Measure title: **Production of Renewable Energies for Trolleybus Lines in Coimbra**

City: **Coimbra** *Project:* **MODERN** *Measure number:* **01.08**

Executive summary

This measure comprises the elaboration of a technical, environmental, economical and financial feasibility study to implement a small-hydro power plant in the existing local river dam and use this electricity to supply Coimbra's trolleybus and electric minibus fleet with renewable energy.

The innovative aspects of this measure – the use of the existing river dam for the production of renewable energy to supply the trolley bus lines and the electric bus batteries used in PT operations – are very relevant because they contribute to improve the economic and environmental performance of a clean PT system with reduced investments.

The feasibility study prepared within the CIVITAS MODERN period concluded that this measure is viable at a relatively low cost and has the potential to generate revenues that support the operation and permit the gradual recuperation of the investment.

The results of the measure indicate that in a short period of time the operation small-hydro would generate positive impacts over the average operating revenues and over the decrease of green-house gas emissions at the national level (decrease of 1 million ton CO2 per year) . With the implementation of the measure it is estimated a revenue of 200 k€/year and the investment (1,7 million Euros) has a simple pay-back period of 8,5 years, which is considered cost effective in terms of other investments in small hydro plants.

The feasibility study for the small-hydro power generation in the existing local river dam is the CIVITAS MODRN measure with the major media coverage in Coimbra and had a very positive impact in the scientific community.

The implementation of the study showed that:

- Direct feed of the fleet should be carefully considered given the irregularities in the energy production that may affect the transport system and the considerable costs of energy transformation.
- It is important to analyse with anticipation the possibility of the appearance of several constraints, mainly at the environmental level (impacts on the biodiversity, consequences in case of flooding), but also at the dam specifications level, and to involve experts of several specialities (ex: experts in zoology to study the issues linked to the fish passage) to deal with those constraints.
- Special attention must be given to the administrative / legal aspects because the processes of licensing and request for authorizations could be long and complicated and the involvement of high level decision-makers could be very important to clear the communication channels with national authorities.
- Considering that capital costs in this kind of projects could be significant, positive external factors such as environmental impacts and the importance of the project for the city should be taken into consideration in the economic feasibility study.

A Introduction

A1 Objectives

The measure objectives are:

(A) High level / longer term:

- To improve the global air quality
- To decrease the dependence on fossil fuels

(B) Strategic level:

- To produce renewable energies to use in PT fleet
- To contribute to the reduction of emission of greenhouse gases at national level

(C) Measure level:

(1) To make a technical, economical, environmental and legal feasibility study to implement an electric energy production system (small-hydro) inserted in the existing Coimbra Dam-bridge (Producing at least 750.000 kWh per year)

(2) To produce a digital model of the small-hydro

(3) To carry out awareness campaigns on the benefits of future self production of electricity to supply the trolleybuses lines of the Urban PT operator (SMTUC)

A2 Description

The city of Coimbra has always given priority to clean transport means (trolley cars, electric mini buses, diesel-electric buses, elevators). In this context, a technical, environmental, economical and financial feasibility study has been developed to implement renewable energy production (small-hydro power plant) in an existing local river dam (Fig. 1A and 1B), using the electricity produced to supply the trolleybus and electric minibus fleet of Municipal Public Transportation Services of Coimbra (SMTUC).

Fig. 1A –Existing Dam – Bridge of the Mondego River.

Fig. 1B – The Dam is located near the centre of the City and SMTUC site.

The energy, economic and environmental impacts of possible different locations, as well as of different turbine technologies, for the small-hydro plant were researched in detail, in order to identify the best possible solutions for implementation. These solutions aimed to optimize economic benefits, while at the same time ensuring minimal disturbance to the functioning of the recently built fish-ladder (the media coverage of this CIVITAS measure had catalyses the construction of this fish passage that has long been demanded by the population of Centre Region).

The characteristics of the dam structure (including its location, general data, the hydrological characteristics), the characteristics of the reservoir, dam and spillway, and the main features of the dam and its hydro-mechanical equipment were assessed.

During this stage several small hydro projects were analyzed in the regional water authority (ARHC) to support the Coimbra dam-bridge feasibility study and the administrative procedures. Technical visits were made abroad to 2 turbine manufacturers and 3 similar small-hydro dams.

