1.1.1.1.1 Measure title: **Alternative Fuels in Coimbra**

City: **Coimbra** *Project:* **MODERN** *Measure number:* **01.03**

Executive summary

The rise in oil prices and the pressure for greater environmental sustainability in Public Transportation led the Municipal Public Transportation Services of Coimbra (SMTUC) to test the use of biofuel in their bus fleet. Within this measure SMTUC tested 3 different mixes (30%, 40%, and 50%) of biofuel in 4 buses running in real operational conditions in order to assess the possibility of supplying its entire fleet with this kind of fuel in the future.

The measure began with the design of the test model and was followed by personnel training. The tests started with a 30% biofuel mix and 10 % increments were conducted in each new test cycle, which lasted for about 25’000 km (about 5 months), coinciding with the scheduled maintenance of buses. The analysis at the end of the test period considered the quality of lubricant oils, fuel consumption, number of repairs and maintenance, performance evaluation, and emissions, and the following conclusions have been established:

- No perceptible problems occurred with the 4 buses that reached the objective of 50% of biofuel mix, during a running test period of 20 months and by covering about 100.000 km each one;
- The average operating costs of the 4 buses tested with B30 and B50 biofuel blends resulted to be lower than average operating costs of similar vehicles running on diesel for the same period. The difference has been more evident for B30, where the average operating costs in the ex-post have been 10% lower if compared with similar vehicles running on diesel.
- The use of biofuel as a blend with diesel may lead to some changes in emissions, but for NOx, and CO2 the biofuel revealed in general only a marginal effect. For a B30 blend the savings in the CO and PM emissions will be 20%.
- In the future, if B30 will be used in all vehicles of the SMTUC bus fleet (100 vehicles), the total PM emissions of the fleet in a given year may decrease from about 2,4 tPM/year to 2,0 tPM/year, representing an overall reduction of approximately 17% in terms of PM abatement.
- The hypothetical introduction of B30 in the entire SMTUC bus fleet could represent savings in operating costs around 420.000 €/year and the replacement of approximately 268.000 litres of diesel.

Additionally, an important finding of the tests has been that buses with common rail technology are not suited for the use of biofuels.

The full-scale experimentation for the majority of the SMTUC bus fleet and on regular public service is under consideration. In case the response will be affirmative, priority will be given to using biofuel resulting from recycled oils, such as cooking oils from the university complexes and the two central hospitals. Contacts with the municipal waste management service are also being established to assess the possibility of collecting these oils in the future.

A Introduction

A1 Objectives

The measure objectives are:

(A) High level / longer term:

- To decrease air pollution;
- To decrease the dependence on fossil fuels.

(B) Strategic level:

- To improve the city's air quality;
- To replace the use of fossil fuels by biofuels.

(C) Measure level:

(1) To test, by running at least 10 cycles per bus, the reliability of increasing the percentages of biofuel mixes in 4 different models of Urban PT buses in order to surpass 25% of biofuel mix of SMTUC[1] fleet in the future.

(2) To demonstrate that the emissions of CO may decrease by 15% in PT vehicles in Coimbra.

(3) To carry out awareness campaigns to highlight the importance of using alternative fuels.

A2 Description

Since CIVITAS is a demonstration project, this measure was not limited to a "laboratory analysis" of biofuel usage; moreover a full scale experimentation on regular public service lines has been carried out.

SMTUC (urban public transportation operator) tested different mixes of biofuel in 4 buses (with specifications EURO 3 and EURO 4) running in real operational conditions in order to assess the possibility of supplying its entire fleet with this kind of fuel in the future. The area affected corresponds to the SMTUC network influence, which means, all the urban area and also great part of the municipality of Coimbra. The tests have been carried out by using biofuel blended with different percentages included between 30% and 50% in order to obtain, namely, the following trial information:

- Energy consumption and atmospheric pollution caused by emissions;
- Percentage of biofuel tolerated by conventional motors of different bus models and manufacturers;
- Economic comparison between the use of biofuel and conventional diesel.

[1] Urban public transportation operator

The first phase consisted in the test set-up, definition of the data assessment, the testing methods, the testing equipment, as well as the trial planning.

Similar projects were analysed and a site visit to a PT operator with large experience in biofuel was carried out. Also biofuel experts and technical departments of higher education entities and biofuel suppliers have been assessed.

Market analysis has been performed including the possibility of using a portion of recycled organic biofuel collected by the municipal waste management services in the various hospitals and university facilities.

In this phase it was also decided that the tests will be more ambitious than initially foreseen, namely by using B_{30}, B_{40} and B_{50} biofuel mix, and the adequate testing equipment and methodology have been defined.

Four recent types of buses were selected to perform the tests in urban and suburban conditions and the planning activities took place.

The trial phase has been divided into three stages in which different fuel mixtures have been tested, beginning with 30% and increasing by 10% the mix in each stage until reaching a maximum of 50% – i.e., B_{30}, B_{40}, and B_{50} biofuel mix. Fuel mix tests have been conducted every 25 thousand kms (roughly 5 months), which coincides with the scheduled maintenances of the fleet.

At the end of each stage, SMTUC conducted a sequence of analysis to determine the results of the experiment, namely:

- Quality of lubricant oils (carried out by the lubricant oil supplier);
- Fuel consumption evaluation;
- Number of repairs and maintenance;
- Performance evaluation (through driver surveys on bus performance);
- Analysis of emissions - (CO), (CO2), (NOX), and small particles (with the support of an engineering school).

The analysis to the quality of the lubricant didn’t detected any symptoms of abnormal engine wear, as well as the buses performances seems to be normal in the drivers perception through the related surveys.

With B30 the two buses equipped with “common rail” technology in the diesel injection, had problems in this fuel feed system, forcing the stop of the tests for this type of buses. Considering that the biofuel tests only involved 4 buses, it was considered important to change these buses by other 2 buses equipped with different technology. The time needed to prepare these buses caused a gap between the initial buses running the tests and the new ones. To allow a more complete and effective monitoring of all buses it was decided to extended the tests until September 2012. This fact obliged to a consequent 4 month extension of the measure duration to comprise the evaluation tasks.

No perceptible problem occurred with the 4 buses that reached the objective of 50% of biofuel mix, 2 during 20 months and about 100.000 km each one.

To increase the awareness level of the measure the buses tested had promotional material on the left and the rear sides communicating that these vehicles were running with biofuel. Also awareness campaigns involving other regional fleet operators have been carried out.

B Measure implementation

B1 Innovative aspects

The innovative aspects of the measure are:

- **New policy instrument, national** – In Portugal a 5% biofuel integration of all diesel commercialised is compulsory by law. However, higher mixtures are rarely used due to the manufacturers' warranty limitations. A full-scale experimentation on regular public service lines will permit to raise these limits, changing present practices.

  This measure will have an important impact on the practice of the general state of the art in Portugal, due the tests with high percentages of biofuel (blends until 50% biofuel).

B2 Research and Technology Development

The research and technology development consisted mainly in knowledge acquisition and the Test Model Design: Definition of the testing methods, the data assessment, the testing equipment and the trial planning (buses used, percentage of mixture per stage, duration of each stage, etc.).

Analysis of similar projects and experiences, including a site visit to the Urban Transports Company of Braga (TUB), has been carried out to increase the knowledge level of SMTUC technicians on biofuel issues.
Contacts with experts in engineering schools and with biofuel suppliers have been also carried out, as well as market analyses.
The specifications of tests and adequate testing equipment were defined:

- The initial plan, which expected 20% biofuel mix for the starting level and increments of 1% in each test cycle, was abandoned because it was considered that it was not ambitious enough and difficult to assess changes between each step. Taking into consideration the knowledge acquired and the TUB results, 3 tests steps with B_{30}, B_{40} and B_{50} were considered more appropriate;
- It was also decided that each bus would have run in real operational conditions during 25.000 km (about 5 months) in each of the 3 steps of biofuel mix, which coincides with the scheduled maintenances of the fleet.
- Tests performed: Quality of lubricant oils (carried out by the lubricant oil supplier); Fuel consumption evaluation; Number of repairs and maintenance; Performance evaluation (through driver surveys on bus performance); Analysis of emissions (with the support of an engineering school).

After this stage the 4 buses to be tested were selected. Model details are reported in the following table:

Table B2.1 – Type of buses to be tested

Type of Bus	Make/Model
Bus (Euro 3)	Mercedes O 530 CITARO
	Volvo B7L
Bus (Euro 4)	Volvo B7LE – 2 Buses

The biofuel market and the SMTUC needs concerning this fuel were also studied: Possible biofuel distributors were contacted to obtain prices, quantities and availability. It was decided that the biofuel was supplied directly to the SMTUC installations, where it was stored in specially dedicated reservoirs. Previously a study on the average consumption of the chosen trial buses was conducted and it was verified that in 2009 they consumed around 9600 litres of diesel. Taking into consideration the monthly consumption of diesel, and supposing that the consumption of biofuel will be equivalent, the same amount of fuel was applied (altering only the mix ratio).

The following table identifies the amount of fuel (Diesel / Biofuel) necessary for each mixture:

Table B2.2 – Monthly consumption of fuel

Fuel mix	Monthly Consumption	
	Diesel	Bio fuel
B30	6.720 (L)	2.880 (L)
B40	5.760 (L)	3.840 (L)
B50	4.800 (L)	4.800 (L)

The supplying of fuel proceeded according to the following process: The regular diesel has been used as a reference and for the mixtures it has been stored in an existing reservoir on the SMTUC lot. In regards to the biofuel (B100), it has been delivered and stored in external reservoirs also at the SMTUC site. The desired mixture has then been done by using an automatic pump with a measurement device.

The following figures exemplify the delivery, mixture and fuelling processes.

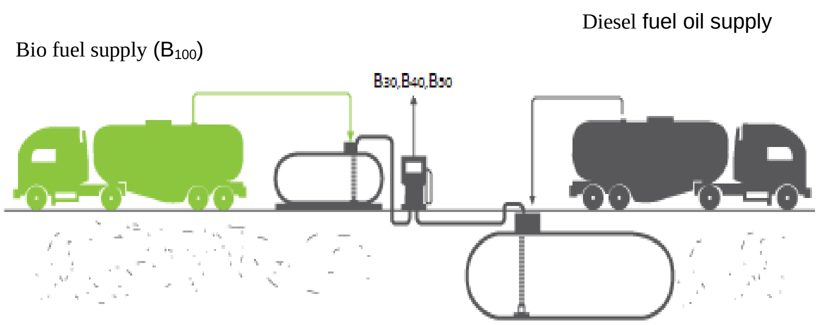


Figure B2.1 – Supplying the fuels and accomplishing the mixture

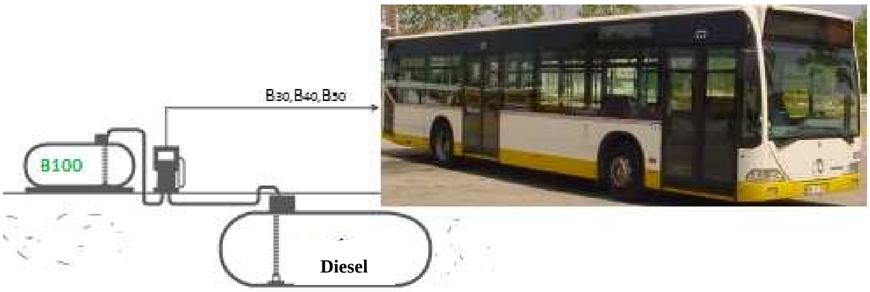


Figure B2.2 – Fuelling the Vehicles

The legislation in this field was also assessed: The reservoirs comply with the security norms in accordance with Class B1 and which are consecrated in the following Portuguese legal diplomas:

- Decree nº 36 270, 09 May, 1947
- Ordinance nº 131/2002, 09 February.

The fuelling process was in accordance with the national legislation in effect, namely:

- Decree nº 36270, 09 May, 1947;
- Ordinance nº 131/2002, 09 February;
- Ordinance nº 1188/2003, 10 October;
- Ordinance nº 1515/2007, 30 November;
- Decree nº 389/2007, 30 November.

The planning of the activities took into consideration also that the fuel mix stages must be balanced in order to have a representative sample of the routes and zones (urban and suburban) served by the SMTUC network.

It was also defined that no analysis to the wear in the motor and the injection system would be performed during each test stage due to the high costs associated with those tests. Accordingly, the monitoring of the engine performance and damages has been carried out in alternative and the maximum percentage for biofuel mixture was defined as 50% because beyond this limit the information available was scant and there was very little experience in other PT operators.

In this field the methodology to evaluate the measure impact was also carried out: An assessment of the available indicators was made, as well as the design of the necessary surveys. The methodology and equipment for the direct measurement of the buses emissions was also studied and a partnership with an engineering school of higher education has been defined to assure these instantaneous measurements (only for some of the gas emissions with the buses parked in the SMTUC garage).

Finally the risk management was assessed and the recovery actions / contingency plans were defined.

B3 Situation before CIVITAS

The rising price of oil and the detrimental consequences brought on by traffic pollution and energy inefficiencies have motivated authorities to implement more sustainable energy policies. The use of biofuel has been gaining considerable significance in the public transportation sector. However, in Portugal the use of biofuel is still relatively low.

Besides the 5% of bio diesel integration in all fuel oil commercialised in Portugal, generally little use of alternative fuels exists in fleets at national level.

In Coimbra, the situation is the same, though the Municipality has taken a first step in order to reverse the situation by buying a waste collection truck operated with Bio Diesel.

SMTUC, besides its commitment to the use of electric energy, through its fleet of trolley cars, electric mini-buses and buses with diesel-electric traction, is committed to transform its conventional bus fleet into energetically cleaner and efficient vehicles. This will anticipate, along the years, the legal deadlines to implement the measures proposed by several European Directives for Diesel Engines (Euro II, III and IV), but which never used natural gas or biofuel in their fleet.

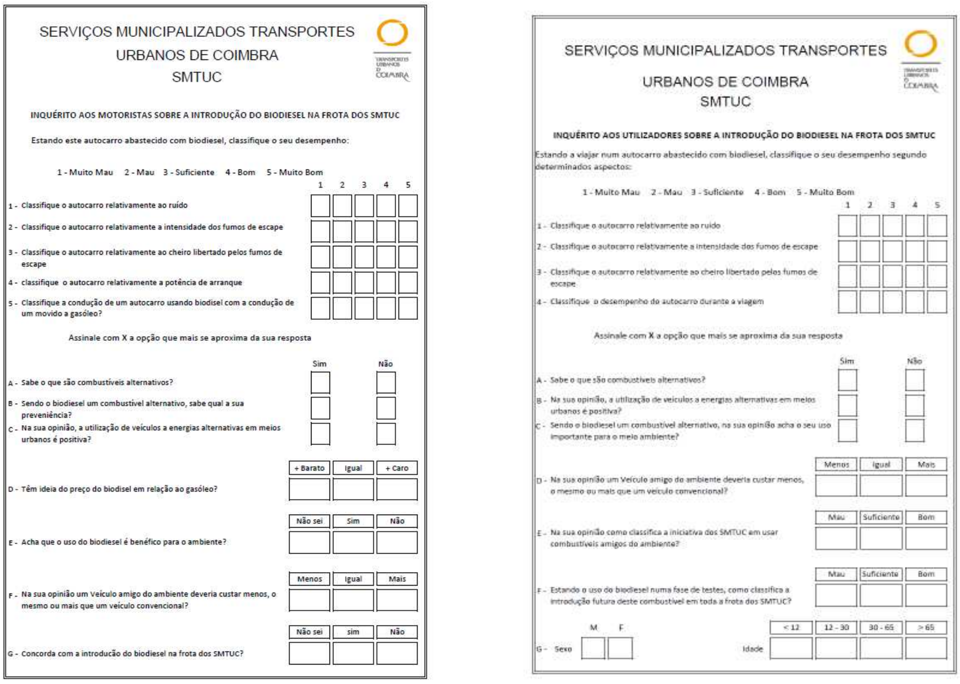
With this CIVITAS measure SMTUC intended to increase its knowledge on biofuel usage and verify if the tests with buses running in real operational condition fuelled by biofuel could demonstrate the environmental importance and the technical and economic feasibility for SMTUC to expand the use of Biofuel to a major part of its fleet.

