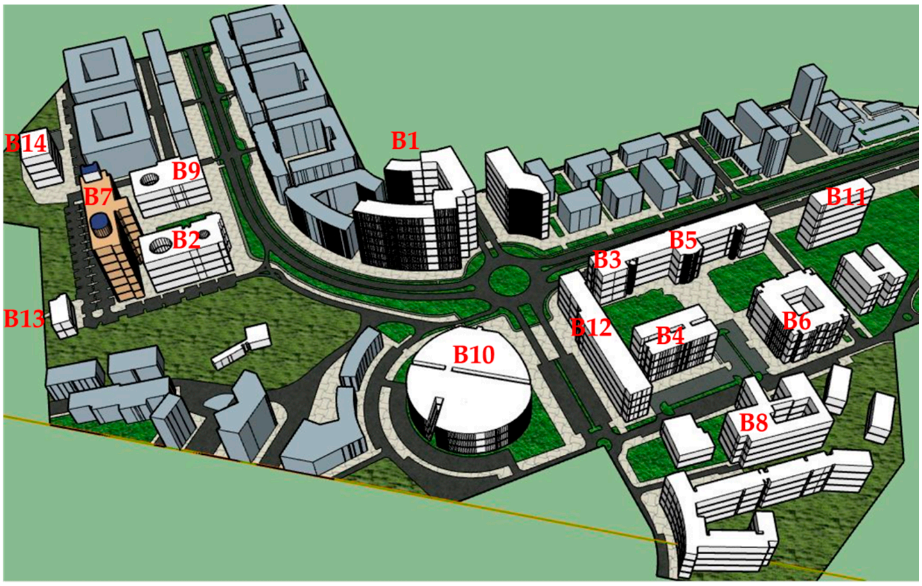

Figure 3. The different university buildings studied on the Donostia-San Sebastián campus (information about each building is provided in Appendix A).

The sample used in the study consists of higher education institutions (faculties) and other buildings that are necessary for the teaching, research, or management dynamics of the university (Figure 3). The faculties include the School of Engineering of Gipuzkoa; the Faculty of Economics and Business; the School of Education; Philosophy and Anthropology; the School of Computing; the School of Psychology; the School of Chemistry; the Technical School of Architecture; the Faculty of Law and the School of Education. Buildings with other uses are the Carlos Santamaria Centre (the central campus library), the Joxe Mari Korta Centre (RDI), the Ignacio Mª Barriola Centre (which contains the campus lecture hall consisting of 32 classrooms, rooms with other uses, an auditorium, and houses the majority of campus services); the Villa Julianategui (Campus Vice-Rectorship) and the most recent building, the Polyvalent Training and Innovation Centre (Centro Elbira Zipitria Zentroa). The aforementioned buildings are modelled using the NEST tool. To clearly investigate the area, private residential buildings adjoining the campus of Donostia-San Sebastián are also modelled.

2.2. Assessment Tool: NEST

NEST is a tool for the environmental, economic, and social analyses of an urban space and uses the Trimble SketchUp 3D modelling software; one of the most commonly used 3D graphic design programmes by designers and urban planners. NEST can be used to directly analyse a digital 3D model of a part of a city of interest. The tool is used to evaluate a series of indicators that have been developed on a scientific basis.

One of the great virtues of NEST is its graphical interface, which is very ergonomic because data can be simply entered into the geometric model to perform an easy, rapid, and effective analysis of real scenarios and proposed scenarios that are theoretically more sustainable. NEST takes into account four main elements of urban planning: (1) Buildings, (2) land use (roads, parking lots, green spaces, etc.), (3) infrastructure (street lighting), and (4) the mobility of the users of the urban space under study. NEST data can be entered or extracted in four different ways: (i) Manually (MA), (ii) manually through the NEST drop-down menu (MN), (iii) automatically by NEST (A), and (iv) imported using the software program Integrated Environmental Solutions (IES) [40]. Oregi et al. [29], and also, Leon et al. describe the assessment process, indicators, assessment scope, and hypothesis considered by NEST [38].

2.3. Scenarios and Strategies

To determine the improvement produced by a more sustainable university campus in conjunction with the environmental proposals in the strategic plan of the city, a baseline scenario or the prior-current situation must be analysed. Data for both the campus and the city can then be used to propose a refurbishment scenario to comply with the Covenant of Mayors guidelines at the international level (Figure 4).

Figure 4. Scheme of the different scenarios analysed.

2.3.1. Baseline

To evaluate the importance of integrating simulation tools into this type of study, we use two different methodologies to study the city of Donostia-San Sebastián and the university campus: (1) Monitoring data and (2) simulation using the NEST software.

2.3.2. Refurbishment Scenarios

The refurbishment scenario is based on the SEAP plan established by the municipality. The SEAP is the official municipal document that summarizes the way the city of Donostia-San Sebastián has decided to go in the field of energy management including all the fields and activities in which the city can directly act or influence. The SEAP includes two parts. The first part is the energy diagnosis, which is the picture of all CO_2 emissions produced by energy consumption. The second part is the SEAP itself, which includes the environmental and energy targets and the list of actions to be implemented during next years, including a program for the implementation.