Important data and technical know-how was collected. A preliminary analysis was performed based on reviewed literature and the characteristics of the fish passage project documents. This analysis aimed to assess the best possible location of the turbines, surveillance of fish migrations, and the required water management to allow the maximum performance of all devices (dams, turbine-generators, and fish passage).

A preliminary feasibility analysis for using groups of turbine-generators specifically designed for very low head small hydro turbines in the downstream lochs of Coimbra's dam was also conducted, but this technology was abandoned because the capital costs were must higher than those originally foreseen and the flow needed to have a regular production of energy was higher than the existing average flow.

Some preliminary laboratorial tests were also done in a hydraulic channel to evaluate the performance of key system components.

The best solution for the feed of the trolleybus traction lines was also analysed and all the parts agreed that the sale of the energy produced in the small-hydro to the electricity grid of EDP – the Portuguese electricity supplier – is better than the direct feed, mainly because this last solution will have higher capital costs for the energy transformation and could imply the loss of the surplus of energy.

Finally the main outcomes for the technical feasibility were achieved and a working document was delivered in November 2009 with the description of the methodology and work undertaken in the study, as well as with the analysis of the several layouts and respective results.

In a second stage three solutions remain as the most recommended taking also into consideration the spatial constraints resulting from the fact that the dam was already built but without the objective of energy production in the original project. These solutions were analysed in more detail to find the best compromise between the environmental impact (mainly in the fish passage and in case of flooding) and the economical point of view.

A detailed small hydropower operation computational model was concluded and applied to all possible layouts, in order to estimate the annual revenue of each one. The detailed small hydropower operation computational model provides a DEMO layout of the Coimbra Dam Bridge equipped with turbine-generator units, namely the overture state of each of the 9 radial gates, the flow in each radial gate, the number of operating turbine-generator units and respective energy production.

At the end the layout chosen consists of a VLH-MJ2 turbine generator unit installation in a short channel to be built between the irrigation channel intake and the river area downstream the dam. The lateral location of the water intake makes it easier to divert the fish that are descending the river. This layout will comprise civil construction works of similar type to those involved in the new fish ladder.

Financial issues and institutional arrangements were analysed for the real implementation of the small-hydro in the future. An informal agreement for the authorization of the use of the dam for the production of electric energy for the trolleybus and electric mini-bus transport system was achieved in a meeting with the attendance of the President of the Portuguese Water Authority (INAG), the Mayor and the Mobility Councillor of the Municipality of Coimbra and other stakeholders. Nevertheless, INAG has not yet replied to the administrative request for the addition of the hydropower plant in the Coimbra Dam Bridge made by the Municipality of Coimbra in the beginning of the CIVITAS MODERN project.

The dissemination of the main measure outcomes and technical features was made by the media (e.g., newspapers, magazines, websites) and in presentations in several workshops, seminars and conferences, highlighting the presentation in 3 international events and the publication of papers in 2 indexed international journals.

In June 2012 the final report with the economical, environmental and legal feasibility study, including the financial engineering and institutional arrangements, was delivered.

B Measure implementation

B1 Innovative aspects

The innovative aspects of the measure are:

- **New conceptual approach, internationally**
    - The use of an existing river dam (located in the city centre) for the self-production of renewable energy, in order to supply (indirectly) the trolleybus traction lines, is a project that has not been applied in any other city. The innovation has 3 aspects: 1 - The main capital costs have already been made, because the dam has already been built (in 1981 but with other objectives - control the river flow, supply water for the agriculture and for the paper industry and the improvement of the city landscape and environment – not for the energy production); 2 – The fact that the dam is located in the centre of the city of Coimbra, avoids energy losses and additional costs with the transport of energy (which is usually the case when the energy source is distant from Coimbra); 3 – All the revenues of the electricity production will be used in the exploitation and improvement of the electric dimension of city transport system.

B2 Research and Technology Development

The main work undertaken in this measure was research and technology development as described in the stage 1 of section B.4 of this document. Mainly the energy, economic and environmental impacts of possible different locations have been analysed in detail, as well as the different turbine technologies for the small-hydro plant in order to identify the best solutions for implementation. These solutions aimed to optimize the economic benefits, while at the same time ensuring minimal disturbance to the operation of the recently built fish-ladder. Hydrological analysis of the River Mondego flow has been also carried out.