B4 Actual implementation of the measure

The measure was implemented in the following stages:

Stage 1: Test model design *(October 2009 – September 2010) – Definition until August 2010 of the testing methods, the data assessment, the testing equipment, and the trial planning, namely:*

- *Analysis of similar projects and experiences, including a site visit to the Urban Transports Company of Braga. This company has a wide experience with biofuel, including the use of B_{100} in the daily service of public transportation for a long period.*
- *Contacts with experts and technical departments of higher education.*
- *Market analysis.*
- *Biofuel market experts and supplier consultation.*
  - *After prospecting market availability for biofuel, the supplier for the test phase selected is BIOMOVE. After the trial stage, the future supplier of biofuel will be chosen through public tender. However, there is the possibility of using a portion of recycled organic biofuel collected by the municipal waste management services (namely from the various Hospitals and University facilities).*
- *Definition of the types of tests and adequate testing equipment:*
  - *Biofuel mix will be 30% (B_{30}), 40% (B_{40}), and 50% (B_{50});*
  - *Tests to be performed to: Quality of lubricant oils); Fuel consumption evaluation; Number of repairs and maintenance; Performance evaluation (through driver surveys on bus performance – Fig. B4.1); Analysis of emissions.*



SERVIÇOS MUNICIPALIZADOS TRANSPORTES URBANOS DE COIMBRA
SMTUC

INQUÉRITO AOS MOTORISTAS SOBRE A INTRODUÇÃO DO BIODIESEL NA FROTA DOS SMTUC

Estando este autocarro abastecido com biodiesel, classifique o seu desempenho:

1 - Muito Mau 2 - Mau 3 - Suficiente 4 - Bom 5 - Muito Bom

	1	2	3	4	5
1 - Classifique o autocarro relativamente ao ruído					
2 - Classifique o autocarro relativamente a intensidade dos fumos de escape					
3 - Classifique o autocarro relativamente ao cheiro libertado pelos fumos de escape					
4 - classifique o autocarro relativamente a potência de arranque					
5 - Classifique a condução de um autocarro usando biodisel com a condução de um movido a gasóleo?					

Assinale com X a opção que mais se aproxima da sua resposta

	Sim	Não
A - Sabe o que são combustíveis alternativos?		
B - Sendo o biodiesel um combustivel alternativo, sabe qual a sua preveniência?		
C - Na sua opinião, a utilização de veículos a energias alternativas em meios urbanos é positiva?		

	+ Barato	Igual	+ Caro
D - Têm ideia do preço do biodisel em relação ao gasóleo?			

	Não sei	Sim	Não
E - Acha que o uso do biodiesel é benéfico para o ambiente?			

	Menos	Igual	Mais
F - Na sua opinião um Veiculo amigo do ambiente deveria custar menos, o mesmo ou mais que um veículo convencional?			

	Não sei	sim	Não
G - Concorda com a introducão do biodiesel na frota dos SMTUC?			

SERVIÇOS MUNICIPALIZADOS TRANSPORTES URBANOS DE COIMBRA
SMTUC

INQUÉRITO AOS UTILIZADORES SOBRE A INTRODUÇÃO DO BIODIESEL NA FROTA DOS SMTUC

Estando a viajar num autocarro abastecido com biodiesel, classifique o seu desempenho segundo determinados aspectos:

1 - Muito Mau 2 - Mau 3 - Suficiente 4 - Bom 5 - Muito Bom

	1	2	3	4	5
1 - Classifique o autocarro relativamente ao ruido					
2 - Classifique o autocarro relativamente a intensidade dos fumos de escape					
3 - Classifique o autocarro relativamente ao cheiro libertado pelos fumos de escape					
4 - Classifique o desempenho do autocarro durante a viagem					

Assinale com X a opção que mais se aproxima da sua resposta

	Sim	Não
A - Sabe o que são combustiveis alternativos?		
B - Na sua opinião, a utilização de veiculos a energias alternativas em meios urbanos é positiva?		
C - Sendo o biodiesel um combustivel alternativo, na sua opinião acha o seu uso importante para o meio ambiente?		

	Menos	Igual	Mais
D - Na sua opinião um Veículo amigo do ambiente deveria custar menos, o mesmo ou mais que um veículo convencional?			

	Mau	Suficiente	Bom
E - Na sua opinião como classifica a iniciativa dos SMTUC em usar combustíveis amigos do ambiente?			
F - Estando o uso do biodiesel numa fase de testes, como classifica a introdução futura deste combustivel em toda a frota dos SMTUC?			

G - Sexo: M / F — Idade: < 12 / 12 - 30 / 30 - 65 / > 65

Fig. B4.1 – Driver Survey on bus performance

- *Test vehicle selection and test conditions definition:*
  - *4 recent types of buses were selected to perform the tests that will be carried out in urban and suburban conditions.*
- *Planning of the Activities.*

Stage 2: Training of test personnel *(July 2010 – September 2010) – Training of one technician and one skilled worker in bus engine behaviour analyses (including emissions and oils) and in the design and analysis of questionnaires for drivers of buses with biofuel mix.*

Stage 3: Biofuel Trials *(August 2010 – September 2012) – In a first phase a procedure for Biofuel supply and the purchase of equipment was launched, namely the reservoirs and fuel pump for the Biofuel mix and bus supply.*

The next step consisted in the installation and set-up of the infrastructure and equipment (fig. B4.2), namely:

- *Acquisition of biofuel reservoirs;*
- *Acquisition and installation of fuel pump;*
- *Installation of fuelling infrastructure (piping system);*
- *Provision for testing equipment installation in the SMTUC garage (equipment provided by local establishment of Higher Education, i.e., engineering school).*

Fig. B4.2 – Bus approaching the bio fuel refuelling area equipped with the reservoirs and pump. The bus has stickers informing that is running with bio fuel.

The trial phase has been divided into three periods in which different fuel mixtures have been tested, beginning with 30% and increasing the mix by 10% in each period until achieving a maximum of 50% – i.e., B_{30}, B_{40}, and B_{50} bio fuel mix. Fuel mix tests have been conducted every 25 thousand km (roughly 5 months), which coincides with the scheduled maintenances of the fleet.

The start-up of the tests occurred in February 2011 with the Biofuel mix at 30% (B30):

- *The replacement or cleaning of bus engine parts (engine feed system) in order to receive the biofuel mix has been carried out (Due to the biofuels cleansing properties, the bus engines and reservoirs must first be cleaned with biofuel in order to avoid clogging resulting from particles unleashed from the feed system).*
- *4 buses ran in real operational conditions in the entire SMTUC urban and suburban PT network*
- *The yield tests focused on the quality of lubricant oils (carried out by the lubricant oil supplier), fuel consumption evaluation, number of repairs and maintenance, performance evaluation (through driver surveys on bus performance), and analysis of emissions (with the support of an engineering school).*
- *The activity of monitoring of the tests has been also carried out and included surveys on bus performance and reliability carried out by the buses drivers.*
- *Two buses that have "common rail" technology in the diesel injection, had problems in this feed system, namely with "gel" in the filters and injectors, forcing the stoppage of the tests on 5th and 10th May 2011 (mix at 30%). The other 2 buses continued the tests without problems and the tests began with the Biofuel mix at 40% on 11th July 2011.*

The above mentioned methodology was also used with the 40% biofuel mix and with B_{50} after February 2012. To reach the initial and more significant sample, another 2 buses were added to the tests in replacement of the 2 stopped with problems in the "common rail" system.

The biofuel tests ended in September 2012 allowing for a large period and extension running of the tests. The analysis to the quality of the lubricant didn't detected any symptoms of abnormal engine wear, as well as the buses performances seems to be normal in the drivers perception through the related surveys.. So, no perceptible problem occurred with the 4 buses that reached the objective of 50% of biofuel mix, 2 during 20 months and about 100.000 km each one.

To increase the awareness level of the measure the buses in test had promotional material on the left side and in the rear communicating of the buses that they are running with biofuel. Also awareness campaigns have been carried out, involving other regional fleet operators.

B5 Inter-relationships with other measures

Measures 01.03 and 01.08 were grouped because they both have direct impact on SMTUC emissions. However, measure 01.08 is a feasibility study and therefore has no potential to generate impacts on SMTUC emissions during CIVITAS MODERN implementation. Thus, measure 01.08 is related to measure 01.03 but they are not identified as a bundling of measures for impact evaluation purpose.

- **Measure no. 01.08** – The production of renewable energies for trolleybus lines in Coimbra could have also impact on the SMTUC emissions if the results of the feasibility study will be positive and the generation of renewable energies will be implemented in the future.

C Evaluation – methodology and results

C1 Measurement methodology

C1.1 Impacts and Indicators

Table C1.1.1 – Considered Indicators.

No.	Impact	Indicator	Data used	Comments
1	Operating Costs	Average Operating Costs (€/vkm)	Total operational costs; Total vehicle-km	SMTUC Data
2	Fuel consumption	Average Vehicle fuel efficiency (MJ/vkm)	Total energy consumed; Total vehicle-km	SMTUC Data
3	Fuel consumption	Fuel Mix (% per type of fuel)	Energy consumption for the fuel considered; Total energy consumed	SMTUC Data
4	Emissions	Average CO Emissions (g CO/vkm)	Fuel; Vehicle; Diesel Consumption; Pollutant; Emission Factor	SMTUC Data Portuguese National and Informative Inventory Report 2012
5	Emissions	Average CO_2 Emissions (g CO_2/vkm)	Fuel; Vehicle; Diesel Consumption; Pollutant; Emission Factor	SMTUC Data Portuguese National and Informative Inventory Report 2012
6	Emissions	Average NOx Emissions (g NOx/vkm)	Fuel; Vehicle; Diesel Consumption; Pollutant; Emission Factor	SMTUC Data Portuguese National and Informative Inventory Report 2012
7	Emissions	Average PM Emissions (g PM/vkm)	Fuel; Vehicle; Diesel Consumption; Pollutant; Emission Factor	SMTUC Data Portuguese National and Informative Inventory Report 2012
8	Awareness	Awareness level – bus drivers	Total number of SMTUC bus drivers with knowledge of the measure; Total number of responding SMTUC bus drivers	SMTUC Data
9	Acceptance	Acceptance level – bus drivers	Total number of SMTUC bus drivers who favourably receive the measure; Total number of responding SMTUC bus drivers	SMTUC Data
10	Awareness	Awareness level - Marketing	Number of buses running with biofuel having sticker; Number of buses running with biofuel.	SMTUC Data

The biofuel tests have been carried out in 4 buses of different brands, running in operation conditions with 30%, 40% and 50% biofuel mixes. Each mix stage had a duration according to the maintenance program (25.000 km - 5 to 7 months) **and other 4 buses with the same brand, but fuelled with 100% mineral diesel, operated simultaneously in similar conditions** (buses tested and reference buses were all of the same series, so in addition to have the same brand, they have been purchased at same time and had similar mileages – between 371.483km and 376.770 km for series of Volvo B7L and between 557.097km and 594.729km for the other series). This procedure allowed the comparison between the scenario after measure implementation (ex-post) and the scenario in case the measure would have not been implemented (comparison between the ex-post and the business-as-usual scenario in similar conditions).

To allow the comparison between the ex-post scenario and the conditions before measure implementation (ex-ante scenario), **the recorded SMTUC data related to the 4 buses involved in the tests has been assessed**. This data refers to a complete 12 months set of indicators during the year before the beginning of the measure implementation **with these 4 buses fuelled with 100% mineral diesel**. The comparison for each blend has been carried out with similar periods in the baseline to mitigate the effect of the seasonality.

This methodology allowed the assessment of the measure impacts on indicators 1 to 7, the comparison with the baseline and business-as-usual (BAU) scenarios, but the comparison between different mixes wasn't convenient because the tests periods were different (the weather variations have influence in the performance of engines powered by biofuel). This situation has been aggravated by the fact that the composition of the brand of the 4 buses tested changed from the B30 stage to the B50 stage. In fact 2 buses equipped with "common rail" technology in the injectors stopped the tests 3 months after the tests began, due to problems in the fuel feed system caused by the biofuel use. The 2 buses have been changed by other 2 buses of different brand, but having consequent different impacts too. Any case this problem hadn't influence in the comparison Ex-post – Ex-ante or Ex-post – BAU because the reference buses have been also changed in accordance.

The detailed description of the indicator methodologies is as follows:

- **Indicator 1 (*Average Operating Costs*)** – Ratio of total operating costs incurred in the operation of the 4 vehicles being tested with biofuel, divided by the total number of vehicle-km of these 4 vehicles (€/vehicle-km).

  A = B / C, where:

  - ✓ A = Average operational costs for the bus service (€/vehicle-km).
  - ✓ B = Total operational costs of the 4 vehicles being tested, including fuel consumption and maintenance costs with material and personnel (€).
  - ✓ C = Total vehicle-km performed by the 4 vehicles being tested.

  Both data are related to the 4 vehicles being tested, excepted for the BAU scenario, in which 4 reference buses has been used, all operating in similar public transport network conditions. The reference buses have the same brands of the buses being tested and operated simultaneously. For the baseline and BAU scenario the buses has been fuelled with 100% mineral diesel. Results from the total operational costs have origin in SMTUC regular procedure of registering its expenditures with fuel consumption and other related operating costs like maintenance costs (including material and personnel costs). The number of vehicle-kilometres, results from the subtraction of non-performed trips data to the scheduled ones. The data reliability is maximised due to an objective data collection among SMTUC records on performed and scheduled trips, which in turn are recorded following reliable procedures.

- **Indicator 2 (*Vehicle fuel efficiency*)** – Ratio of energy consumed by the 4 vehicles being tested, divided by the total number of vehicle-km of these 4 vehicles (MJ/vehicle-km).

  A = B / C, where:

  ✓ A = Average vehicle efficiency (MJ/vehicle-km)

  ✓ B = Total energy consumed by the 4 vehicles being tested (MJ)

  ✓ C = Total vehicle-km performed by the 4 vehicles being tested

  All data are related to the 4 vehicles being tested, excepted for the BAU scenario, in which 4 reference buses has been used, all operating in similar public transport network conditions. The reference buses have the same brands of the buses being tested and operated simultaneously. For the baseline and BAU scenario the buses has been fuelled with 100% mineral diesel. Results from energy consumption by the SMTUC bus vehicles is metered using SMTUC regular procedure of registering fuel consumption by these vehicles every time each vehicle is fuelled and converting it into total energy consumption using bibliographic sources. The number of vehicle-kilometres, results from the subtraction of non-performed trips data to the scheduled ones. The data reliability is maximised due to an objective data collection among SMTUC records on performed trips, which in turn are recorded following reliable procedures. In fact, each driver registers the trips performed, being the extension of the trip recognized. The number of trips is validated by the software of the Automatic Vehicle Management system that gives back up to the network operation.

- **Indicator 3 (*Fuel Mix*)** – Percentage of the market share of transport fuel for each type of fuel used in a given period (%).

  A = B / C × 100, where

  ✓ A = Fuel mix, or percentage for the fuel considered (%)

  ✓ B = Total energy consumption for the fuel considered (MJ)

  ✓ C = Total energy consumed for all SMTUC vehicles (MJ)

  All data are related to the SMTUC fleet. Results from energy consumption by the SMTUC fleet is metered using SMTUC regular procedure of registering fuel consumption for each type of fuel every time each vehicle is fuelled and converting it into total energy consumption using bibliographic sources. The data reliability is maximised due to an objective data collection.