3. Results

The different results of the baseline scenario and the proposal of refurbishment strategies that affect both the city and the university will be broken down.

3.1. Baseline Scenario

The baseline is defined as the current scenario of the city of Donostia-San Sebastián and of the university campus related to the total global warming potential (GWP) emissions and emissions per habitant or user in 2015 year. The results of the city and the university are analysed separately for subsequent discussion.

3.1.1. City of Donostia-San Sebastián

Data on the energy consumption of the city and its emissions are obtained from different publications of the municipal, regional, and Basque Country authorities [41–47]. A comparative analysis of the information from the different data sources is used to compose a sample of the most relevant outputs or results for this study (Table 1). The main districts that make up the city of Donostia-San Sebastián are modelled in NEST to determine the CO_2 emissions of the sample (Table 1). The city of Donostia-San Sebastián is modelled in NEST (Figure 5), using information from different origins. The building geometry in the model is defined using DXF files provided by the city planning department and from cadastral information.

Table 1. Data analysis for the city of Donostia-San Sebastián.

	Monitored Data (Year 2015)		**Simulated Data—NEST Tool**		**Difference between GWP Results**
	GWP Emissions		**GWP Emissions**		
	Kg CO_2-eq	**Kg CO_2-eq/habitant**	**Kg CO_2-eq**	**Kg CO_2-eq/habitant**	
Buildings	2.79×10^8	1.49×10^3	2.48×10^8	1.33×10^3	−11%
Transport	5.36×10^8	2.87×10^3	4.48×10^8	2.40×10^3	−16%
TOTAL	8.15×10^8	4.36×10^3	6.96×10^8	3.73×10^3	−15%

(**a**) (**b**)

Figure 5. Two of the districts modelled in the neighbourhood evaluation for sustainable territories (NEST) for the city of Donostia-San Sebastián. (**a**) "Ensanche Cortazar" district; (**b**) "Parte Vieja" district.

Information on the energy performance of each building in the city is obtained from previous studies [29], and the Register of Energy Performance Certificates of the Basque Country [48]. The following statistics for the Donostia-San Sebastián inhabitants are determined from the mobility plan: 30% travel in private cars, 30% by bus, 3% by train, 25% by bicycle, and 17% by foot [46]. Based on Ecoinvent v3.0, NEST defines the environmental impact of the different mobility systems. The conversion factor from car, bus, tram, train, bicycle, and walking to GWP will be 0.29, 0.10, 0.09, 0.08, 0.00, and 0.00 (kg CO_2-eq/(user·km)), respectively.

A comparison of the results of the two calculation methodologies for the city of Donostia-San Sebastián shows that the monitoring global warming potential (GWP) data are 11% and 16% higher than the simulation results for the building and transportation sectors, respectively. Note that the main causes of this difference are the uncertainty in many of the hypotheses used in the two calculation processes and different quantification measures, such as the scope of the parameters. However, this difference is acceptable because the simulation can be used to rapidly evaluate the most sustainable option among different proposals. The identification of the most sustainable option remains valid after comparing the simulation and monitoring results. It is important to bear in mind the percentage deviation between the results of the two methodologies while acknowledging that simulation is indispensable.

In spite of the energy impact that it may suppose, the SEAP of Donostia-San Sebastián does not consider as input the energy consumption of the municipal sewage. Furthermore, the SEAP does not propose any strategy to reduce the environmental impact related to this process. Therefore, the municipal sewage will be out of the scope of this study.

3.1.2. Campus of Donostia-San Sebastián

Several parameters are monitored and quantified for the university campus in Donostia-San Sebastián for each of the campus buildings from 2015–2017 (see Appendix A). Note that the monitoring is limited to inventorying the different energy consumption points. Through the correct definition of "conversion factor" values, the energy consumption is transformed into environmental impact. For the natural gas source, the related impacts were deduced from the Ecoinvent database, applying the "Heat production, natural gas, at boiler modulating" process. The conversion factor from natural gas applied by this study to GWP will be 0.2 (kg CO_2-eq/kWh). For the oil source, the related impacts were deduced from the Ecoinvent database, applying the "heat production, light fuel oil, at boiler 100 kW, non-modulating" process and its conversion factor applied by this study to GWP will be 0.34 (kg CO_2-eq/kWh). Finally, the conversion factor from electricity (Spain 2016) applied during this case study to GWP will be 0.3 (kg CO_2-eq/kWh).

Information for the buildings that compose the campus in Donostia-San Sebastián are obtained from different UPV/EHU documents [49], to compile Table 2, which shows the environmental impacts associated with the mobility of users (workers, teachers, and students) of the Donostia-San Sebastián campus for 2015.

Table 2. Emissions from the university campus after the correction of the baseline scenario.