Accordingly, we can highlight some aspects as following:

- Recent new turbines specially developed for very low head have been identified and these technologies (Straflo Matrix and VLH MJ2 turbo generating units) were considered in several possible layouts that were designed to allow hydropower addition to the existing Coimbra dam bridge.

- A computational simulation model was developed and used to test the hydraulic operational aspects connected to hydropower addition and to evaluate electric energy production revenue.

  The detailed small hydropower operation computational model provides a DEMO layout of the Coimbra Dam Bridge equipped with turbine-generator units, namely the overture state of each of the 9 radial gates, the flow in each radial gate, the number of operating turbine-generator units and respective energy production.

- Some laboratorial tests were conducted in an open flume channel to evaluate tail-water levels in case turbo generating units were installed in the spillway sill.

  The headwater level curve is conditioned by two distinct hydraulic behaviour mechanisms:

  1) When inflow is low the headwater level curve can be modelled by computing the water mass balance in the upstream reservoir;

  2) However, when the inflows become considerably high, all the radial gates are fully opened and the headwater level is no longer resulting from water mass balance in the upstream reservoir. Instead the headwater levels results from the natural hydraulic upstream river rating curve once human intervention is no longer possible.

To compute the aspects referred to above, a simulation model was used with decision criteria to guide the operation of the hydropower plant. This model was being tested and will be used also in the forthcoming studies.

In a first stage a correlation between headwater level and upstream inflow has been used, based on the analysis of historical records collected after the construction of the Coimbra Dam Bridge.

The downstream river tailwater level curve is derived from historical hydrometric data.

The tailwater curve at the end of the spillway sill required some further investigation. Laboratorial tests showed that it was possible to ensure adequate tailwater submergence of the Turbine Generators Units (TGU) using a flap gate at the end of the spillway sill. The scale model tests provided an experimental tailwater curve slightly different from the theoretical tailwater curve approximation assumed in previous computations. This experimental tailwater curve was obtained using the sill end flap gate to ensure adequate tailwater submergence of the TGU.

Besides headwater and tail water curves, approximate efficiency curves were derived based on data provided from the manufacturers. The minimum and maximum operating heads and the minimum and maximum operating flows, for both technologies, were also included in the study.

Both TGU technologies present the same prevailing advantage: they do not need a powerhouse. The TGU are compact units that can be installed directly in contact with the flow in the exterior environment.

Another advantage of StrafloMatrix™ and VLH-MJ2 technologies is the ability of the units' removal in case of exceptional high flows.

In our study it was predicted that for flows superior to 1200m3/s (the flood flow capacity of the Coimbra Dam Bridge is 2000 m3/s) the units would be removed from the river flow.

After careful analysis 3 possible layouts for each of the two TGU technologies were selected, totalizing 6 possibilities to be analysed at economical and fish-pass impact level.

- These three locations for the turbines were analyzed in more detail, namely a location close to the fish-pass of the dam, a location between the fish-pass and the central gate, and a location near the irrigation channel in the right margin of the dam (Fig. 2). In general, it is admissible that the implementation of turbines on any of the above mentioned locations may interfere with the attraction ability performed by the fish-pass, meaning that its minimization constituted a goal for the working team.

The location close to the fish-pass is the most disruptive in terms of introducing a possible source of diversion of the fish migration, and therefore is not recommended.

The other possible location for the turbines (between the fish-pass and central gate) would be the one which will bring lower differences to the flow distribution, in comparison to the present water management situation. In this case, the location should be closer to the gate operating regularly, used to perform the water discharge operation in the Coimbra's dam-bridge. The gates can be manipulated in agreement to the water flow needed by the turbine to produce energy. The final result will be nearly the same in terms of distribution of the water flow, with the main water volume discharged through the central part of the river, as it is presently (with no turbine implemented).

However the turbine placement on the irrigation channel on the right margin seems the best location for the turbine-generator, since it is located as far as possible away from the upstream entrance of the fish-pass and will minimize the competition in the attraction of the fish.