- **Indicator 4 (*CO Emissions*)** – Average CO emissions per vehicle-km (g CO/vehicle-km)

  A = B / C, where:

  ✓ A = Average CO emissions per vehicle-km (g/vehicle-km)

  ✓ B = Total CO emissions of the 4 vehicles being tested (g)

  ✓ C = Total vehicle-km performed by the 4 vehicles being tested

All data are related to the 4 buses being tested, excepted for the BAU scenario, in which 4 reference buses has been used, all operating in similar public transport network conditions. The reference buses have the same brands of the buses being tested and operated simultaneously. For the baseline and BAU scenario the buses has been fuelled with 100% mineral diesel.

The calculation of total CO emissions is based on country data given by the Portuguese Environment Agency (Portuguese National Inventory and Informative Report on Greenhouse Gases, 2012). More precisely, it was used a CO implied emission factor, expressed in kg/MJ, that according to the Portuguese Environment Agency was determined using a Tier 3 methodology (based model with COPERT).

Data from vehicle-kilometres performed by SMTUC vehicles is coming from report reading. Results from vehicle-kilometres come from the subtraction of non-performed trips data to the scheduled ones. The data reliability is maximised due to an objective data collection among SMTUC records on performed and scheduled trips, which in turn are recorded following reliable procedures.

- **Indicator 5 (CO_2 Emissions)** – Average CO_2 emissions per vehicle-km (gCO_2/vehicle-km)

  A = B / C, where:

  - ✓ A = Average CO_2 emissions per vehicle-km (g/vehicle-km)
  - ✓ B = Total CO_2 emissions of the 4 vehicles being tested (g)
  - ✓ C = Total vehicle-km performed by the 4 vehicles being tested

  All data are related to the 4 buses being tested, excepted for the BAU scenario, in which 4 reference buses has been used, all operating in similar public transport network conditions. The reference buses have the same brands of the buses being tested and operated simultaneously. For the baseline and BAU scenario the buses has been fuelled with 100% mineral diesel.

  The calculation of total CO_2 emissions is based on country data given by the Portuguese Environment Agency (Portuguese National Inventory and Informative Report on Greenhouse Gases, 2012). More precisely, it was used a CO_2 implied emission factor, expressed in kg/MJ, that according to the Portuguese Environment Agency was determined using a Tier 3 methodology (based model with COPERT).

  Data from vehicle-kilometres performed by SMTUC vehicles is coming from report reading. Results from vehicle-kilometres come from the subtraction of non-performed trips data to the scheduled ones. The data reliability is maximised due to an objective data collection among SMTUC records on performed and scheduled trips, which in turn are recorded following reliable procedures.

- **Indicator 6 (*NOx Emissions*)** – Average NOx emissions per vehicle-km (gNOx/vehicle-km)

  A = B / C, where:

  - ✓ A = Average NOx emissions per vehicle-km (g/vehicle-km)

- ✓ B = Total NOx emissions of the 4 vehicles being tested (g)
- ✓ C = Total vehicle-km performed by the 4 vehicles being tested

All data are related to the 4 buses being tested, excepted for the BAU scenario, in which 4 reference buses has been used, all operating in similar public transport network conditions. The reference buses have the same brands of the buses being tested and operated simultaneously. For the baseline and BAU scenario the buses has been fuelled with 100% mineral diesel.

The calculation of total NOx emissions is based on country data given by the Portuguese Environment Agency (Portuguese National Inventory and Informative Report on Greenhouse Gases, 2012). More precisely, it was used a NOx implied emission factor, expressed in kg/MJ, that according to the Portuguese Environment Agency was determined using a Tier 3 methodology (based model with COPERT).

Data from vehicle-kilometres performed by SMTUC vehicles is coming from report reading. Results from vehicle-kilometres come from the subtraction of non-performed trips data to the scheduled ones. The data reliability is maximised due to an objective data collection among SMTUC records on performed and scheduled trips, which in turn are recorded following reliable procedures.

- **Indicator 7 (*Small Particulate Emissions*)** – Average Small Particulate emissions per vehicle-km (g/vehicle-km)

A = B / C, where:

- ✓ A = Average Small Particulate emissions per vehicle-km (g/vehicle-km)
- ✓ B = Total Small Particulate emissions of the 4 vehicles being tested (g)
- ✓ C = Total vehicle-km performed by the vehicles being tested

All data are related to the 4 buses being tested, excepted for the BAU scenario, in which 4 reference buses has been used, all operating in similar public transport network conditions. The reference buses have the same brands of the buses being tested and operated simultaneously. For the baseline and BAU scenario the buses has been fuelled with 100% mineral diesel.

The calculation of total PM emissions is based on country data given by the Portuguese Environment Agency (Portuguese National Inventory and Informative Report on Greenhouse Gases, 2012). More precisely, it was used a PM implied emission factor, expressed in kg/MJ, that according to the Portuguese Environment Agency was determined using a Tier 3 methodology (based model with COPERT).

Data from vehicle-kilometres performed by SMTUC vehicles is coming from report reading. The number of vehicle-kilometres, results from the subtraction of non-performed trips data to the scheduled ones. The data reliability is maximised due to an objective data collection among SMTUC records on performed and scheduled trips, which in turn are recorded following reliable procedures.

- **Indicator 8** (*Awareness level – bus drivers*) – Percentage of the SMTUC bus drivers with knowledge of the measure on account of provided information (%).

  A = B / C × 100, where:

  - ✓ A = Percentage of bus drivers with knowledge of the measure (%)
  - ✓ B = Total number of respondents with knowledge of the measure
  - ✓ C = Total number of respondents

  The Awareness level of the measure is measured through a Survey, set up to measure the Awareness and Acceptance Level of the SMTUC bus drivers.

  This survey is composed of specific questions that resume the bus driver's attitude towards the actions undertaken on the scope of the measure. The first survey has been carried out to the entire SMTUC bus drivers (284) from 2nd November 2009 to 11th December 2009, before measure start, and the survey was repeated from 7th November 2011 to 16th December 2011, when all SMTUC bus drivers (281) had experienced the driving of buses running with biofuel. The surveys were delivered directly to each driver and were accompanied with direct contacts made to promote its success. Concerning the ex-ante survey 176 responses has been received back from the 284 inquired and in relation to the 281 ex-post surveys 193 responses has been received back.

- **Indicator 9** (*Acceptance level - bus drivers*) – Percentage of the SMTUC bus drivers who favourably receive the measure (%).

  A = B / C, where:

  - ✓ A = Percentage of bus drivers who favourably receive the measure (%)
  - ✓ B = Total number of respondents who favourably receive the measure
  - ✓ C = Total number of respondents

  The Acceptance level of the measure is measured through a Survey, set up to measure the Awareness and Acceptance Level of the SMTUC bus drivers.

  This survey is composed of specific questions that resume the bus driver's attitude towards the actions undertaken on the scope of measure. The first survey has been carried out to the entire SMTUC bus drivers from 2nd November 2009 to 11th December 2009, before measure start, and the survey was repeated from 7th November 2011 to 16th December 2011, when all SMTUC bus drivers had experienced the driving of buses running with biofuel. The surveys were delivered directly to each driver and were accompanied with direct contacts made to promote its success.

- **Indicator 10** (*Awareness level – marketing*) – Percentage of the vehicles being tested that have a sticker communicating that the bus is running with biofuel (%).

  A = B / C, where:

  - ✓ A = Percentage of vehicles being tested that have a sticker communicating the use of biofuel (%)

- ✓ B = Total number of vehicles being tested that have a sticker communicating the use of biofuel
- ✓ C = Total number of vehicles being tested with biofuel.

C1.2 Establishing a Baseline

In order to verify the achievement of the targets associated with the measure implementation, for the indicators 1 to 7 it was established a baseline, **using ex-ante recorded data of the 4 buses being tested** (with specifications EURO 3 and EURO 4 fuelled 100% mineral diesel) from January 2010 to January 2011, just before the beginning of the start-up tests with the Biofuel mix at 30% (B30), in February 2011.

To mitigate the seasonality effect, the baseline has been split in 3 periods that corresponds each one to the similar periods used later to test each biofuel blend in these buses. This methodology **allowed later the comparison of the impacts of the use of biofuel blends in the same buses running previously with mineral diesel in similar conditions**. For example, for the baseline of the tests with B30 fuel mix carried out from February 2011 to June 2011 has been selected the recorded data of the same buses running with 100% mineral diesel from February 2010 to July 2010.

The evaluation of the measure results are based on the SMTUC operational records and particular data required for indicators presented in point C1.1, with exception of the indicators 8 and 9, for which was used a drivers survey carried out by SMTUC, in order to assess the measure acceptance level by the buses drivers. As mentioned above, the emissions were determined using country data given by the Portuguese Environment Agency (Portuguese National Inventory and Informative Report on Greenhouse Gases, 2012). More precisely, it was used implied emission factors for diesel, expressed in kg/MJ, that according to the Portuguese Environment Agency were determined using the Tier 3 methodology (based model with COPERT). So the emissions has been calculated using the fuel consumption and the correct emission factors.

The next table shows the emission factors that were used for emissions calculations (Ex-Ante and Business As Usual), taking into consideration the vehicle type (bus) and the fuel (diesel).:

Table C1.2.1: Emission Factors, Diesel.

Pollutant	Emission Factors (kg/MJ)
CO	0,0001732
CO_2	0,074
NOx	0,0007429
PM	0,0000223

Source: Portuguese Environmental Agency, 2012.

The results of the baseline, for each indicator, are presented in the following specific tables:

Indicator 1: Average Operating Costs

Table C1.2.2: Average Operating Costs (€/vkm), Ex-Ante.

Indicator and Data Used (4 Vehicles Being Tested)	Feb-Jun 10	Jul-Dec 10	Jan-Jul 10
Fuel Consumption Costs (€) [1]	42.908	49.933	58.005
Maintenance costs with personnel (€) [2]	3.455	4.906	4.434
Maintenance costs with material (€) [3]	8.406	11.936	10.788
Total costs (€) 4 = [1+2+3]	54.769	66.774	73.227
Total vehicle-km (vkm) [5]	109.017	120.756	148.190
Average Fuel Costs (€/vkm) [1/5]	0,394	0,414	0,391
Average operating costs (€/vkm) [4/5]	**0,502**	**0,553**	**0,494**

Indicator 2: Average Vehicle fuel efficiency

Table C1.2.3: Average Vehicle fuel efficiency (MJ/vkm), Ex-Ante.

Indicator and Data Used (4 Vehicles Being Tested)	Feb-Jun 10	Jul-Dec 10	Jan-Jul 10
Total energy consumed by the vehicles (MJ) [1]	1.777.544	2.018.953	2.416.273
Total vehicle-km (vkm) [2]	109.017	120.756	148.190
Average Fuel Efficiency (MJ/vkm) [1/2]	**16,305**	**16,719**	**16,305**

Indicator 3: Fuel Mix

Table C1.2.4: Fuel Mix (% per type of fuel), Ex-Ante.

Indicator and Data Used (SMTUC bus fleet)	Feb-Jun 10	Jul-Dec 10	Jan-Jul 10
Total Energy consumed by the Diesel vehicles (MJ)	45.056.215	53.348.939	63.177.078
Total Energy consumed by the Biofuel vehicles (MJ)	0	0	0
Total Energy consumed by the Electric vehicles (MJ)	1.222.186	721.674	1.587.409
Fuel Mix		-	-
- Diesel %	**97,36%**	**98,67%**	**97,55%**
- Biofuel %	**0,00%**	**0,00%**	**0,00%**
- Electric %	**2,64%**	**1,33%**	**2,45%**

Indicator 4: Average CO Emissions

Table C1.2.5: Average CO emissions per vehicle-km (g CO/vkm), Ex-Ante.

Indicator and Data Used (4 Vehicles Being Tested)	Feb-Jun 10	Jul-Dec 10	Jan-Jul 10
Total energy consumed by the vehicles (MJ) [1]	1.777.544	2.018.953	2.416.273
Emission Factor (kg CO/MJ) [2]	0,0001732		
Total CO emissions of the vehicles (g) [3=1x2]	307.871	349.683	418.499
Total vehicle-km (vkm) [4]	109.017	120.756	148.190
Average CO emissions per vehicle-km (g CO/vkm) [3/4]	**2,824**	**2,896**	**2,824**

Indicator 5: Average CO_2 Emissions

Table C1.2.6: Average CO_2 emissions per vehicle-km (g CO_2/vkm), Ex-Ante.

Indicator and Data Used (4 Vehicles Being Tested)	Feb-Jun 10	Jul-Dec 10	Jan-Jul 10
Total energy consumed by the vehicles (MJ) [1]	1.777.544	2.018.953	2.416.273
Emission Factor (kg CO_2/MJ) [2]	0,074		
Total CO_2 emissions of the vehicles (g) [3=1x2]	131.538.271	149.402.492	178.804.224
Total vehicle-km (vkm) [4]	109.017	120.756	148.190
Average CO_2 emissions per vehicle-km (g CO_2/vkm) [3/4]	**1.206,585**	**1.237,226**	**1.206,588**

Indicator 6: Average NOx Emissions (g NOx/vkm)

Table C1.2.7: Average NOx emissions per vehicle-km (g NOx/vkm), Ex-Ante.

Indicator and Data Used (4 Vehicles Being Tested)	Feb-Jun 10	Jul-Dec 10	Jan-Jul 10
Total energy consumed by the vehicles (MJ) [1]	1.777.544	2.018.953	2.416.273
Emission Factor (kg NOx/MJ) [2]	0,0007429		
Total NOx emissions of the vehicles (g) [3=1x2]	1.320.538	1.499.880	1.795.049
Total vehicle-km (vkm) [4]	109.017	120.756	148.190
Average NOx emissions per vehicle-km (g NO_x/vkm) [3/4]	**12,113**	**12,421**	**12,113**

Indicator 7: Average PM Emissions (g PM/vkm)

Table C1.2.8: Average PM emissions per vehicle-km (g PM/vkm), Ex-Ante.

Indicator and Data Used (4 Vehicles Being Tested)	Feb-Jun 10	Jul-Dec 10	Jan-Jul 10
Total energy consumed by the vehicles (MJ) [1]	1.777.544	2.018.953	2.416.273
Emission Factor (kg PM/MJ) [2]	0,0000223		
Total PM emissions of the vehicles (g) [3=1x2]	39.639	45.023	53.883
Total vehicle-km (vkm) [4]	109.017	120.756	148.190
Average PM emissions per vehicle-km (g PM/vkm) [3/4]	**0,364**	**0,373**	**0,364**

Indicator 8: Awareness level – bus drivers

Taking into account that for the considered baseline, the measure was not in implementation yet, the awareness level, defined as the % of the number of bus drivers with knowledge of the measure in the universe of total responding operators, must be equal to 0%.

Indicator 9: Acceptance level - bus drivers

The acceptance level was quantified by means of a survey carried out by SMTUC between 2 November 2009 and 11 December 2009, with a question placed to all buses drivers (284): "Do you agree with the introduction of biofuel in fleet of SMTUC?". It must be clear that the acceptance level in the baseline was measured between Nov 2009-Dec 2009, well before the beginning of the measure implementation.

The next table shows the Acceptance level of the SMTUC bus drivers before the measure implementation.

Table C1.2.9: Acceptance level (%), Ex-Ante.