	Monitored Data (Average 2015–2017 Years)		**Simulated Data—NEST Tool**		**Difference between GWP Results**
	GWP Emissions		**GWP Emissions**		
	Kg CO_2-eq	**Kg CO_2-eq/habitant**	**Kg CO_2-eq**	**Kg CO_2-eq/habitant**	
Buildings	4.87×10^6	4.40×10^2	5.56×10^6	5.02×10^2	14%
Transport	4.94×10^6	4.46×10^2	4.12×10^6	3.72×10^2	−21%
TOTAL	1.01×10^6	9.11×10^2	9.68×10^6	8.74×10^2	−4%

The first revision of the campus model is developed in parallel in NEST (Figure 6), based on a model developed by Leon et al. [38]. However, the monitoring data show that the initial simulation model needs to be calibrated in two regards. First, the number of campus users is adjusted, because 12,248 users were used in Leon et al.'s study [38], whereas a corresponding mean value of 11,066 is determined for 2015–2017 from the monitoring process. Second, regarding transportation, the information in the documents show a new hypothesis for the mode of displacement of the campus users [49]: 36% travel in a private car, 30% by bus, 12% by train, 15% by bicycle, and 7% by foot. Table 2 shows the GWP emissions of the Donostia-San Sebastián campus that are obtained after defining and modelling all of the hypotheses for each building and the transport scenario in NEST.

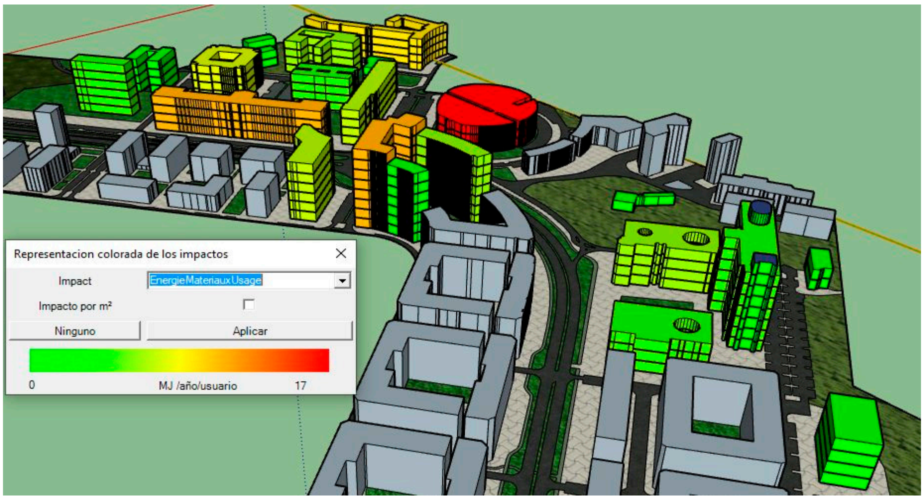

Figure 6. Graphical evaluation of the simulation of impacts for the campus with NEST.

A comparison of the results of the two calculation methodologies for the Donostia-San Sebastián campus shows that the monitored GWP data are 14% lower for the building sector and 21% higher for the transport sector than the simulation results. However, the total difference between the two methodologies is only 4%.

Considering the differences in the results for the buildings, the simulation process of NEST is based on a series of default assumptions to assess the energy consumption and environmental behaviour of the buildings. Considering these assumptions, it is understood that there will be certain variation between the building simulation result and the real performance of the building [50–52]. The reasons for the performance gap in a particular building can be several but in general, the performance gap happens due to the accuracy of the default values in the building simulation, variation of the weather data, or the influence of user, understood as user behaviour. Regarding transportation, it is very difficult to completely match the hypotheses simulated in the initial model with the monitored data, because the latter are based on questionnaires given out to campus users. This difference in the hypotheses results in an estimated impact for the transportation sector that is 21% higher for the university survey data than that calculated by NEST simulation.

3.2. *Refurbishment Scenarios*

3.2.1. Joint Plan Scenarios

In previous studies by Oregi et al. [29] and Leon et al. [38], theoretical rehabilitation scenarios associated only with the university were proposed and were not related to the action plans of the city of Donostia-San Sebastián. By contrast, in this study, the values and strategies defined by the SEAP of Donostia-San Sebastián [42], are used as a starting point to align the strategies of the university at the general level with those of the municipality at the local level. The SEAP of Donostia-San Sebastián comprises four strategic lines of action: (1) Energy efficiency, (2) renewable energies, (3) mobility, and (4) waste. The guidelines proposed by the city plan for adequate waste management (boosting second-hand markets (in particular), general awareness campaigns to promote reuse, promotion of reusable diapers, creating an infrastructure for territorial composting, taking advantage of surplus stores, etc.) are not aligned with university waste management strategies. Therefore, waste-related improvement actions are outside the scope of this study.