The location in this area will reduce the turbulence near the left margin, allowing the fish shoals to use this space to reorganize and orient before proceeding with the ascending migration. Concerning the selection of the best model to use, the VLH-MJ2 model is more cost-effective and more fish-friendly than the StrafloMatrix model, especially due to the blades' lower rotation speed.

Therefore, the best solution, from an economical point of view, was also identified as this last layout (Layout V2 in the figure 2), which is similar to the very successful Millau small hydropower plant in France, in operation since 2007 (which have survived several large floods). Exactly like the Coimbra Dam Bridge V2 layout, the Millau small hydropower plant has a short right river bank channel that bypasses the river weir and feeds a single VLH-MJ2 4500 mm diameter turbine. In the Millau small hydropower there is a fish ladder in the opposite river bank, that is, the fish ladder is in the left river bank exactly as in the Coimbra Dam Bridge V2 layout.

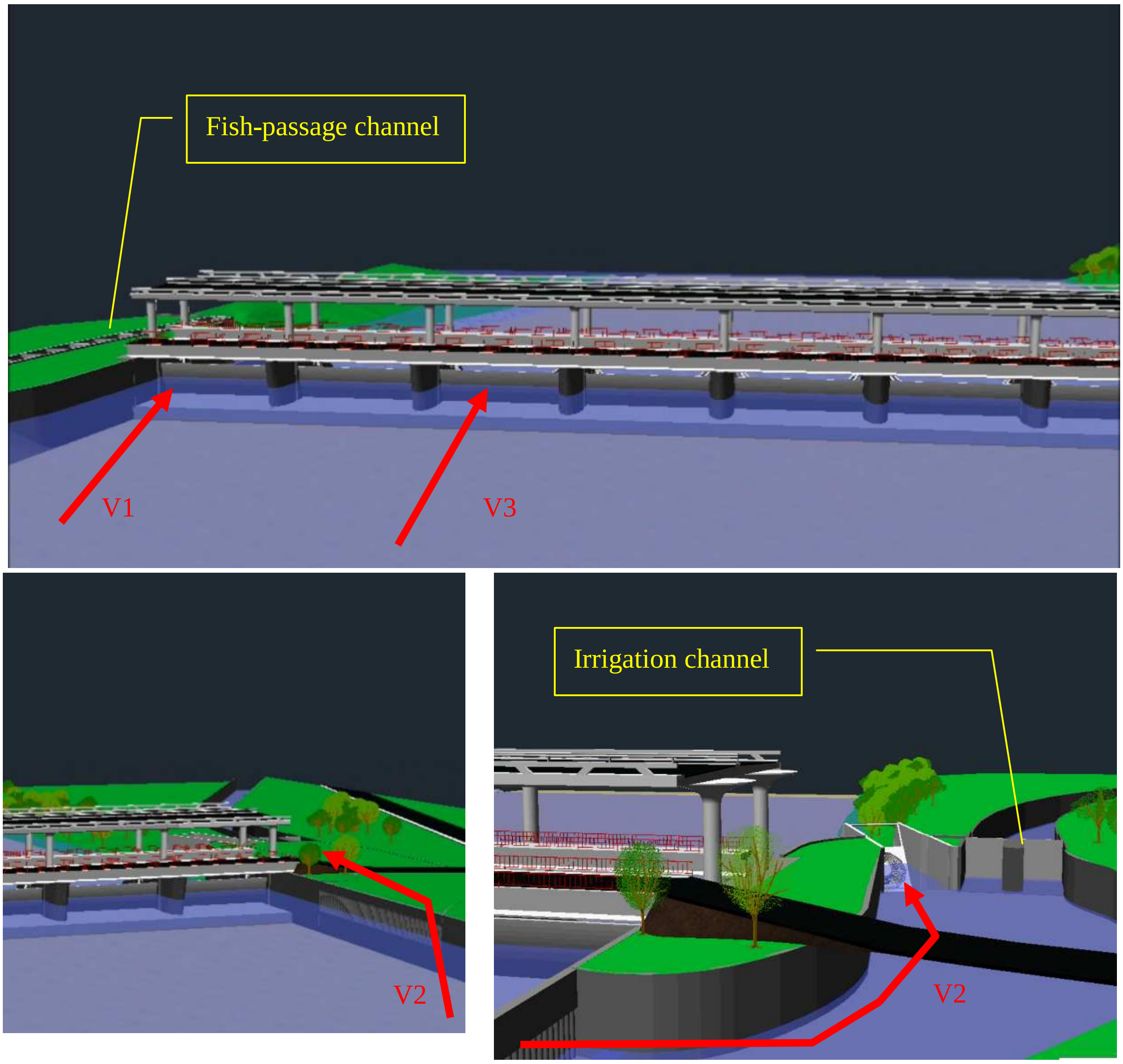


Fig. 2 – The 3 possible layouts for the VLH-MJ2 turbine generator unit installation – V1 in the first gate of the dam, near the fish-passage channel, V2 using the existing irrigation channel intake and V3 in the third gate.

The V2 layout consists of a VLH-MJ2 turbine generator unit installation in a short channel to be built between the irrigation channel intake and the river area downstream the dam (Fig. 3 and 4). The lateral location of the water intake makes it easier to divert the fish that are descending the river. This layout will comprise civil construction works of similar type to those involved in the new fish ladder.