Indicator and Data Used	Time Period	Ex-Ante Values
Number of Positive Answers to the Question "Do you agree with the introduction of biofuel in fleet of SMTUC?" [1]	2 Nov 2009- 11 Dec 2009	118
Total number of responding bus drivers [2]		176
Acceptance level (%) [1/2]		**67,05**

Indicator 10: Awareness level - marketing

For the same motive stated for indicator 8, the awareness level - marketing for the considered baseline must be equal to 0% (no buses could had the sticker communicating that they run with biofuel before the biofuel usage).

C1.3 Building the Business-as-Usual scenario

As mentioned in the Project Evaluation Plan document, the business as usual (BAU) scenario should consider the possible autonomous city development if a certain measure is not going to be implemented. For this measure particular case, the BAU is used to predict what would have happened in terms of possible adoption of biofuel blends for PT fleet if the measure would not have been implemented.

The CIVITAS MODERN was crucial to implement the testing of biofuel in SMTUC buses and without it, the testing would never take place within the period of the project. Taken into account that without CIVITAS no intervention would be foreseen, the BAU scenario will describe the autonomous trend to be followed by each of the indicators presented above, considering that in the BAU scenario, the 4 vehicles being tested would have run on 100% diesel instead of a biofuel mix.

The methodology used for the calculation of the emissions is similar to the one used for the baseline.

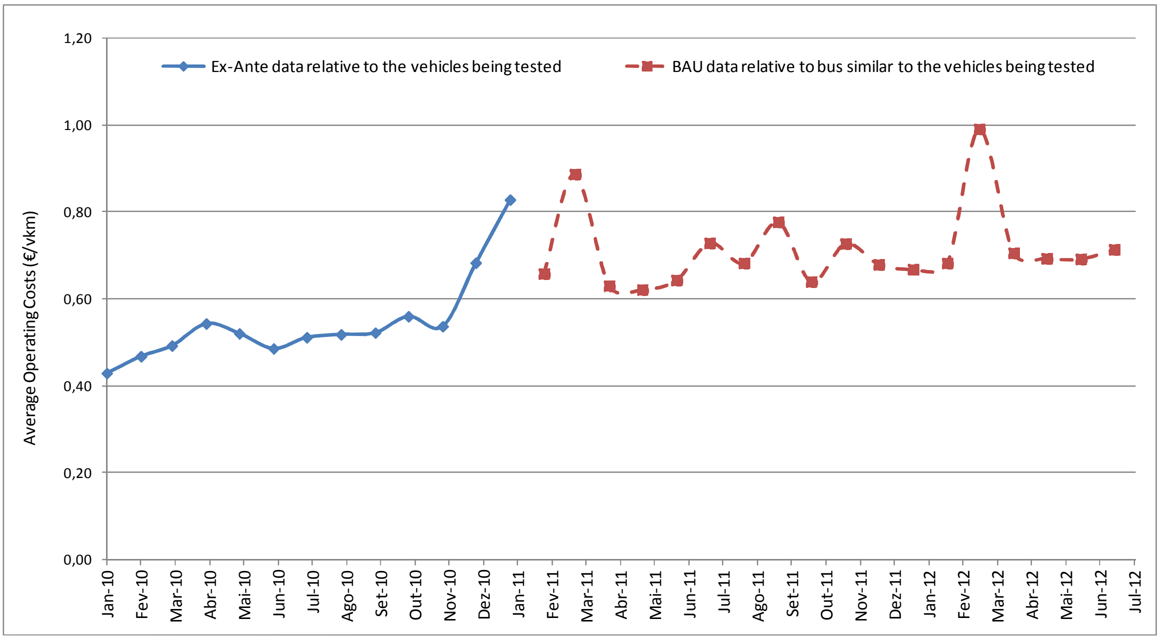
<u>Indicator 1: Average Operating Costs</u>

The BAU is in fact the average operating costs of 4 buses similar to the 4 vehicles being tested (same brand and series), running simultaneously and in similar operation conditions, but fuelled only on diesel instead of a biofuel mix. The BAU includes data registered in the period after the measure implementation, more precisely after Jan 2011 when the first buses where tested with B30, and the subsequent periods were coincident with the periods of the tests for each biofuel blend.

It is considered that there are no effects of other factors that may have influence in this indicator. In this case the BAU is just the real evolution of the baseline situation for 4 buses similar to the 4 vehicles being tested with biofuel during the same period, but consuming only diesel.

The same kind of rational was applied to the indicators of energy and emissions, taking into consideration the specific data used for calculation purposes.

The following Graph and tables, present Ex-Ante data and BAU associated to indicator 1 – Average Operating Costs.



Graph C1.3.1– Evolution of the average operating costs (€/vkm) of the vehicles being tested, Ex-ante and BAU scenario (Jan 2010 – Jul 2012).

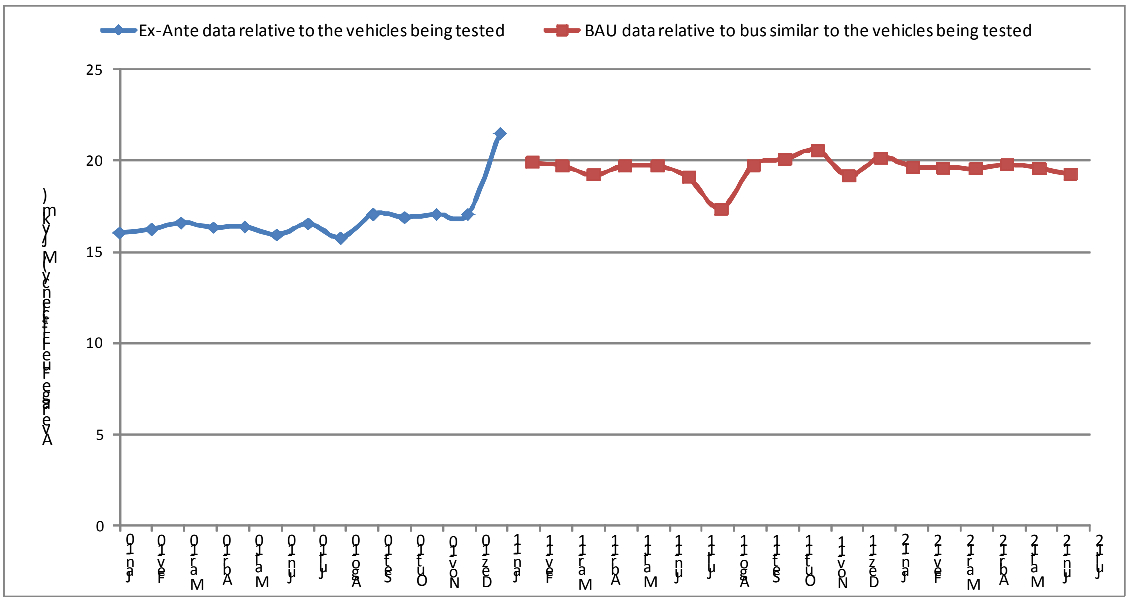
Overall the BAU trend reflects the increase of fuel and maintenance costs. This fact is particular evident in March 2011 and March 2012 where the maintenance costs, both for material and personnel, are higher in comparison with other months, but similar to January 2011 (ex-ante), and results mainly from regular engine revisions made each 25.000 Km (moment also used by SMTUC for change the biofuel mix). The BAU comprises 3 periods between Feb 2011 and July 2012, each one equal to the correspondent period for the specific bio fuel blend to allow the comparison with results achieved in homologous months of the ex-post period.

Table C1.3.1: Average Operating Costs (€/vkm), BAU.

Indicator and Data Used (4 Vehicles Being Tested)	Feb-Jun 11	Jul-Dec 11	Jan-Jul 12
Fuel Consumption Costs (€) [1]	48.194	52.715	64.444
Maintenance costs with personnel (€) [2]	2.714	3.704	5.961
Maintenance costs with material (€) [3]	8.089	9.875	9.533
Total costs (€) 4 = [1+2+3]	58.997	66.293	79.937
Total vehicle-km (vkm) [5]	85.969	93.827	108.748
Average fuel costs (€/vkm) [1/5]	0,561	0,562	0,593
Average operating costs (€/vkm) [4/5]	**0,686**	**0,707**	**0,735**

Indicator 2: Average Vehicle fuel efficiency

The same kind of rational was applied for establishing the BAU of the Average Vehicle fuel efficiency and the data is shown in Graph C1.3.2 and in the following tables.



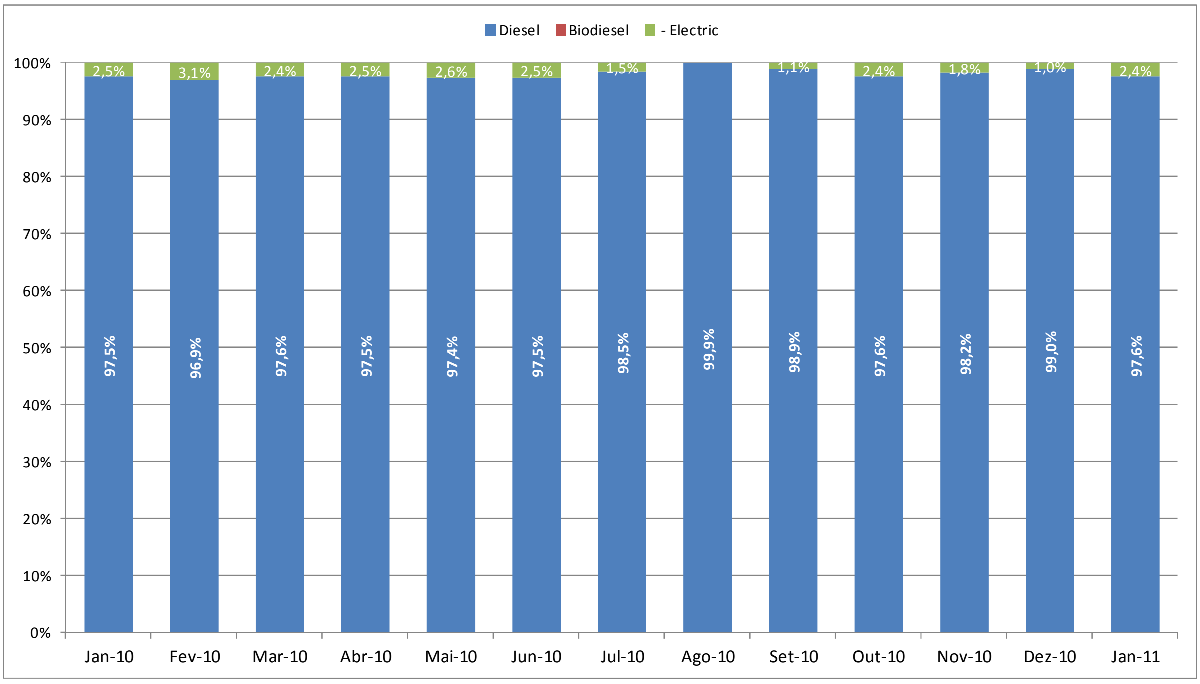
Graph C1.3.2 - Evolution of the average fuel efficiency (MJ/vkm) of the vehicles being tested, Ex-Ante and BAU scenario (Jan 2010 – Jul 2012).

Table C1.3.2: Average Vehicle fuel efficiency (MJ/vkm), BAU.

Indicator and Data Used (4 Vehicles Being Tested)	Feb-Jun 11	Jul-Dec 11	Jan-Jul 12
Total energy consumed by the vehicles (MJ) [1]	1.688.733	1.824.193	2.139.196
Total vehicle-km (vkm) [2]	85.969	93.827	108.748
Average Fuel Efficiency (MJ/vkm) [1/2]	**19,644**	**19,442**	**19,671**

Indicator 3: Fuel Mix

If the measure had not been implemented, the BAU would have followed the same trend of the baseline, which means that the contribution of the biofuel to the SMTUC fuel mix would have continued to be null, and the diesel would have probably kept the main role, with percentages in fuel mix above 96%, and with a minor contribution of the electric vehicles, between 1-2,5% (Graph C1.3.3).



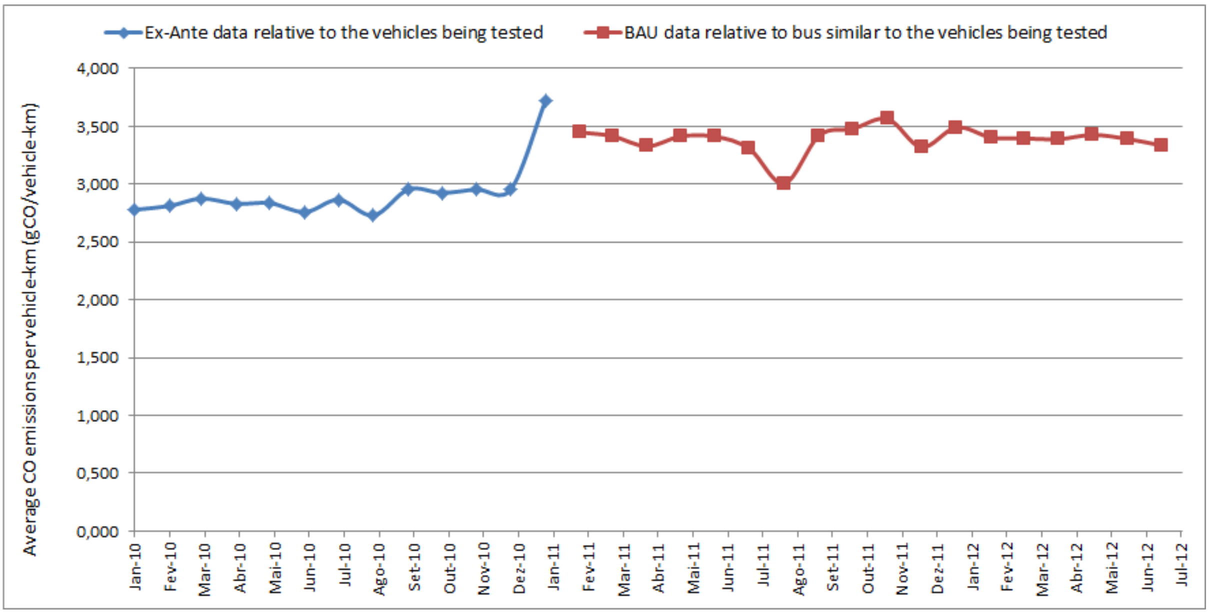
Graph C1.3.3 - Evolution of the fuel mix (% of type of fuel) of the SMTUC bus fleet, Ex-Ante and BAU scenario (Jan 2010 – Jul 2012).

Indicator 4 (CO Emissions)

For this indicator, the BAU is represented by the emissions associated with diesel consumption of 4 buses similar to the 4 vehicles being tested with biofuel in terms of technology, given the fact that if the measure had not been implemented this would have been the real situation.

In addition, the BAU scenario assumes that the 4 vehicles being tested with biofuel would not be replaced for another technology with lower emission factors.

Considering this criteria, for the BAU, the average CO emissions per vehicle km (vehicles running on diesel), are presented in , Graph C1.3.4 and Table C1.3.3



Graph C1.3.4 - Evolution of the average CO emissions per vehicle km of the vehicles being tested, Ex-Ante and BAU scenario (Jan 2010 – Jul 2012).

Table C1.3.3: Average CO emissions per vehicle-km (g CO/vkm), BAU.