The first part of the study results is based on SEAP data (Table 3) and indicates the GWP emissions resulting from the application of 100% of the strategies for each strategic line. The relevance of each strategy group for a 100% reduction of GWP emissions is presented. However, all of the strategies have not been and will not be applicable to the city of Donostia-San Sebastián. Thus, in collaboration with different public stakeholders, the authors provide a critical review in the "revised data" section. This new section reflects three types of data: (1) The percentage of application or applicability of each strategy group; (2) the reduction in GWP emissions for this percentage of implementation; and lastly, (3) the relevance of each strategy group to 100% reduction in GWP emissions after reviewing the applicability of the strategies (more information about each SEAP strategy can be found in Appendix B). The authors use these revised values to determine the strategies for consideration in this study in terms of realisable actions implemented between 2011 and 2019 in the municipality of Donostia-San Sebastián.

Table 3. Summary table of improvement strategies according to the SEAP of Donostia-San Sebastián.

	Data according to SEAP		Revised Data		
	Emissions Avoided (tCO_2)	Percentage with Respect to the Total Reduction	Applicability (%)	Emissions Avoided (tCO_2)	Percentage with Respect to the Total Reduction
Efficiency					
Increase performance heating and cooling equipment	6272	2.7%	10.7%	671	0.4%
Heating and cooling consumption reduction	32,043	14.0%	33.5%	10,721	6.1%
Change the energy mix of the generation system	864	0.4%	2.9%	25	0.0%
Reduce lighting consumption	22,561	9.9%	92.9%	20,952	12.0%
Reduce heating demand	5963	2.6%	83.7%	4,992	2.9%
Reduce appliances consumption	4168	1.8%	80.0%	3,334	1.9%
Total efficiency	71,871	31.4%	56.6%	40,696	23.3%
Renewable					
Photovoltaic	6344	2.8%	0.3%	16	0.0%
Aero generators	1887	0.8%	0.0%	0	0.0%
Thermal solar	3234	1.4%	1.4%	44	0.0%
Geothermal	1856	0.8%	8.8%	164	0.1%
Biomass	754	0.3%	50.0%	377	0.2%
Biogas	5682	2.5%	0.0%	0	0.0%
Total renewable	19,757	8.6%	3.0%	601	0.3%
Mobility					
Increase biofuels	6776	3.0%	88.3%	5,984	3.4%
Reduce transportation consumption	126,448	55.2%	100.0%	126,448	72.4%
Electric vehicle	4117	1.8%	20.0%	823	0.5%
Total mobility	137,341	60.0%	97.0%	133,255	76.3%
TOTAL	228,969		76.2%	174,553	

According to the SEAP data, the strategic line of mobility is the sector in which up to 60% of total GWP reduction can be obtained. Thus, the main action group is focused on the "Reduce transportation consumption", whose application contributes 55.2% to the total reduction in GWP emissions. The strategic line of energy efficiency contributes 31.4% to the total reduction in GWP and includes action groups such as "Heating & cooling consumption reduction" and "reduce lighting consumption", whose application would contribute 14.0% and 9.9%, respectively, to the total reduction in GWP emissions. Within this line of efficiency, there are 28 other strategies with an overall influence below one percent (see the data in Appendix B). Lastly, the strategic line of renewable systems contributes 8.6% to the total reduction in GWP. This line includes action groups such as "Photovoltaic" and "Biogas", whose application would contribute 2.8% and 2.5%, respectively, to the total reduction in GWP emissions.

The estimated reduction in GWP emissions changes completely under an objective and critical review of the application or applicability of these strategies. With the support of different public stakeholders, the authors have conducted an exhaustive study on the application of each of the strategies in the municipality of Donostia-San Sebastián, tracking all of the actions based on different public sources and data from the energy department of the city of Donostia-San Sebastián.

An immediate conclusion that can be drawn is that it is essential to maintain the implementation of mobility strategies because of their 97% applicability. An opposite conclusion is drawn for the implementation of renewable technologies in Donostia-San Sebastián, for which only three percent of the SEAP proposed objectives has been implemented over the last eight years. Lastly, the applicability of most of the strategies associated with the strategic line of efficiency is projected to exceed 50%, and these strategies should therefore be considered in the study.

The strategies considered in this study based on a critical interpretation of the SEAP data are shown in Table 4. Following the existing SEAP guidelines, these strategies will be applied over a 10-year period (2020–2030). A cut-off is defined for action groups with applicability that is greater than 20% and a contribution above two percent to reducing final GWP emissions. Contrary to some European guidelines [53–55], this study will not consider any strategy associated with the strategic line of renewable technologies because of the low applicability of these strategies in the municipality of Donostia and the reduced impact on the final results proposed by SEAP. Regarding the final selected strategies, the applicability selection criterion has been maintained, but the selection criterion for the contribution to the reduced final GWP emissions has been changed to 0.4%. The strategies in this study are selected based on the percentage contribution to the total GWP reduction from the data reviewed (see Appendix B).