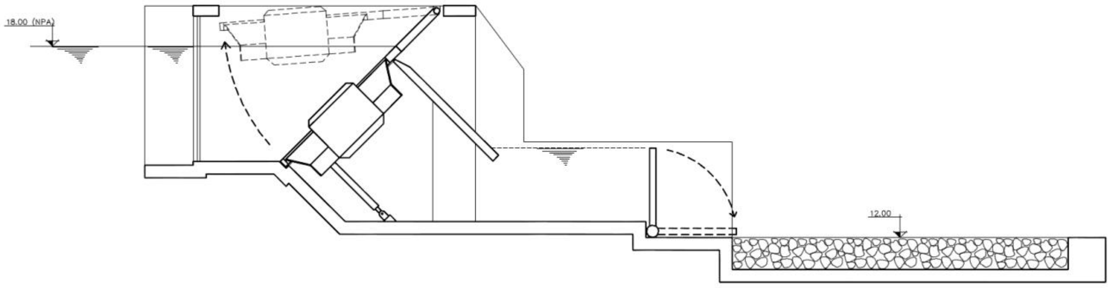


Fig.3 – Side view of layout V2

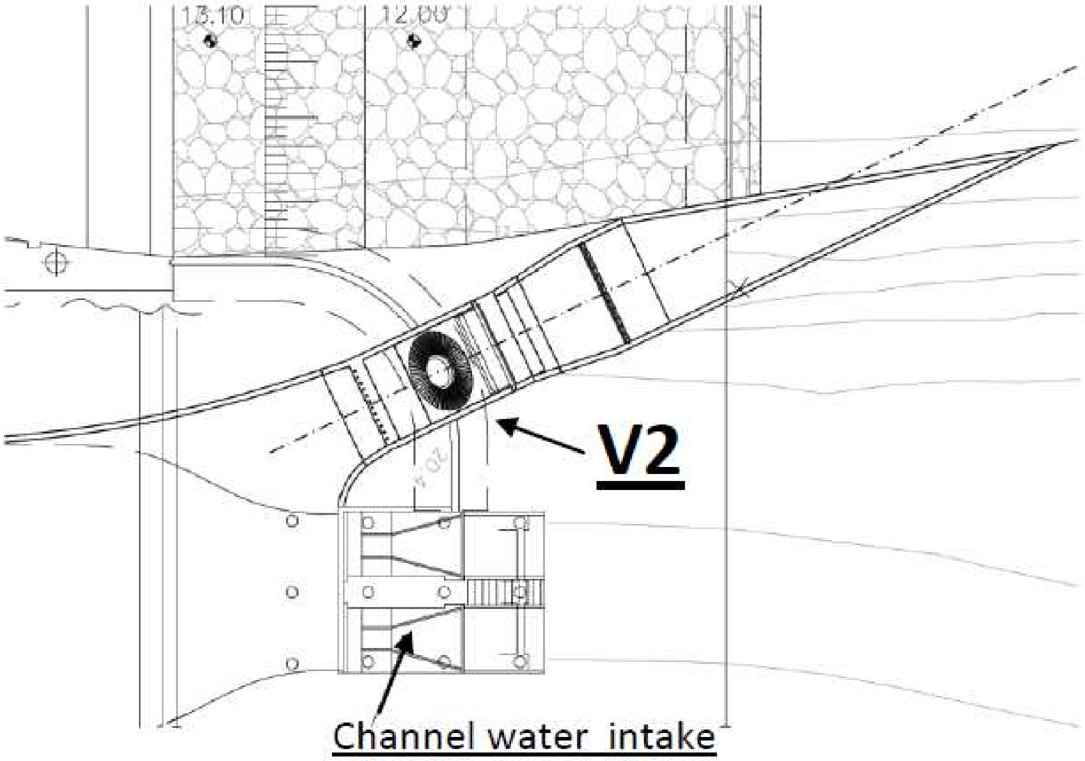


Fig.4 – Top view of layout V2

In conclusion, the research and development work allowed for am analysis which provided the best solution from the technological, economic and environmental point of view (particularly in terms of project feasibility). The solution recommended was a VHL-MJ2 turbine generator unit installed in a derivation of the existing irrigation channel intake. The investment will be 1 700 000 € for an annual energy production of 2,6 GWh, more then 3,5 times the energy needed to feed the trolleybus fleet. The annual revenues from this production will be 200 000 € and the simple payback period will be 8,5 years.

The study has been delivered and disseminated through several channels, including papers and publications in specialized media.

B3 Situation before CIVITAS

Coimbra's trolleybus electric traction network is fed by grid energy from the national supplier (EDP). The energy mix contained about 38% renewable energies in 2006 (45% in 2010). In 2006, the electric energy consumption of the trolleybus corresponded to 748.000 kWh and implied a cost of 78.600 Euros for SMTUC, plus electric energy to charge the batteries of its 3 electric minibuses.

Coimbra has a 60 year history of trolleybus, being the only Portuguese city, which did not abandon its network; to the contrary, in recent years the network has increased.

One of the factors, which hinders trolleybus network extension, is the increasing cost of electric energy. That is one of the main motivations of SMTUC to find solutions allowing for an energetically "cleaner", efficient and economically favourable supply.

Introducing a renewable energy source (hydro) into the system generates social benefits related with the local production of electric energy (reducing energy grid losses) and associated reduction of greenhouse gases that will improve the energy and environment footprint of the SMTUC transport fleet. In addition to these social benefits, this measure will increase the operating revenues by generating a new income related with the sale of the surplus of the small hydro plant energy production. The new income will be used to cover the depreciation of the investment at short time but in the future SMTUC could benefit from these extra revenues by increasing and renewing the electric fleet, as well as to raising the offer of public transportation made by these environmentally friendly vehicles.