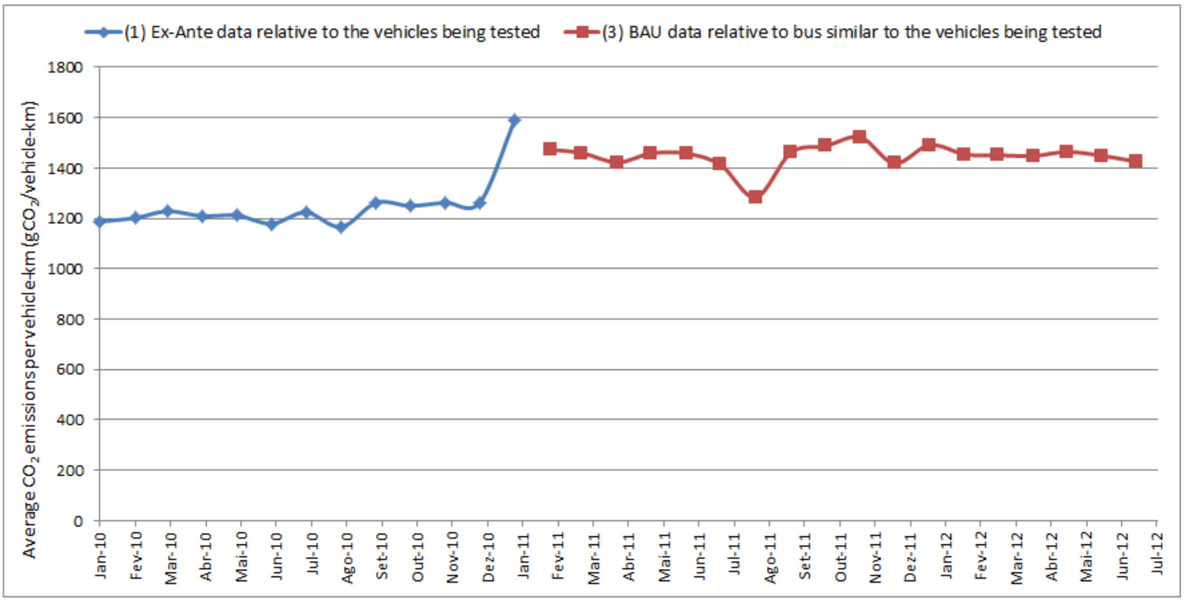
Indicator and Data Used (4 Vehicles Being Tested)	Feb-Jun 11	Jul-Dec 11	Jan-Jul 12
Total energy consumed by the vehicles (MJ) [1]	1.688.733	1.824.193	2.139.196
Emission Factor (kg CO/MJ) [2]	0,0001732		
Total CO emissions of the vehicles (g) [3=1x2]	307.871	349.683	418.499
Total vehicle-km (vkm) [4]	85.969	93.827	108.748
Average CO emissions per vehicle-km (g CO/vkm) [3/4]	**3,402**	**3,367**	**3,407**

Indicator 5 (CO_2 Emissions)

For this indicator, the BAU is represented by the emissions associated with diesel consumption of 4 buses similar to the 4 vehicles being tested with biofuel in terms of technology, given the fact that if the measure was not implemented that will be the real situation.

In addition, the BAU scenario assumes that 4 vehicles being tested with biofuel will not be replaced for another technology with lower emission factors.

Considering this criteria, for the BAU, the average CO_2 emissions per vehicle km (vehicles running on diesel), are presented in , Graph C1.3.5 and Table C1.3.4



Graph C1.3.5 - Evolution of the average CO_2 emissions per vehicle km of the vehicles being tested, Ex-Ante and BAU scenario (Jan 2010 – Jul 2012).

Table C1.3.4: Average CO_2 emissions per vehicle-km (g CO_2/vkm), BAU.

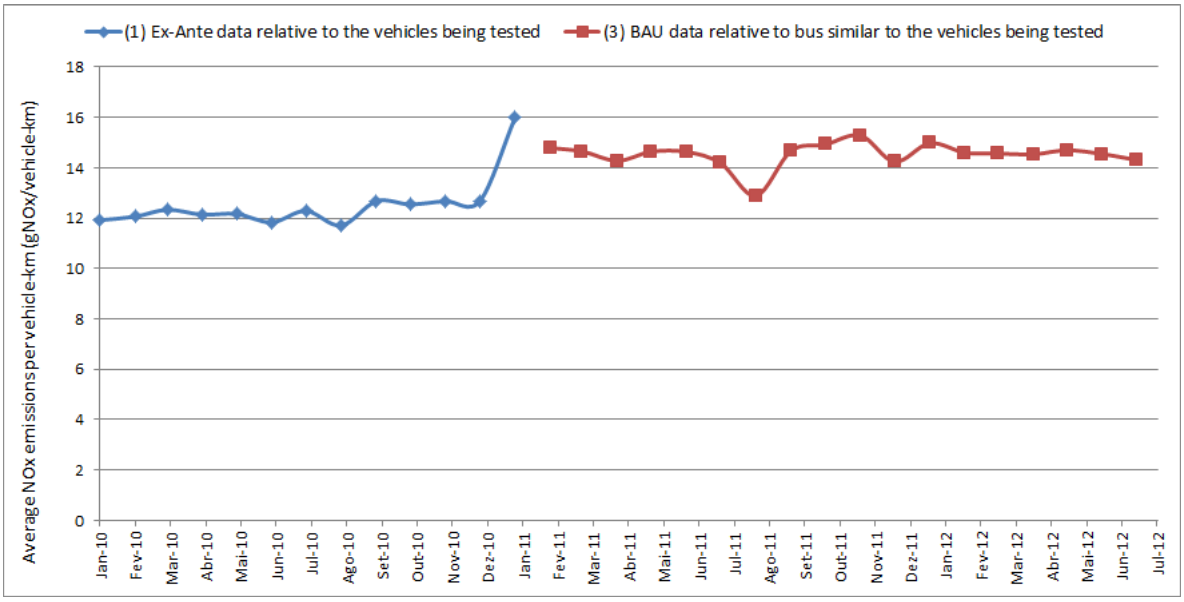
Indicator and Data Used (4 Vehicles Being Tested)	Feb-Jun 11	Jul-Dec 11	Jan-Jul 12
Total energy consumed by the vehicles (MJ) [1]	1.688.733	1.824.193	2.139.196
Emission Factor (kg CO_2/MJ) [2]	0,074		
Total CO_2 emissions of the vehicles (g) [3=1x2]	124.966.253	134.990.273	158.300.500
Total vehicle-km (vkm) [4]	85.969	93.827	108.748
Average CO_2 emissions per vehicle-km (g CO_2/vkm) [3/4]	1.453,620	1.438,715	1.455,664

Indicator 6 (NOx Emissions)

For this indicator, the BAU is represented by the emissions associated with diesel consumption of 4 buses similar to the 4 vehicles being tested with biofuel in terms of technology, given the fact that if the measure was not implemented that will be the real situation.

In addition, the BAU scenario assumes that 4 vehicles being tested with biofuel will not be replaced for another technology with lower emission factors.

Considering this criteria, for the BAU, the average NOx emissions per vehicle km (vehicles running on diesel), are presented in , Graph C1.3.6 and Table C1.3.4



Graph C1.3.6 - Evolution of the average NOx emissions per vehicle km of the vehicles being tested, Ex-Ante and BAU scenario (Jan 2010 – Jul 2012).

Table C1.3.5: Average NOx emissions per vehicle-km (g NOx/vkm), BAU.

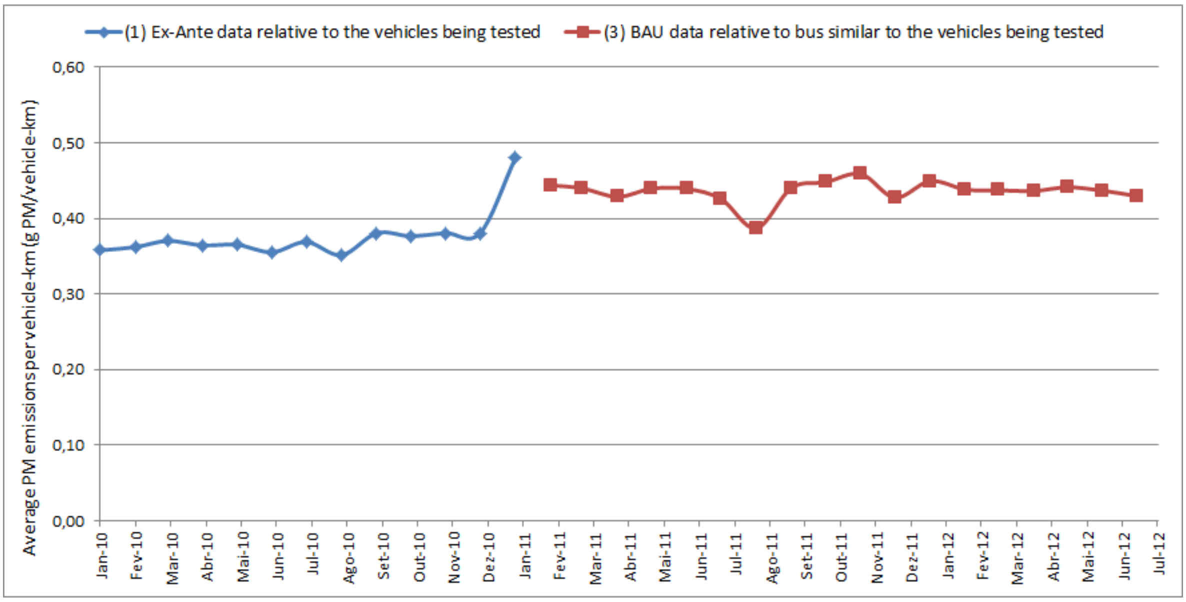
Indicator and Data Used (4 Vehicles Being Tested)	Feb-Jun 11	Jul-Dec 11	Jan-Jul 12
Total energy consumed by the vehicles (MJ) [1]	1.688.733	1.824.193	2.139.196
Emission Factor (kg NOx/MJ) [2]	0,0007429		
Total NOx emissions of the vehicles (g) [3=1x2]	1.254.560	1.355.193	1.589.209
Total vehicle-km (vkm) [4]	85.969	93.827	108.748
Average NOx emissions per vehicle-km (g NO_x/vkm) [3/4]	14,593	14,444	14,614

Indicator 7 (Small Particulate Emissions)

For this indicator, the BAU is represented by the emissions associated with diesel consumption of 4 buses similar to the 4 vehicles being tested with biofuel in terms of technology, given the fact that if the measure was not implemented that will be the real situation.

In addition, the BAU scenario assumes that 4 vehicles being tested with biofuel will not be replaced for another technology with lower emission factors.

Considering this criteria, for the BAU, the average PM emissions per vehicle km (vehicles running on diesel), are presented in , Graph C1.3.7 and Table C1.3.6.



Graph C1.3.7 - Evolution of the average PM emissions per vehicle km of the vehicles being tested, Ex-Ante and BAU scenario (Jan 2010 – Jul 2012).

Table C1.3.6: Average PM emissions per vehicle-km (g PM/vkm), BAU.

Indicator and Data Used (4 Vehicles Being Tested)	Feb-Jun 11	Jul-Dec 11	Jan-Jul 12
Total energy consumed by the vehicles (MJ) [1]	1.688.733	1.824.193	2.139.196
Emission Factor (kg PM/MJ) [2]	0,0000223		
Total PM emissions of the vehicles (g) [3=1x2]	37.659	40.680	47.704
Total vehicle-km (vkm) [4]	85.969	93.827	108.748
Average PM emissions per vehicle-km (g PM/vkm) [3/4]	0,438	0,434	0,439

Indicator 8: Awareness level - bus drivers

The awareness level is measured by considering the % of the SMTUC bus drivers with knowledge of the measure. For this indicator, the BAU is equal to the baseline situation, because if the measure had not been implemented, the awareness level would have been as before, equal to 0%. It is considered that there are no effects of other factors that have any influence in this indicator.

Indicator 9: Acceptance level - bus drivers

In the baseline situation, the acceptance level, measured as the % of buses drivers that agree with the introduction of biofuel in SMTUC fleet was about 67%. If the measure had not been implemented, there would be no reasons to assume that this acceptance level would have been different. In this case the BAU is equal to the baseline situation, meaning that bus drivers would have the same kind of acceptance level if the measure was not going to be implemented. The acceptance level in the baseline was measured between Nov 2009-Dec 2009, before the measure implementation, by means of a specific question placed on the Driver's Survey.

Table C1.3.7: Acceptance level (%), Ex-Ante and BAU.

Indicator and Data Used	Time Period	Ex-Ante and BAU Values
Number of Positive Answers to the Question "Do you agree with the introduction of biofuel in fleet of SMTUC?" [1]	2 Nov 2009- 11 Dec 2009	118
Total number of responding operators [2]		176
Acceptance level (%) [1/2]		**67,05**

Indicator 10: Awareness level - marketing

This indicator is measured as the percentage of the vehicles being tested that have a sticker communicating that the bus is running with biofuel. For the BAU, and considering that the measure was not implemented, the awareness level will be equal to a 0%, just like in the baseline situation.

C2 Measure results

The results are presented under sub headings corresponding to the areas used for indicators – economy, energy, environment, society and transport. When relevant, the data is illustrated by graphs in order to analyze trends, values and be more readable.

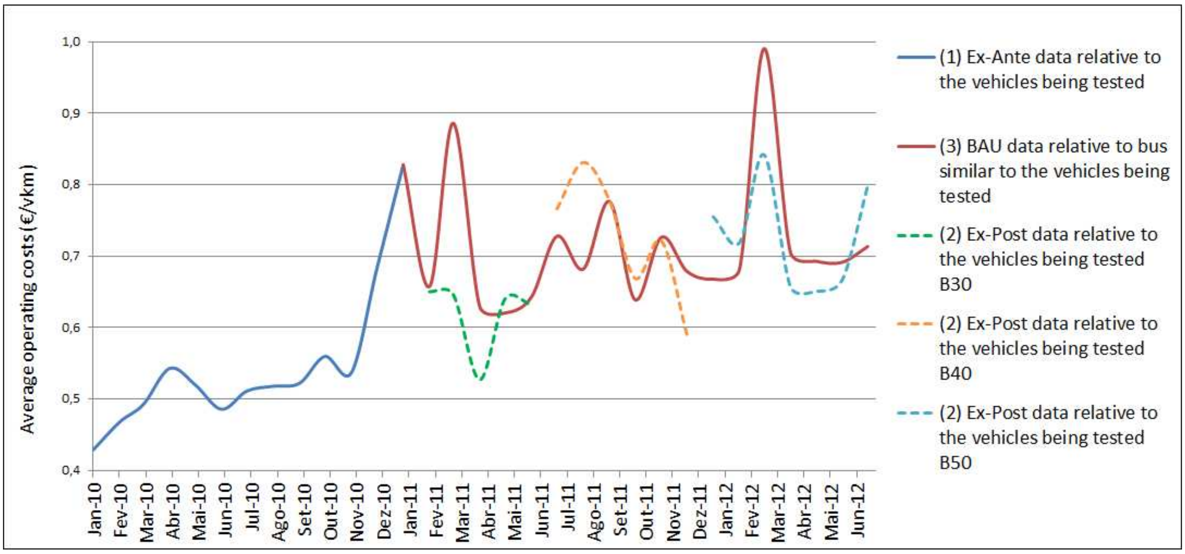
C2.1 Economy

Table C2.1.1: Average Operating Costs (€/vkm), Ex-Post.

Indicator and Data Used (4 vehicles being tested with biodiesel)	B30, Feb 11-Jun 11	B40, Jul 11-Dec 11	B50, Jan 12-Jul 12
Fuel Consumption Costs (€) [1]	34.530	23.387	50.531
Maintenance costs with personnel (€) [2]	3.024	1.921	3.434
Maintenance costs with material (€) [3]	5.787	8.592	8.144
Total costs (€) 4 = [1+2+3]	43.341	33.901	62.108
Total vehicle-km (vkm) [5]	70.312	46.917	86.234
Average Fuel costs (€/vkm) [1/5]	**0,491**	**0,498**	**0,586**
Average operating costs (€/vkm) [4/5]	**0,616**	**0,723**	**0,720**

In the majority of the ex-post period (Table C2.1.1 and Graph C2.1.1), it is possible to observe that the 4 vehicles being tested with B30 and B50, have lower average operating costs in comparison to BAU scenario for buses similar to the vehicles being tested, but running on diesel instead of biofuel mix. This is mainly a result of lower fuel consumption costs in the ex-post period in comparison with BAU due to lower biodiesel costs with respect to the diesel.