As shown in Table 4, for the 10 strategies to be evaluated by NEST in this study, SEAP has limited application to a particular building typology. For example, four of the ten strategies defined in Table 4 are limited to residential or commercial buildings. In addition, strategy 8 ("Acquisition of clean vehicles by the city") is limited to city vehicles. Therefore, although 10 strategies are proposed for evaluation at the municipal level in the study, only five of these strategies can be applied at the university campus level. Thus, universities should analyse different municipal policies for mobility on their campuses to achieve an optimal and coherent global mobility policy.

3.2.2. Results of Joint Refurbishment Scenario

A separate NEST model is developed for each strategy, and the reduction in the GWP emissions by the application of each strategy is shown in Table 5. In addition, three new scenarios are identified: In the first scenario (strategy 11), all of the energy efficiency strategies are applied together; in the second scenario (strategy 12), all of the mobility strategies are applied together; and in the third scenario (strategy 13), all of the strategies in Table 5 are applied together. The emissions reduction is calculated using the following values from Table 1; Table 2: GWP emissions from Donostia-San Sebastián of 6.96 $\times 10^8$ and 9.68×10^6 kg CO_2-eq from the university campus.

Table 4. Applicability of SEAP strategies, between the city and the university campus.

Strategic Line	Acting Group	Strategy	Strategy to Integrate in NEST	Applicability	
				City of Donostia	University Campus
Energy Efficiency	Heating and cooling consumption reduction	Climate control regulation and insulation improvement of rehabilitation equipment	1-Improve the energy performance of existing equipment of tertiary buildings by 20%	YES	YES
		Public awareness campaigns	2-Reduce the energy demand of residential buildings by 25%	YES	NO
		Preparation of guides with saving measures in the tertiary sector	3-Reduce the energy demand of tertiary buildings by 20%	YES	YES
	Reduce lighting consumption	Lighting system regulation systems	4-Reduce the lighting consumption of tertiary buildings by 25%	YES	YES
		Improve efficiency of the home lighting system	5-Reduce the lighting consumption of residential buildings by 30%	YES	NO
		Renew street lighting	6-Reduce the lighting consumption of commercial buildings by 40%	YES	NO
	Reduce heating demand	Improve the efficiency of 20% of the windows	7-Reduce the heating energy demand of residential buildings by 36%	YES	NO
		Renewal of 5% of existing homes with high benefits			
Mobility	Increase biofuels	Acquire clean vehicles through the town hall	8-Adapt private car emissions	YES	NO
		Acquire clean vehicles by public bodies	9-Adapt the emissions of private cars and buses	YES	YES
		Empowerment of clean distribution vehicles			
	Reduce transport related consumption	Program to improve and boost pedestrian mobility	10-Adapt the current mobility model of NEST, mainly promoting pedestrians and bicycles and trying to replace the private vehicle as much as possible with the bus or/and the train	YES	YES
		Cycle mobility improvement and promotion program			
		Program to improve the competitiveness of public transport			
		Implement mobility management program			
		Implement education and communication program in sustainable mobility			
		Private vehicle and freight transport management program			

Table 5. Number of GWP emissions avoided in each strategy.

Strategy	GWP Emissions (kg CO_2-eq)		GWP Emissions (kg CO_2-eq/person)	
	City of Donostia	University Campus	City of Donostia	University Campus
1	6.93×10^8	9.29×10^6	3.71×10^3	8.40×10^2
2	6.89×10^8	9.68×10^6	3.69×10^3	8.75×10^2
3	6.80×10^8	8.57×10^6	3.65×10^3	7.74×10^2
4	6.89×10^8	9.12×10^6	3.69×10^3	8.25×10^2
5	6.92×10^8	9.68×10^6	3.71×10^3	8.75×10^2
6	6.72×10^8	9.68×10^6	3.60×10^3	8.75×10^2
7	6.79×10^8	9.68×10^6	3.64×10^3	8.75×10^2
8	6.93×10^8	9.68×10^6	3.71×10^3	8.75×10^2
9	6.88×10^8	9.56×10^6	3.69×10^3	8.64×10^2
10	5.53×10^8	8.53×10^6	2.96×10^3	7.71×10^2
11	6.19×10^8	7.62×10^6	3.31×10^3	6.89×10^2
12	5.42×10^8	8.40×10^6	2.90×10^3	7.59×10^2
13	4.64×10^8	6.35×10^6	2.49×10^3	5.73×10^2