B4 Actual implementation of the measure

The measure was implemented in the following stages:

Stage 1: Research to implement an electric energy production system (small- hydro) *(Oct 2008—Oct 2011) During this stage the research activities to implement an electric energy production system (small-hydro) to supply the electricity for the trolleybuses and the electric mini-buses of SMTUC was carried out. The work undertaken included the research in terms of applicable technologies, implementation and simulation of the exploration of the small hydropower plant. It was a technical, economic, environmental and legal feasibility study to implement the small-hydro inserted in the existing Coimbra dam bridge and began with the following activities:*

- *Regional and national activities coordination in order to obtain information for the study.*
- *Preliminary feasibility analysis for using groups of turbine-generators specifically designed for very low head small hydro turbines in the downstream lochs of Coimbra's dam.*
- *Gathering national and administrative legislation and procedures concerning electricity production from hydropower.*
- *Data collection regarding trolleybuses and electric mini buses lines (characteristics, load diagrams...). Seasonal water supply variation, optimal dimensioning of the generator system, and fish migrating facilities were also studied.*

In order to identify the best solutions to be implemented, the energy, economic and environmental impacts of possible different locations, as well as the different turbine technologies for the small-hydro plant was investigated in detail. These solutions aimed at optimising the economic benefits, while at the same time ensuring minimal disturbance to the operation of the fish passage though the dam. The impact in the fish migration was studied initially with the data provided in the project for the fish-ladder. The media coverage of this CIVITAS measure helped catalyse the construction of the fish passage that has long been *demanded by the population of centre region. For this reason at the end of this stage some data was provided directly by measurements in the recently built fish-ladder.*