As explained in the section C1 the difference between different blending is due to the variation of weather conditions and of the buses composition (type) from a stage of biofuel mix to another.



Graph C2.1.1 - Evolution of the average operating costs (€/vkm) of the vehicles being tested, (Jan 2010 – Jul 2012).

Table C2.1.2: Average Operating Costs results.

Indicator	Ex-Ante		
	Feb-Jun 10	Jul-Dec 10	Jan-Jul 10
Average Fuel Costs (€/vkm)	0,394	0,414	0,391
1. Average Operating Costs (€/vkm)	**0,502**	**0,553**	**0,494**

Indicator	BAU			Ex-Post			Difference Ex Post- Ex Ante			Difference Ex Post - BAU		
	Feb-Jun 11	Jul-Dec 11	Jan-Jul 12	B30 Feb-Jun 11	B40 Jul-Dec 11	B50 Jan-Jul 12	B30	B40	B50	B30	B40	B50
Average Fuel Costs (€/vkm)	0,561	0,562	0,593	0,491	0,498	0,586	0,097	0,084	0,195	-0.07	-0,064	0,007
1. Average Operating Costs (€/vkm)	**0.686**	**0,707**	**0,735**	**0,616**	**0,723**	**0,720**	**0,114**	**0,170**	**0,226**	**-0,070**	**0,016**	**-0,015**

Comparing the ex-post and ex-ante results, it's possible to conclude that the average operating costs are higher in the ex-post period. However it should be highlighted that the fuel consumption costs were higher in 2011 and 2012 (ex-post period) in comparison with ex-ante period (Jan 2010-Jan 2011), as a result of higher oil prices. The average operating costs of B30 in the ex-post period is approximately 20% higher than the ex-ante values just in line with the increase of fossil fuel costs between periods.

Centring the focus of the analysis in the BAU and ex-post average operating costs, the results shows that the average operating costs with B30 and B50 biofuel blends are lower, respectively -0,007€/vkm (-10%) and -0,015 €/vkm (2%), than the BAU costs for the same time periods, Table C2.1.1.

After the below analyse of the fuel efficiency this phenomenon could be better addressed. The problem is the increase in the fuel consumption that didn't has been compensated by the decrease in the biofuel prices comparing to the diesel prices. The results could be others if more quantity of biofuel will be purchased, namely the prices of the biofuel will decrease if SMTUC negotiate the prices to fuel all the fleet in spite the 4 buses used for the tests.

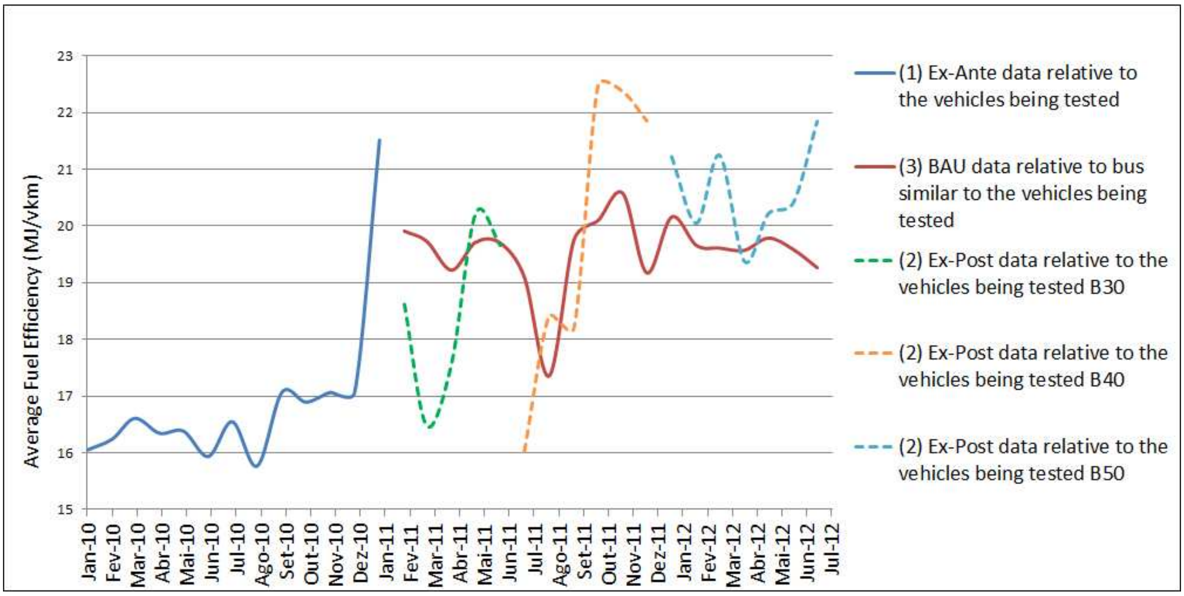
C2.2 Energy

C2.2.1 Average Fuel Efficiency

Table C2.2.1.1: Average Fuel Efficiency (MJ/vkm), Ex-Post.

Indicator and Data Used (4 vehicles being tested with biodiesel)	B30, Feb 11-Jun 11	B40, Jul 11-Dec 11	B50, Jan 12-Jul 12
Total energy consumed by the vehicles (MJ) [1]	1.269.194	929.102	1.775.449
Total vehicle-km (vkm) [2]	70.312	46.917	86.234
Average Fuel Efficiency (MJ/vkm) [1/2]	**18,051**	**19,803**	**20,589**

The results presented in the graph, C2.2.1.1 and Table C2.2.1.2, show that excluding a particular period (between January and April of 2011) when the vehicles were tested with B30, the average fuel efficiency of the 4 vehicles being tested with biofuel blends is normally not as good as the ones registered for similar vehicles running on diesel. This difference is worst when comparing the results with the baseline than the comparison with the BAU scenario. The reasons seems to be the difference in the weather conditions between the 2 periods (the baseline during 2010 and the ex-post results during 2011 and 2012), while the BAU scenario has been assessed with the 4 reference buses running simultaneously with the 4 buses being tested.



Graph 2.2.1.1 - Evolution of the average fuel efficiency (MJ/vkm) of the vehicles being tested, (Jan 2010 – Jul 2012).

Table C2.2.1.2: Average Fuel Efficiency results.

Indicator	Ex-Ante		
	Feb-Jun 10	Jul-Dec 10	Jan-Jul 10
2. Average Fuel Efficiency (MJ/vkm)	16,305	16,719	16,305

Indicator	BAU			Ex-Post			Difference Ex Post - Ex Ante			Difference Ex Post - BAU		
	Feb-Jun 11	Jul-Dec 11	Jan-Jul 12	B30 Feb-Jun 11	B40 Jul-Dec 11	B50 Jan-Jul 12	B30	B40	B50	B30	B40	B50
2. Average Fuel Efficiency (MJ/vkm)	19,644	19,442	19,671	18,051	19,803	20,589	1,746	3,084	4,283	-1,593	0,361	0,918

C2.2.2 Fuel Mix

Table C2.2.2.1: Average Fuel Mix (%), Ex-Post.

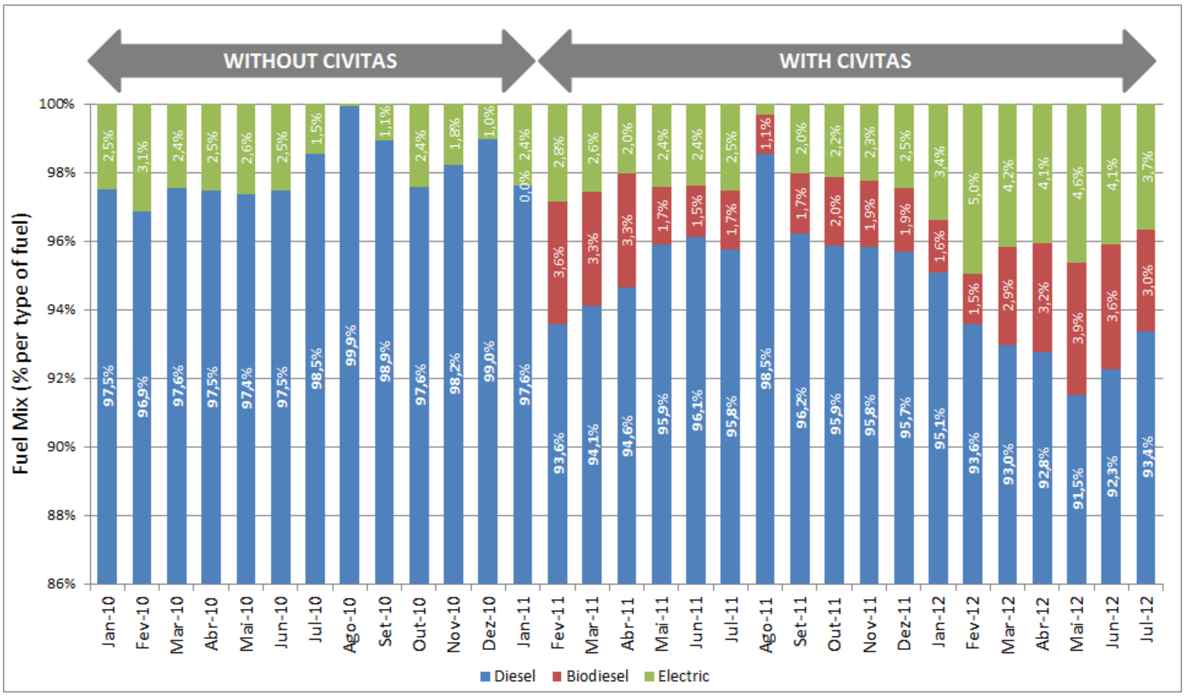
Indicator and Data Used (SMTUC bus fleet)	B30, Feb 11-Jun 11	B40, Jul 11-Dec 11	B50, Jan 12-Jul 12
Total Energy consumed by the Diesel vehicles (MJ)	45.215.585	51.376.541	59.966.092
Total Energy consumed by the Biofuel vehicles (MJ)	1.269.194	929.102	1.775.449
Total Energy consumed by the Electric vehicles (MJ)	1.170.022	1.065.894	2.654.155
Fuel Mix (%)		-	-
- Diesel	**94,88%**	**96,26%**	**93,12%**
- Biofuel	**2,66%**	**1,74%**	**2,76%**
- Electric	**2,46%**	**2,00%**	**4,12%**

The impact of measure implementation is clear (Table C2.2.2.1). The biofuel contribution in SMTUC fuel mix, increases from 0% to 2,76%. On the contrary, the weight of diesel in SMTUC overall fuel mix decreases approximately 4,43%, Table C2.2.2.2 and Graph C2.2.2.1.

Table C2.2.2.2: Average Fuel Mix results.

Indicator	Ex-Ante		
3. Fuel Mix (% per type of fuel)	**Feb-Jun 10**	**Jul-Dec 10**	**Jan-Jul 10**
- Diesel	97,36%	98,67%	97,55%
- Biofuel	0,00%	0,00%	0,00%
- Electric	2,64%	1,33%	2,45%

Indicator	BAU			Ex-Post			Difference Ex Post - Ex Ante			Difference Ex Post - BAU		
	Feb-Jun 11	Jul-Dec 11	Jan-Jul 12	B30 Feb-Jun 11	B40 Jul-Dec 11	B50 Jan-Jul 12	B30	B40	B50	B30	B40	B50
3. Fuel Mix (% per type of fuel)												
- Diesel	97,36%	98,67%	97,55%	94,88%	96,26%	93,12%	-2,48%	-2,40%	-4,43%	- 2,48%	- 2,40%	- 4,43%
- Biofuel	0,00%	0,00%	0,00%	2,66%	1,74%	2,76%	2,66%	1,74%	2,76%	2,66%	1,74%	2,76%
- Electric	2,64%	1,33%	2,45%	2,46%	2,00%	4,12%	-0,19%	0,66%	1,67%	- 0,19%	0,66%	1,67%



Graph C2.2.2.1 - Evolution of the fuel mix of the SMTUC bus fleet, with and without CIVITAS implementation (Jan 2010 – Jul 2012).

C2.3 Environment

Given the fact that there is no specific data coming from direct emissions measurements, is important to state that according to EMEP/European Environment Agency (EEA) emission inventory guidebook 2009, updated May 2012, on exhaust emissions from road transport[2], the use of biofuel as a blend with diesel may lead to some change in emissions, and this fact was taken into consideration on the calculations. The values proposed in the following table are differences in emissions caused by different biofuel blends with fossil diesel, and correspond to a Euro 3 vehicle/engine technology, just like the vehicles that were tested in the context of this specific measure.

Pollutant	Vehicle Type	B10	B20	B100
CO_2	Passenger Cars	-1.5%	-2.0%	
	Light duty vehicles	-0.7%	-1.5%	
	Heavy duty vehicles	0.2%	0.0%	0.1%
NO_x	Passenger Cars	0.4%	1.0%	
	Light duty vehicles	1.7%	2.0%	
	Heavy duty vehicles	3.0%	3.5%	9.0%
PM	Passenger Cars	-13.0%	-20.0%	
	Light duty vehicles	-15.0%	-20.0%	
	Heavy duty vehicles	-10.0%	-15.0%	-47.0%
CO	Passenger Cars	0.0%	-5.0%	
	Light duty vehicles	0.0%	-6.0%	
	Heavy duty vehicles	-5.0%	-9.0%	-20.0%
HC	Passenger Cars	0.0%	-10.0%	
	Light duty vehicles	-10.0%	-15.0%	
	Heavy duty vehicles	-10.0%	-15.0%	-17.0%

Source: (EEA/EMEP, 2009)

Taking into account that the EMEP/EEA emission inventory guidebook does not explicitly refer biodiesel blends similar to the ones that were tested, B30, B40 and B50, the differences in emissions caused by different biofuel blends expressed in %, were derived from linear regression of the values presented in the table above.

Table C2.3.1: Derived emission factors, Diesel+Biodiesel.

Pollutant	Emission Factors (kg/MJ)		
	B30	**B40**	**B50**
CO	0,000157	0,000154	0,000152
CO_2	0,074		
NOx	0,000775	0,000779	0,000785
PM	0,0000182	0,0000173	0,0000163

Source: Adapted from EMEP/EEA 2009.

According to the EMEP/EEA emission inventory guidebook, the effect of biofuel on other technologies may vary, but the extent of the variation is difficult to estimate in the absence of detailed data. With regard to NO_x, CO_2 and CO, any effect of technology should be negligible, given the marginal effect of biofuel on these pollutants in general.

In the next results of the average emissions 2 general issues have been addressed, both related to the results of the indicator Average Fuel Efficiency:

[2] http://eea.europa.eu/emep-eea guidebook

- The already reported difference in the fuel efficiency that is low when comparing the results with the baseline than with the BAU scenario, due different whether conditions. This fact influenced the related indicator of the emissions, causing worst results in the comparison between the ex-post and the baseline scenario.
- For some blends and some pollutants seems that the above assessed decrease in the fuel efficiency have a higher influence than the decrease in the emissions factor related to the biofuel use, causing an increase in the emissions.

The next tables show the results of the emissions (CO, CO_2, NO_X and PM), as well as the comparison with the baseline and the BAU.

<u>Indicator 4: Average CO Emissions</u>

Table C2.3.2: Average CO emissions per vehicle-km (g CO/vkm), Ex-Post.