The results of the analysis for the city of Donostia-San Sebastián show that, as shown by the SEAP plan for the city of Donostia-San Sebastián, strategy 10 for the city's mobility model results in the highest GWP emissions reduction of 20.6% (1.43×10^8 kg CO_2-eq) relative to the 2015 scenario. The implementation of efficiency strategies reduces GWP emissions by up to 11.2% (7.75×10^7 kg CO_2-eq). Within this strategic line, the following strategies stand out: "Renewable shop lighting" (6 strategy), "Improving the efficiency of residential buildings by replacing windows and energy-rehabilitating housing" (strategy 7) and "Developing guidelines with savings measures for the tertiary sector" (strategy 3), which reduce 2015 GWP emissions by 3.4% (2.37×10^7 kg CO_2-eq), 2.5% (1.73×10^7 kg CO_2-eq), and 2.2% (1.55×10^7 kg CO_2-eq), respectively. Finally, the application of all of the strategies considered in this study (strategy 13), would reduce GWP emissions by 33.3% (2.32×10^8 kg CO_2-eq) annually compared to the current scenario. The signatory cities to the 2017 Global Covenant of Mayors for Climate and Energy committed to reducing emissions in 2030 by 40% of those for the base year 2007. Considering that GWP emissions of the city of Donostia-San Sebastián were 9.92×10^8 kg CO_2-eq in 2007 [42], an evaluation of the scenarios proposed by this study shows that the city of Donostia-San Sebastián could meet its commitment by implementing this joint plan with the university. In turn, the city would meet the objective set by the European Commission [56], which defined an objective of reducing GWP emissions from reference year by a minimum of 40% by 2030.

As shown in Table 4, only five strategies for reducing GWP emissions from the university campus have been applied. In comparison to the results for the city, given that the impact of the buildings is 57% of the total GWP impact of the campus, the strategic line with the greatest amount of reduced GWP emissions is that of energy efficiency, at a reduction of up to 21.3% (2.06×10^6 kg CO_2-eq) of total campus emissions. Within this line, strategy 3 ("Preparation of guidelines with savings measures for the tertiary sector") stands out by reducing emissions by 11.5% (1.11×10^6 kg CO_2-eq). An improved mobility scenario can also significantly reduce total GWP campus emissions by up to 13.2% (1.28×10^6 kg CO_2-eq).

Table 5 shows a second measure that can be used to analyse the impact of GWP on each user in the city and the university campus. The effect of applying each strategy is similar to the total results. However, the impacts of the university campus are approximately 10 times below those of the city. There are two contributions to this difference. First, the level of energy efficiency of the different buildings of the campus is quite high, resulting in lower consumption than for older buildings in different city districts. Second, more users consume the same number of resources in the university than in the city. Therefore, the impact per person is lower for the university than for the city, where there is a lower density.

4. Discussion

Three considerations can be identified from the study and the obtained results: The city-campus relationship (1); the applicability of the strategic analysis; (2) and the integration of tools (3).

First, the single location of the campus within the urban network of the city of Donostia-San Sebastián results in a direct relationship between the two evaluated elements. At the same time, strategies or commitments of the city in terms of mobility or energy efficiency directly affect the two evaluation scales. However, university campuses normally develop their own strategies without considering the trends or commitments of the city in which they are located. This study is an attempt to reflect how strategies defined at the municipal level can be applied at the university campus level and how these actions environmentally impact the city. In this study, the small university campus contributed only 1.4% of the total GWP emissions of the city in 2015. The application of all of the strategies proposed in this study (scenario 13), reduces the total GWP emissions of the campus by 34.5% (with respect to 2015). This reduction is greater when the simulated reform scenario in NEST is in conjunction with the city and applying the municipal plans. Considering previous research carried out on the whole of the Basque Country University [38], where university campus reform scenarios based only on university policies were applied, (without taking into account municipal policies), the reduction was smaller.

The second consideration shows the need to constantly monitor the implementation and applicability of action strategies defined by documents such as SEAPs, which have a long perspective (10 years). The socio-economic or normative changes that occur over this timeframe can significantly alter any proposed scenario, reducing or eliminating the feasibility of application of a previously proposed strategy. The same happens with the university's plans that are linked to the Basque Government, following long-term European directives (2020, 2030, and 2050). Taking into account the socioeconomic changes that also affect the university, it can be periodically simulated, in a few weeks, what is the most sustainable option. However, from the comparison between the previous simulation carried out and the monitoring of the University consumption collected between 2015 and 2018, it shows that, although the simulation allows detecting the most sustainable reform scenario, in the case of the university the simulation data has suffered greater variations than in the city, so the university must take this in consideration, and corroborate the simulation data with constant monitoring.

The third consideration shows the potential of tools, such as NEST, to evaluate and define future scenarios. This study has shown that it is not always easy to obtain values for the energy consumption or GWP emissions that are in agreement with monitoring data. However, in this study, the highest difference between the monitored values and the NEST simulation results was 21% (mobility of the university campus), which could be viewed positively. Most significantly, the monitoring information for the city or the energy consumption of all of the buildings of the university campus were obtained by different public entities over a period of three years, whereas the modelling and calculation process was completed in three weeks for the city and one week for the campus. In addition to the rapidity of the simulations, this type of tool can be used to calibrate the input data to the actual application of each strategy. In this way, the evaluation model becomes a dynamic model that can be adapted to each moment, facilitating rapid decision-making on the most sustainable design solution. Lastly, these tools enable the potential of strategies to be analysed at either the municipal or local level, including for a given and smaller area of a municipality. In this way, those responsible for the university campus can estimate the reduction in GWP emissions of the campus from the application of municipal strategies or perform a parallel analysis of the effect of these strategies on the city. For this last consideration, different public actors of the city of Donostia-San Sebastián and the university campus, who currently work and choose strategies separately from each other, must work together in order to optimise resources, enabling the design, analysis, and quantification of the impact of each decision at different scales.