In the meantime, several small hydro projects were analyzed with the regional water authority (ARHC) to support the Coimbra dam-bridge feasibility study and administrative procedures. Technical visits were made to the ANDRITZ HYDRO turbine laboratory in Linz, to the Agonitz small hydropower (pilot project of Hydromatrix and Straflomatrix turbines) and to the Chievo small hydro power plant, which has considerable similarities to the Coimbra dam-bridge. Important data and technical know-how was collected. Also technical visits were made to the MJ2 Technologies S.A.R.L. design office and the small hydropower pilot project equipped with a VLH-MJ2 turbine, in Millau, France, which also has considerable similarities to the Coimbra dam-bridge project. Important data and technical know-how was again collected.

A preliminary analysis was made based on reviewed literature and documents with the characteristics of the fish passage project for the Coimbra dam. The referred analysis was performed on the best possible location of turbines, surveillance of fish migrations, and the required water management to allow the maximum performance of all devices (dams, turbine-generators, and fish passage).

Preliminary feasibility analysis for using groups of turbine-generators specifically designed for very low head small hydro turbines in the downstream lochs of Coimbra's dam were also conducted, but this technology was abandoned for two reasons: 1 - the capital costs were much higher than those originally foreseen taking into consideration the values provided by the manufacturers; 2 - The flow needed to have a regular production of energy was higher than the existing average flow (the risk of flooding is augmented if gates have top be closed to increase the water level / flow rate).

Some preliminary laboratorial tests have also been done in a hydraulic channel to evaluate the performance of key system components (Fig. 5).

Fig. 5 - Laboratorial tests considering 3 turbines in a scale model of the Coimbra Dam spillway sill.

The technical feasibility of hydropower addition to the Coimbra Dam Bridge was developed considering an international survey of similar sites. Based on the research two hydropower small impact technologies with strong resemblances with the Coimbra Dam Bridge project were identified: the Chievo project where the StrafloMatrix™ technology is installed and the Millau project were the VLH-MJ2 technology is installed. Taking into account the space constraints in the Coimbra Dam Bridge, three possible locations were considered for turbines installation (Straflomatrix-S1, S2, S3 and VLH-V1, V2, V3 as shown in fig.6).

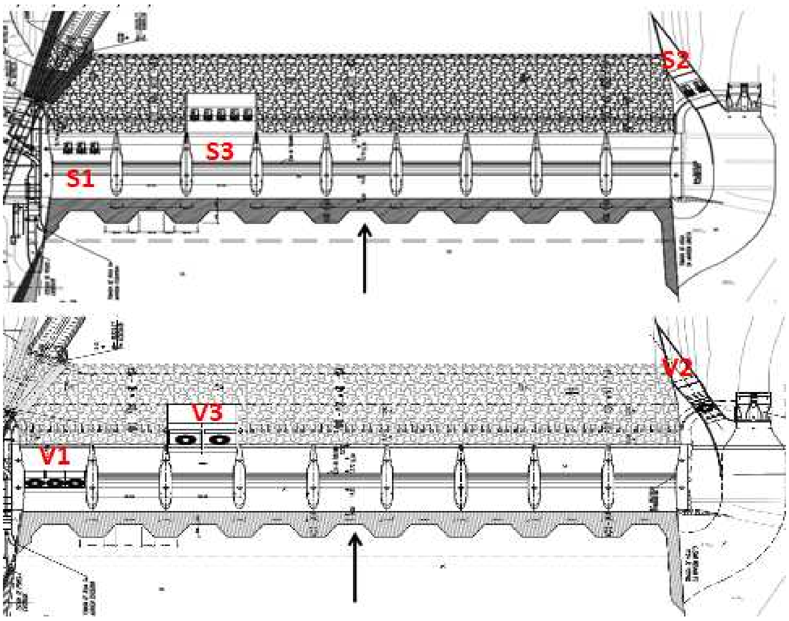


Fig. 6 -Top view of the different layouts.