Indicator and Data Used (4 Vehicles Being Tested)	B30 Feb-Jun 11	B40 Jul-Dec 11	B50 Jan-Jul 12
Total energy consumed by the vehicles (MJ) [1]	1.269.194	929.102	1.775.449
Emission Factor (kg CO/MJ) [2]	0,000157	0,000154	0,000152
Total CO emissions of the vehicles (g) [3=1x2]	199.381	143.541	269.377
Total vehicle-km (vkm) [4]	70.312	46.917	86.234
Average CO emissions per vehicle-km (g CO/vkm) [3/4]	2,836	3,059	3,124

The results presented in Table C2.3.3, shows that when comparing the results of the ex-post period with the BAU scenario the average CO emissions have a reduction, with the major relevance for the B30 blend (-20%). Comparing with the baseline, the average CO emissions increases by a small percentage for all biodiesel blends that were tested. Considering only B30, the average emissions increased from 2,824 gCO/vkm in the baseline period to 2,836 gCO/vkm in the ex-post, representing an overall increase of about 0,4%.

Table C2.3.3: Average CO emissions results.

Indicator	Ex-Ante		
	Feb-Jun 10	Jul-Dec 10	Jan-Jul 10
Average CO emissions per vehicle-km (g CO/vkm)	2,824	2,896	2,824

Indicator	BAU			Ex-Post			Difference: Ex Post – Ex ante			Difference: Ex-post-BAU		
	Feb-Jun 11	Jul-Dec 11	Jan-Jul 12	Feb-Jun 11	Jul-Dec 11	Jan-Jul 12						
				B30	B40	B50	B30	B40	B50	B30	B40	B50
Average CO emissions per vehicle-km (g CO/vkm)	3,402	3,367	3,407	2,836	3,059	3,124	0,012	0,164	0,300	-0,567	-0,308	-0,283

Indicator 5: Average CO_2 Emissions

Table C2.3.4: Average CO_2 emissions per vehicle-km (g CO_2/vkm), Ex-Post.

Indicator and Data Used (4 Vehicles Being Tested)	B30 Feb-Jun 11	B40 Jul-Dec 11	B50 Jan-Jul 12
Total energy consumed by the vehicles (MJ) [1]	1.269.194	929.102	1.775.449
Emission Factor (kg CO_2/MJ) [2]	0,074	0,074	0,074
Total CO_2 emissions of the vehicles (g) [3=1x2]	93.920.341	68.753.539	131.383.237
Total vehicle-km (vkm) [4]	70.312	46.917	86.234
Average CO_2 emissions per vehicle-km (g CO_2/vkm) [3/4]	1.335,765	1.465,429	1.523,567

As mentioned above, the use of biofuel has a marginal effect in terms of CO_2 emissions. The results presented in Table C2.3.5 reflect this aspect, but in any case for B30 has been assessed a decrease in the emissions when comparing the results with the BAU scenario.

Table C2.3.5: Average CO_2 emissions results.

Indicator	Ex-Ante		
	Feb-Jun 10	Jul-Dec 10	Jan-Jul 10
Average CO_2 emissions per vehicle-km (g CO_2/vkm)	1.206,585	1.237,226	1206,588

Indicator	BAU			Ex-Post			Difference: Ex Post – Ex ante			Difference: Ex-post-BAU		
	Feb-Jun 11	Jul-Dec 11	Jan-Jul 12	Feb-Jun 11	Jul-Dec 11	Jan-Jul 12						
				B30	B40	B50	B30	B40	B50	B30	B40	B50
Average CO_2 emissions per vehicle-km (g CO_2/vkm)	1.453,620	1.438,715	1.455,664	1.335,765	1.465,429	1.523,567	129,181	228,203	319,979	-117,854	26,715	67,903

Indicator 6: Average NOx Emissions (g NOx/vkm)

Table C2.3.6: Average NOx emissions per vehicle-km (g NOx/vkm), Ex-Post.

Indicator and Data Used (4 Vehicles Being Tested)	B30 Feb-Jun 11	B40 Jul-Dec 11	B50 Jan-Jul 12
Total energy consumed by the vehicles (MJ) [1]	1.269.194	929.102	1.775.449
Emission Factor (kg NOx/MJ) [2]	0,00077	0,00078	0,00078
Total NOx emissions of the vehicles (g) [3=1x2]	983.428	724.051	1.392.844
Total vehicle-km (vkm) [4]	70.312	46.917	86.234
Average NOx emissions per vehicle-km (g NOx/vkm) [3/4]	13,987	15,433	16,152

As mentioned in the EMEP/EEA emission inventory guidebook, the introduction of biofuel in the diesel normally implies an increase in terms of NOx emissions. For B30, the average NOx emissions increased lightly from an average value of 12,113 g NOx/vkm in the baseline period to 13,987 g NOx/vkm in the ex-post period. But the assessed results for a B30 blend shows a reduction in the emissions when comparing the ex-post with the BAU scenario.

Table C2.3.7: Average NOx emissions results.

Indicator	Ex-Ante		
	Feb-Jun 10	Jul-Dec 10	Jan-Jul 10
Average NOx emissions per vehicle-km (g NOx/vkm)	12,113	12,421	12,113

Indicator	BAU			Ex-Post			Difference: Ex Post – Ex ante			Difference: Ex-post-BAU		
	Feb-Jun 11	Jul-Dec 11	Jan-Jul 12	Feb-Jun 11	Jul-Dec 11	Jan-Jul 12						
				B30	B40	B50	B30	B40	B50	B30	B40	B50
Average NOx emissions per vehicle-km (g NOx/vkm)	14,593	14,444	14,614	13,987	15,433	16,152	1,873	3,012	4,039	-0,607	0,989	1,538

Indicator 7: Average PM Emissions (g PM/vkm)

Table C2.3.8: Average PM emissions per vehicle-km (g PM/vkm), Ex-Post.

Indicator and Data Used (4 Vehicles Being Tested)	B30 Feb-Jun 11	B40 Jul-Dec 11	B50 Jan-Jul 12
Total energy consumed by the vehicles (MJ) [1]	1.269.194	929.102	1.775.449
Emission Factor (kg PM/MJ) [2]	0,0000182	0,0000173	0,0000163
Total PM emissions of the vehicles (g) [3=1x2]	23.039	16.036	29.021
Total vehicle-km (vkm) [4]	70.312	46.917	86.234
Average PM emissions per vehicle-km (g PM/vkm) [3/4]	0,328	0,342	0,337

The results presented in Table C2.3.9, shows that when comparing the results of the ex-post period with baseline and BAU scenario, the average PM emissions decreases for all biofuel blends that were tested. Considering only B30, the average emissions decreased 20% when comparing the ex-post with the BAU scenario and 10% in the comparison with the baseline.

Table C2.3.9: Average PM emissions results.

Indicator	Ex-Ante		
	Feb-Jun 10	Jul-Dec 10	Jan-Jul 10
Average PM emissions per vehicle-km (g PM/vkm)	0,364	0,373	0,364

Indicator	BAU			Ex-Post			Difference: Ex Post – Ex ante			Difference: Ex-post-BAU		
	Feb-Jun 11	Jul-Dec 11	Jan-Jul 12	Feb-Jun 11	Jul-Dec 11	Jan-Jul 12						
				B30	B40	B50	B30	B40	B50	B30	B40	B50
Average PM emissions per vehicle-km (g PM/vkm)	0,438	0,434	0,439	0,328	0,342	0,337	-0,036	-0,031	-0,027	-0,110	-0,092	-0,102

C2.4 Society

C2.4.1 Awareness level – bus drivers

After measurement implementation, 100% of the SMTUC bus drivers have now knowledge of the measure extent, Table C2.5.1.1.

Table C2.4.1.1: Awareness level results.

Indicator	Ex-Ante Baseline	BAU	Ex Post	Difference: Ex Post –Ex Ante	Difference: Ex Post – BAU
	Jan 2010-Jan 2011	Feb 2011-Jul 2012	Feb 2011-Jul 2012		
8. Awareness Level (%)	0	0	100	100	100

C2.4.2 Acceptance level – bus drivers

Next tables show results of the Acceptance level of the SMTUC bus drivers after the measure implementation and the comparison with the baseline and BAU cases.

Table C2.4.2.1: Acceptance level (%), Ex-Post.

Indicator and Data Used	Time Period	Ex-Post Values
Number of Positive Answers to the Question "Do you agree with the introduction of biofuel in fleet of SMTUC?" [1]	7 Nov 2011-16 Dec 2011	167
Total number of responding drivers [2]		193
Acceptance level (%) [1/2]		**86,53**

Table C2.4.2.2: Acceptance level results.

Indicator	Ex-Ante Baseline 2 Nov 2009-11 Dec 2009	BAU	Ex Post Nov 2011-Dec 2011	Difference: Ex Post –Ex Ante	Difference: Ex Post – BAU
9. Acceptance Level (%)	67,05	67,05	86,53	19,48	19,48

The measure acceptance level increases from 67% to 86%, approximately 20%, which indicates that the measure has a significant level of acceptance in SMTUC universe.

C2.4.3 Awareness level - marketing

All of the four vehicles being tested with biofuel have now a sticker and so the percentage of the vehicles being tested that have a sticker communicating the measure is in fact 100% (Table C2.5.3.1).

Table C2.4.3.1: Awareness level- marketing, results.

Indicator	Ex-Ante Baseline Jan 2010-Jan 2011	BAU	Ex Post Feb 2011-Jul 2012	Difference: Ex Post –Ex Ante	Difference: Ex Post – BAU
10. Awareness Level – Marketing (%)	0	0	100	100	100

C3 Achievement of quantifiable targets and objectives

No.	Target	Rating
1	To test by running at least 10 cycles per bus the reliability of increase the percentages of biofuel mixes in 4 different brands of Urban PT fleet in order to surpass the 25% of biofuel mix of SMTUC fleet in the future. The buses being tested ran a different cycle each week (changing the real operation conditions between cycles). So each bus ran between 20 to 81 cycles largely surpassing the objectives. The tests has been carried out with biofuel mixes from 30% to 50% that largely exceeded the initially foreseen	★★★
2	To demonstrate that with this measure may decrease by 15% emissions of CO related to PT vehicles in Coimbra. To reduce the emission of greenhouse gases related to PT vehicles in Coimbra by 2%. CO and PM emissions could achieve a decrease of 20% with the low biofuel mix tested (30%)	★★★
3	To carry out awareness campaigns to highlight the importance of using alternative fuels. All the buses running biofuel mix have a sticker informing this fact. Other campaigns have been also carried out and the measure has been presented in several events and to other fleet operators.	★★
NA = Not Assessed O = Not Achieved ★ = Substantially achieved (at least 50%) ★★ = Achieved in full ★★★ = Exceeded		

C4 Up-scaling of results

As described above, the measure consisted in testing different biofuel mix's (B30, B40 and B50) in 4 buses running in real operation conditions, in order to assess the possibility of supply SMTUC entire fleet. For this measure, up-scaling will be a necessary process to estimate the impacts of the measure, not only on 4 vehicles, but on the entire SMTUC bus fleet, of about 100 buses.

Operating Costs

Table C4.1: Average operating costs (€/vkm).

Average Operating Costs (€/vkm)	B30	B40	B50
	Feb 11 – Jun 11	Jul 11 – Dec 11	Jan 12 – Jul 12
Ex-Post data relative to the vehicles being tested [1]	0,616	0,723	0,720
BAU data relative to bus similar to the vehicles being tested [2]	0,686	0,707	0,735
Difference (A-B) [1-2]	**-0,07 (-10%)**	0,016	-0,015

Considering the data collected and the results presented in the above table, it's possible to estimate the impact that biofuel will have in the entire SMTUC fleet in terms of average operating costs. For this exercise it will be assumed two main issues: 1) The 100 vehicles of the SMTUC fleet will run on B30, which would be a conservative perspective; 2) Based on historical data, the entire fleet would have an annual value of approximately 6.000.000 vkm. Based on this assumptions the introduction of B30 in the entire SMTUC bus fleet could represent savings of about 420.000 €/year.

Fuel Consumption

Table C4.2: Average vehicle fuel efficiency (MJ/vkm)

	B30	B40	B50
	Feb 11 – Jun 11	Jul 11 – Dec 11	Jan 12 – Jul 12
Ex-Post data relative to the vehicles being tested (A)	18,051	19,803	20,589
BAU data relative to bus similar to the vehicles being tested (B)	19,644	19,442	19,671
Difference (A-B)	-1,593 (-8%)	0,361	0,918

Taking into consideration the above assumptions, 100 vehicles running on B30 and 6.000.000 vkm for the entire SMTUC fleet, the measure up-scaling could result in savings of approximately 9.555.769 MJ of diesel consumption. Based on data of Portuguese Environment Agency, diesel Low Heating Value is 42,60 GJ/t and average density is 0,835 kg/l, and so the measure up scaling will represent the replacement of approximately 268.000 l of diesel.

Emissions

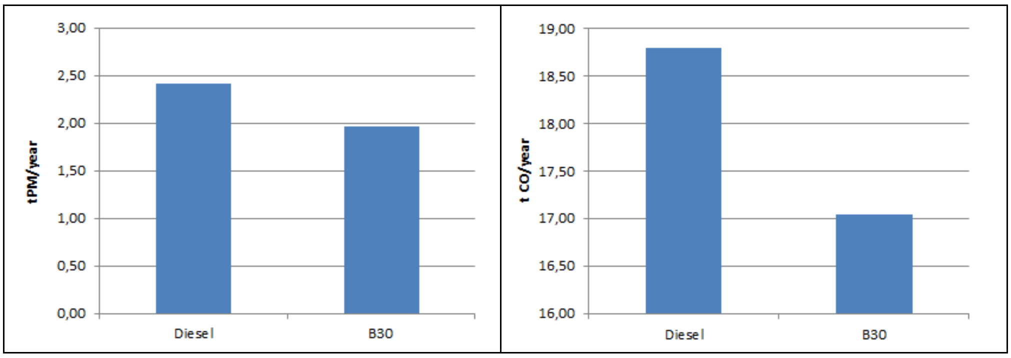
As mentioned in point C2.3 of the report, the use of biofuel as a blend with diesel may lead to some change in emissions. According to EMEP/EEA emission inventory guidebook 2009, the more relevant changes in terms of emissions are related to two specific pollutants, PM and CO.

Table C4.3: Emission factors for PM and CO,kg/MJ.

Average Emission Factors (4 vehicles being tested with biodiesel)	PM		CO	
	Diesel	B30	Diesel	B30
	0,0000223	0,0000182	0,000173	0,000157

Source: Portuguese Environmental Agency 2012 and EMEP/EEA, 2009.

If B30 was used in all vehicles of the SMTUC bus fleet, and assuming an annual diesel consumption of 3.026.128,64 litres, the total PM emissions of the fleet in a given year, may fall from about 2,4tPM/year to 2,0 tPM/year, representing an overall reduction of approximately 17%. For CO, the reduction may not be so dramatic, but will still represent a decrease of 10%, from 18,8 tCO/year to 17,0 tCO/year.



Graph C4.1and C4.2: Measure up scaling potential results on emissions per year.

C5 Appraisal of evaluation approach

Taken into consideration that was not made direct measurements of the vehicles exhaust emissions, the approach to emissions estimation was based on average European emission factors that were determined using based model methodology with COPERT.

The calculation of total emissions of the vehicles being tested and of the rest of the SMTUC bus vehicles, is based on emission factors, specific for pollutant and type of vehicle technology (e.g. Conventional, Euro 1, ...), according to the EMEP/European Environment Agency (EEA) emission inventory guidebook 2009, updated May 2012, on exhaust emissions from road transport[3]. These average European emission factors were determined using the Tier 3 methodology (based model with COPERT) which follows in using typical values for driving speeds, ambient, temperatures, highway-rural-urban mode mix, trip length.