The evaluation of the proposed scenarios, wherein the strategy of the university is aligned with the municipal policies of the city of San Sebastian, can be used to achieve higher levels of sustainability. In this case, it has been possible to verify how a scenario of joint refurbishment between the city and the university, according to municipal sustainability plans (SEAP), allows cities to assure compliance with agreements at European level such as the Global Covenant of Mayors for Climate and Energy. Therefore, it is proven that the university can contribute to the environmental improvement of cities. The sustainability of a university can no longer be limited to improving a particular faculty building or the sustainability of the university as a whole but requires the establishment of strategies to develop synergies with the municipal environmental policies of the cities in which university campuses are located.

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Appendix A

Table A1. Monitored data for the campus of Donostia-San Sebastián.

	ID	Faculty (PDI)	Students	Admin. Staff. (PAS)	Total Users	Electricity Consumption (kWh)	Natural Gas Consumption (kWh)	Diesel Consumption (kWh)
Gipuzkoa School of Engineering	B1	172	1335	30	1537	793,521	708,984	75
Faculty of Economics and Business	B2	79	1077	14	1170	196,750	527,404	0
Faculty of Education, Philosophy and Anthropology	B3	150	1377	21	1548	552,087	1,033,126	0
Faculty of Computer Science	B4	152	670	23	845	553,200	456,816	0
Faculty of Psychology	B5	136	1179	20	1335	605,183	862,678	0
Faculty of Chemistry	B6	184	691	26	901	685,031	697,161	0
Superior Technical School of Architecture	B7	99	807	14	920	293,733	622,594	0
Faculty of Low	B8	103	1124	31	1258	188,151	545,374	0
Teacher-Training College	B9	82	1087	13	1182	159,610	406,778	0
Carlos Santamaria Center	B10	0	1852	7	1859	1,302,316	524,763	0
Joxe Mari Korta Center	B11	3	4516	5	4524	1,957,695	624,214	0
Ignacio Mª Barriola Center	B12	0	1000	0	1000	216,114	646,357	0
Villa Julianategui (Vicerectorate of Campus)	B13	1	0	57	58	45,325	50,895	0
Multipurpose Training and Innovation Center (Elbira Zipitria Center)	B14	25	245	5	275	215,688	59,124	0

Appendix B

Table A2. Complete table of data according to the SEAP, summarized in Table 3.

	Energy Saving (kwh)	Emissions Avoided (tCO_2-eq)	Percentage of Emissions Avoided with Respect to the Total (%)	Real Application	"Real" Emissions Avoided (tCO_2-eq)
Increase Performance Heating and Cooling Equipment					
1.1.1 Replace 17 boiler (condensation/low temperature) and heat pumps	1,029,420	214	0.087%	94%	201
1.1.2 Improve efficiency of 17 emitting systems	302,670	56	0.023%	53%	30
1.2.7 Replacement of existing boilers in 15,760 homes	21,568,943	3990	1.616%	6%	239
1.3.1 Improve boiler performance of 30%	10,875,000	2012	0.815%	10%	201
Heating and Cooling Consumption Reduction					
1.1.4 Regulation of air conditioning and improvement of insulation of rehabilitation equipment	6,131,692	993	0.402%	100%	993
1.1.8 Expand energy telemanagement systems	3,432,719	970	0.393%	35%	339
1.1.10 Good practices regarding heating and lighting control	119,723	30	0.012%	100%	30
1.1.11. Implement energy management software	1,837,862	517	0.209%	100%	517
1.1.14 Training of municipal technical staff	869,051	209	0.085%	100%	209
1.2.0 Citizen awareness campaigns	21,406,433	5326	2.157%	100%	5326
1.3.6 Energy management of 75% of buildings in the sector	43,345,000	11,220	4.544%	1%	112
1.3.8 Preparation of guides with saving measures for the tertiary sector	42,852,124	12,778	5.175%	25%	3194
Change the Energy Mix of the Generation System					
1.2.9 Centralized systems (DH) in residential areas of Asia	540,738	100	0.040%	25%	25
1.3.4 Install microcogeneration in the hotel and residential sector of the elderly (34 establishments). The average size of each installation of this type is 35 kWt and 16 kWe	3,848,891	410	0.166%	0%	0
1.3.9 Install centralized systems (DH) in the services sector (three systems are considered)	1,912,100	354	0.143%	0%	0
Reduce Lighting Consumption					
1.1.5 Improve the lighting installations of 68 buildings	879,134	334	0.135%	40%	134
1.1.15 Replacement mercury vapor lamps	37,454	14	0.006%	100%	14
1.1.16 Prevent light pollution, improving the energy efficiency of luminaires	1,530,000	568	0.230%	100%	568
1.1.17 Public lighting control system	20,000	7	0.003%	100%	7
1.1.18 Energy management software for public lighting	50,340	19	0.008%	100%	19
1.1.19 Implement innovative lighting technologies	39,850	15	0.006%	100%	15
1.1.20 Lighting system regulation systems	3,000,000	1113	0.451%	80%	890
1.2.6 Improve efficiency of the home lighting system (50,000 bulbs)	2,682,750	1020	0.413%	100%	1020
1.2.8 Renew electrical installations	3,900,722	1483	0.601%	20%	297
1.2.11 Environmental education in the school environment	2,378,493	627	0.254%	100%	627
1.3.2 Renew street lighting	45,675,000	17,361	7.031%	100%	17,361