The EMEP/EEA air pollutant emission inventory guidebook (formerly referred to as the EMEP CORINAIR emission inventory guidebook) provides guidance on estimating emissions from both anthropogenic and natural emission sources. It is designed to facilitate reporting of emission inventories by countries to the UNECE Convention on Long-range Trans boundary Air Pollution and the EU National Emission Ceilings Directive.

Overall, the approach to emissions estimations was based in a solid bibliographic source. Taking into account that exist some uncertainties related to the effect of biofuel for different technologies and pollutants, the direct measurements would probably be a more accurate method for emissions indicators.

During a second phase after POINTER revision the split of the baseline data in 3 periods corresponding to each test period per bio fuel blend has been carried out. This methodology allowed a more correct comparison ex-post – baseline scenarios, namely taking into consideration the seasonality effects.

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3 http://eea.europa.eu/emep-eea guidebook

C6 Summary of evaluation results

The key results are as follows:

- **Average Operating Costs Reduction** – The average operating costs of the 4 vehicles tested with B30 and B50 biofuel blends, are lower than average operating costs of similar vehicles running on diesel for the same period. The difference is more evident for B30, were the average operating costs in the ex-post are 10% lower than the BAU scenario (similar vehicles running on diesel).

- **PM Emissions Reductions** – The use of biofuel as a blend with diesel may lead to some change in emissions, but for NO_x and CO_2, biofuel has in general a marginal effect. Considering the average PM emissions per vehicle-km, the results with B30 shows that a reduction from 0,438 g PM/vkm in the BAU scenario to 0,328 g PM/vkm after measure implementation (-20%). For the same blend the reduction in the CO emissions has also been 20%.

  In the future, if B30 was consumed in all vehicles of the SMTUC bus fleet (100 vehicles), the total PM emissions of the fleet in a given year (assuming an annual diesel consumption of 3.026.128,64 litres), may fall from about 2,4 tPM/year to 2,0 tPM/year, representing an overall reduction of approximately 19%.

- **Biofuel Penetration in the Fuel Mix** – The measure implementation, enabled the penetration of biodiesel in the SMTUC fuel mix, from 0% to 2,76%, and at the same time, the weight of diesel in overall fuel mix decreased approximately 4,43%.

- **Acceptance Level Increase** – The measure implementation resulted in a sharp increase of the measure acceptance level by the buses operators, increasing from 67,05% to 86,53%;

- **Measure Upscale –** According to the measure results, the introduction of B30 in the entire SMTUC bus fleet (100 vehicles) could represent savings in operating costs of about 420.000 €/year and a replacement of approximately 268.000 litres of diesel.

C7 Future activities relating to the measure

A full-scale experimentation for the major part of the SMTUC bus fleet and on regular public service is in analysing. In case positive priority will be given to oil residues, such as cooking oils from the large university complexes and the two central hospitals. Contacts with the municipal waste management service is in course to allow the oil collection in the future.

D Process Evaluation Findings

D.1 Deviations from the original plan

The deviations from the original plan comprised:

- **The start level of the percentage of biofuel mix to be tested was higher than the initially planned** – In the planning of the CIVITAS MODERN project there was no experience about biofuel use in Portugal and the bus manufactures advised not surpass 20% biofuel use. For this reason the initial plan forecast that the test start with 21% of biofuel mix, incrementing only 1% between each set of tests. During the measure setup SMTUC technicians carried out visits to other PT operators having fleets running biofuel, namely TUB – the public transportation company of the city of Braga. Using the knowledge obtained during these visits it was decided to start the tests with 30% biofuel mix, incrementing 10% each test set until 50%, the level that TUB considered acceptable for their entire fleet, after having problems when using higher biofuel percentages – they experimented mixes until 100% biofuel percentage, but without important results assessment concerning certain areas as the emissions. This decision allowed more ambitious results but without important risks related to the expected buses performances.

- **The measure was extended more 4 months to allow a more complete and effective monitoring and evaluation of the buses running with biofuel –** Two buses equipped with "common rail" technology in the diesel injection, had problems in this fuel feed system, namely with "gel" in the filters and injectors, forcing the stop of the tests for this type of buses on 5th and 10th May 2011 (mix at 30%). Considering that the biofuel tests only involved 4 buses, it was considered important to change these buses by other 2 buses equipped with different technology. The time needed to prepare these buses caused a gap between the initial buses running the tests and the new ones. For this reason in May 2012 the last buses performed only 10 thousand kilometres with 50% biofuel mix. To allow a more complete and effective monitoring of all buses it was decided to extended the tests until September 2012. This fact obliged to a consequent 4 month extension of the measure duration to comprise the evaluation tasks.

D.2 Barriers and drivers

D.2.1 Barriers

Preparation phase

- **Barrier 1.1 – Technological Barrier** – Lack of know-how and experience about Biofuel use at National level required key measures persons to spend more time in training and knowledge acquisition that the initially foreseen for the preparation phase. In addition there is a cultural resistance to the biofuel use caused by environmental reservations concerning some fuel sources and by some bus manufacturer opinions emphasising the risks of the biofuel use.

Implementation phase

- **Barrier 2.1 – Technological Barrier** – The equipment available by the ISEC (College of Engineering of Coimbra) for the analysis of buses emissions, didn't allow the measure of the weight of gases as foreseen in the evaluation methodology, but only in parts of elements. Also this equipment only measure emissions with the buses stopped in the garage and not in operation. Anyway these data has been used for other monitoring purposes and has been used modelling for the emissions assessment.

Operation phase

- **Barrier 3.1 – Institutional Barrier** – Due to the financial crisis period, the new national legislation didn't allow any more to employ any kind of personnel, causing that all the work in the measure has been carried out by already existing personnel that accumulate with other functions and for some tasks they weren't sufficiently specialized, namely to allow the performance of some special analysis of mechanical wear.

- **Barrier 3.2 – Technological Barrier** – Two buses equipped with "common rail" technology in the diesel injection, had problems in this fuel feed system, namely with "gel" in the filters and injectors, forcing the stop of the biofuel tests for this type of buses on 5^{th} and 10^{th} May 2011 (mix at 30%).

D.2.2 Drivers

Preparation phase

- **Driver 1.1 – Organizational Driver** – Possibility of exchange of experiences with other Portuguese PT operator (Urban PT of Braga) that had already begun the use of biofuel in large scale in their fleet and with other MODERN partners involved in similar measures. The experience transmitted by Urban PT of Braga allowed that people involved in the measure were more confident in the achievement of the results and with more knowledge of the nature and extension of the potential risks.

Implementation phase

- **Driver 2.1 – Involvement Driver** – Offer of support by ISEC (College of Engineering of Coimbra) for the tests involving emissions analysis. Without this expensive equipment it will be impossible to SMTUC make direct measurements of the buses emissions.

Operation phase

- **Driver 3.1 – Involvement Driver** – The participation in the CIVITAS MODERN Project created legal obligations and high motivation for the compromises achievement. These facts were very important always problems occurred during the measure demonstration, avoiding the delay in the decisions (or lack of decisions).

D.2.3 Activities

Preparation phase

- **Activities 1 – Planning Activities** – Taking into consideration the lack of knowledge of SMTUC technicians about biofuel use (barrier 1.1) and the good relationship with the Urban PT of Braga technicians (driver 1.1), it was decided to visit this PT operator and learn with their experience. This activity results in more confident people and a better perception of the risks and allowed the planning of more ambitious test levels – star of the tests with 30% of biofuel mix and steps of 10% between each set of tests, instead of the values initially planned (start with 21% and steps of only 1%).

Implementation phase

- **Activities 2 – Planning Activities** – Taking advantage of the partnership with ISEC (driver 2.1), the equipment for the monitoring of the buses emissions has been tested and demonstrated great utility for the assessment to the emissions with the buses in garage (instantaneous measurement). But the impossibility of using this equipment to measure emissions during the buses operation and the type of the outputs of these measurements (barrier 2.1) avoided the use of the equipment for evaluation purposes. For this reason the direct measurement has been only used for the SMTUC internal monitoring of the tests, including the buses performances, while modelling has been planned to be used for the evaluation activities.

Operation phase

- **Activities 3 – Planning Activities** – Taking into consideration the impossibility to carry out some special analysis of mechanical wear in the engines of the buses running biofuel (barrier 3.1), it was decided to evaluate the buses performances by using surveys designed for the buses drivers perception and by analysing the recorded list of repairs, the engine oil and the emissions.

- **Activities 4 – Technological Activities** – Taking into consideration the minor number of buses running biofuel mixes due the mechanical problems caused by this kind of fuel on the buses with “common rail” technology in the Diesel injection (barrier 3.2) and to allow the achievement of the objectives of the measure (driver 3.1), it was decided to replace the 2 stopped buses by equal number of buses equipped with other technology in the fuel feed system. So SMTUC could conclude the measure with the test of 4 buses, as initially planned.

D.3 Participation

D.3.1 Measure partners

- **Measure partner 1 - Serviços Municipalizados de Transportes Urbanos de Coimbra (SMTUC); Public transport company; Leading role**

SMTUC was responsible for the coordination of the activities of the measure, the work of research, knowledge acquisition and planning of the biofuel tests. Had also made the setup of the measure and it implementation, namely by the installation of the equipment for the fuelling and monitoring of the biofuel tests.

The tests have been also carried out by SMTUC, running the 4 buses dedicated to the tests in real operation in the SMTUC public transportation network.

The data collection regarding the evaluation was also carried out by SMTUC.

- **Measure partner 2 – Câmara Municipal de Coimbra (CMC); City; Principle participant**

CMC supported SMTUC with their experience with the use of biofuel in one waste collection vehicle and has been analysed the possibility of future partnership for the use of a portion of recycled organic biofuel collected by the municipal waste management services in the various hospitals and university facilities. Municipality has been also sensitized for the use of biofuel in their important fleet.

Since October 2011 the Municipality has been also responsible for the dissemination of the CIVITAS MODERN project of Coimbra.

- **Measure partner 3 – Prodeso Ensino Profissional, Lda (PRODESO); High school; Principle participant**

PRODESO was responsible for the dissemination activities for the first three years of the MODERN project of COIMBRA.

- **Measure partner 4 – Perform Energia, Lda (PE); Private company; Principle participant**

PE was the partner responsible for the evaluation of this measure, namely analysing data and results.

D.3.2 Stakeholders

- **Stakeholder 1 – General Public –** The general public will beneficiate with the energy and environmental impacts in case of up-scaling the measure to the entire SMTUC fleet and they could constitute target groups for the biofuel use.

- **Stakeholder 2 – Biomove** – This enterprise was the responsible for the supply of the biofuel used in the tests **(**www.biomove.pt).

- **Stakeholder 3 – Galp energia (Galp)** – This enterprise is a national supplier of energy, mainly fuel and gas. Galp was supplying SMTUC buses with gasoil and lubricants and carried out lubricants analysis on the buses tested (www.galpenergia.com).

- **Stakeholder 4 – Instituto Superior de Engenharia de Coimbra (ISEC)** – ISEC is a public College of Engineering of Coimbra and was responsible for the tests involving emissions, providing the measurement equipment and knowledge, as well as supporting the measurement sessions.

- **Stakeholder 5 – Transportes Urbanos de Braga (TUB)** – TUB is the Urban Public Transport operator of the City of Braga and allowed the exchange of experiences concerning the biofuel use due the fact they already used high level of biofuel percentages before SMTUC started their tests. TUB facilitated a study tour to their site and gave important information that allowed SMTUC to begin the tests with 30% of biofuel mix.

- **Stakeholder 6 – Public Transport Operators** – The public transport operators were a target group for the biofuel use and have been sensitized for the use of biofuel in their fleet.

- **Stakeholder 7 – Media** – Media has been a channel for the dissemination and promotion of the measure and all the events organized had the participation at least of the local media.

D.4 Recommendations

D.4.1 Recommendations: measure replication

- **Cultural resistance to the biofuel use –** Resistance to biofuel use comes from environmental and social opinion makers which protest against some sources of biofuel, namely those originating from industrial vegetable plantations. The use of recycled oils resulting from industrial and manufacturing uses, e.g., cooking oils and motor oils – can be used to try to convince society of the benefits of using biofuels. However, the use of recycled biofuels places extra demands on the suppliers since the availability of this type of biofuel is usually limited.

- **Limitations of common rail technology -** The use of biofuel in vehicles with common rail technology in the fuel feed system is not recommended. The trials demonstrated that even with a reduced amount of biofuel, buses revealed mechanical problems, namely with the appearance of gel-like substance in the filters and injectors.

D.4.2 Recommendations: process

- **More detailed analysis and testing –** When possible, the evaluation process should take into account tests and analyses to the wear of the bus engines. This implies greater financial and technical capacity since the motors will have to be dismounted and every section tested and subsequently remounted.

- **Assess market availability of biofuel** – Before applying biofuel at the fleet level, PT companies should first prospect the market in order to assess the availability of sufficient biofuel to meet the fuel demands. Many times PT companies will have to reach out to several suppliers in order to meet their biofuel needs, since in some countries suppliers still maintain limited stocks.

ANNEX 1

Ex-Ante data relative to the vehicles being tested: Average Operating Costs

Data	Unit	Jan-10	Feb-10	Mar-10	Apr-10	May-10	Jun-10	Jul-10	Aug-10	Sep-10	Oct-10	Nov-10	Dec-10	Jan-11	TOTAL
Costs with fuel consumption	€	6909	6813	9140	8395	9643	8917	8188	8090	8599	9433	7573	8049	8473	**108222**
Maintenance costs with personnel	€	360	542	679	857	780	598	619	813	642	978	583	1271	1700	**10422**
Maintenance costs with material	€	877	1318	1652	2084	1898	1454	1505	1977	1561	2379	1420	3093	1811	**23029**
Total vehicle-km	vkm	19000	18546	23304	20882	23692	22593	20173	21010	20693	22855	17843	18182	14473	**263246**
Average Operating Costs	€/vkm	0,429	0,468	0,492	0,543	0,520	0,486	0,511	0,518	0,522	0,560	0,537	0,683	0,828	**0,538**

Ex-Ante data relative to the vehicles being tested: Average Vehicle Fuel Efficiency

Data	Unit	Jan-10	Feb-10	Mar-10	Apr-10	May-10	Jun-10	Jul-10	Aug-10	Sep-10	Oct-10	Nov-10	Dec-10	Jan-11	TOTAL
Total energy consumed by the vehicles	MJ	304935	301196	386979	341295	388071	360003	333795	331202	353092	386073	304461	310329	311361	**4412792**
Total vehicle-km	vkm	19000	18546	23304	20882	23692	22593	20173	21010	20693	22855	17843	18182	14473	**263246**
Average Fuel Efficiency	MJ/vkm	16,049	16,240	16,606	16,344	16,380	15,934	16,547	15,764	17,063	16,892	17,063	17,068	21,513	**16,763**

Ex-Ante data relative to the vehicles being tested: Fuel Mix

Data	Unit	Jan-10	Feb-10	Mar-10	Apr-10	May-10	Jun-10	Jul-10	Aug-10	Sep-10	Oct-10	Nov-10	Dec-10	Jan-11	TOTAL
Total Energy consumed by the Diesel vehicles	MJ	8831514	8265989	9623217	8991462	9500229	8675318	9289349	8052517	9505281	9182606	8709137	8610049	9418660	116655328
Total Energy consumed by the Biofuel vehicles	MJ	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Energy consumed by the Electric vehicles	MJ	226066	266558	241531	232204	256493	225400	139158	6538	101347	228830	156553	89248	231577	2401502