Table A2. *Cont.*

	Energy Saving (kwh)	Emissions Avoided (tCO_2-eq)	Percentage of Emissions Avoided with Respect to the Total (%)	Real Application	"Real" Emissions Avoided (tCO_2-eq)
Reduce Heating Demand					
1.1.6 Improve the thermal envelope of buildings with characteristics that allow	1,888,188	349	0.141%	16%	56
1.2.1 Implement high-efficiency criteria in new urban developments	161,039	61	0.025%	100%	61
1.2.2 Energy certification A in 100% of new public housing	881,250	250	0.101%	50%	125
1.2.4 Improve the efficiency of 20% of the windows	15,988,662	2958	1.198%	100%	2958
1.2.13 Renovation of 5% of existing homes (3807) with high benefits	9,341,901	1731	0.701%	100%	1731
1.3.3 Certification A in 50% of the new tertiary buildings	3,314,000	614	0.249%	10%	61
Reduce Appliances Consumption					
1.2.5 Renew appliances with better energy efficiency in 25% of appliances	12,921,792	4168	1.688%	80%	3334
Photovoltaic					
2.1.1 Install PV of 149,985 m^2 (6.82 MWp) in public facilities	Non determin,	2585	1.047%	0.25%	6
2.3.1 Install PV on the sides of the tracks (65,127 m^2—2960 kWP)	Non determin,	1122	0.454%	0%	3
2.3.2 Install PV in the buckets of large surfaces (87,682 m^2—3980 kWP)	Non determin,	1511	0.612%	0%	4
2.3.3 Install PV in the car parks (2970 kWP)	Non determin,	1126	0.456%	0%	3
Aerogenerators					
2.1.2 Wind turbine installation. It is planned to install 7.2 MW	Non determin,	1887	0.764%	0%	0
Thermal Solar					
2.1.3 Ensure the efficient operation of solar thermal systems	Non determin,	40	0.016%	100%	40
2.1.4 Implement ST 2000 m^2 on roofs of public buildings	Non determin,	259	0.105%	0%	0
2.2.3 Install 13,000 m^2 of ST in the residential sectorl	Non determin,	1638	0.663%	0%	0
2.3.4 Install 10,000 m^2 of ST in the service sector	Non determin,	1297	0.525%	0%	4
Geotermia					
2.1.5 Incorporate nine units with a total of 630 kW of heat production with geothermal systems	Non determin,	684	0.277%	24%	164
2.3.6 Climate systems with geothermal support	Non determin,	1172	0.475%	0%	0
Biomass					
2.2.1 Forty installations with 3.2 MWt of biomass in the residential sector	Non determin,	754	0.305%	50%	377
Biogas					
2.2.2 Biogas exploitation biogas plant	Non determin,	5682	2.301%	0%	0

Table A2. *Cont.*

	Energy Saving (kwh)	Emissions Avoided (tCO_2-eq)	Percentage of Emissions Avoided with Respect to the Total (%)	Real Application	"Real" Emissions Avoided (tCO_2-eq)
Increase Biofuels					
3.1.1 Acquire clean vehicles by the town hall	4,371,335	1,182	0.479%	33%	390
3.1.2 Encourage the use of clean fuels in vehicles that provide public services	2,185,667	591	0.239%	100%	591
3.2.1 Acquire clean vehicles by the municipality	17,823,370	3563	1.443%	100%	3563
3.2.3 Promotion of clean distribution vehicles	4,798,600	1440	0.583%	100%	1440
Reduce Transportation Consumption					
3.1.3 Development of the sustainable mobility plan	337,634	99	0.040%	100%	99
3.2.4 Program to improve and boost pedestrian mobility	63,208,176	12,635	5.117%	100%	12,635
3.2.5 Program to improve and boost cycling mobility	63,208,176	12,635	5.117%	100%	12,635
3.2.6 Program to improve the competitiveness of public transportation	221,228,617	44,222	17.909%	100%	44,222
3.2.7 Private vehicle and freight transport management program	189,624,529	37,905	15.351%	100%	37,905
3.2.8 Implement mobility management program	63,208,176	12,635	5.117%	100%	12,635
3.2.9 Implement education and communication program in sustainable mobility	31,604,077	6317	2.558%	100%	6317
Electric Vehicle					
3.2.2 Promotion of the electric vehicle	28,151,007	4117	1.667%	20%	823

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