The best solution for the feed of the trolleybus traction lines was also an alysed: the direct feed or the sale of the energy produced in the small-hydro to the electricity grid of EDP – the Portuguese electricity supplier. The solution agreed to was the last one taking in account that the direct feed needs very high capital costs for the energy transformation and could imply the loss of the surplus of energy (these vehicles don't run during some hours in the night and the foreseen energy production will be higher than the energy used by the trolleybuses). The first hydrological analysis to the available flows for the production of electric energy also showed a strong irregularity of current in the Mondego River, raising the probability of the occurrence in some summer days of insufficient energy production for the trolleybuses needs (if the direct feed was applied).

Finally the main outcomes for the technical feasibility were achieved and a working document was delivered in November 2009 with the description of the methodology and work undertaken in the study, as well as with the analysis of the several layouts and respective results.

In a second stage three solutions remained as the most recommended taking also into consideration the space constraints resulting from the fact that the dam was already built but without considering energy production in the original project. These solutions were analysed in more detail to find a good compromise between the environmental impact (mainly in the fish passage and in case of flooding) and the economic factors.

The small-hydro configuration costs and the annual revenue of the average hydrologic year were also calculated, and are presented in the following Figure:

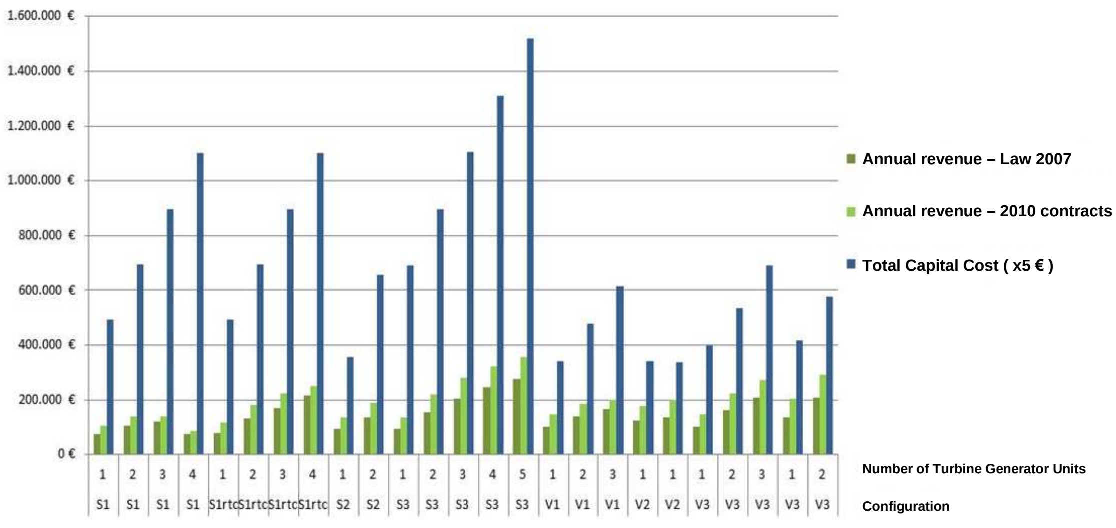


Fig.7- Annual revenue of the average hydrologic year.

Three locations for the turbines were analyzed, namely a location close to the fish-pass (in the same place where the S1 and V1 layouts were represented in Figure 6), a location between the fish-pass and the central gate (approximately in the same place where the S3 and V3 layouts were represented in Figure 6), and a location near the irrigation channel on the right margin of the dam (in the same place where the S2 and V2 layouts were represented in Figure 6). In general, it was considered admissible that the implementation of turbines on any of the above mentioned locations may interfere with the attraction ability performed by the fish-pass, meaning that its minimization constituted a goal for the working team.

Finally the best solution to mitigate the impact onthe fish-pass was achieved and pointed to the turbine placement on the irrigation channel on the right margin (in the same place where the S2 and V2 layouts were represented in Figure 6).

Analyses concerning the selection of the model of turbines to use were also carried out and the option selected was the VLH-MJ2 model because it is more cost-effective (Table B4.1) and more "fish-friendly" than the StrafloMatrix model (particularly due to the lower rotation speed of the blades).

Table B4.1-Ranking of the Net Present Value, considering a discount rate of 4% using the electricity rates in "Decreto-Lei n.º 225/2007".

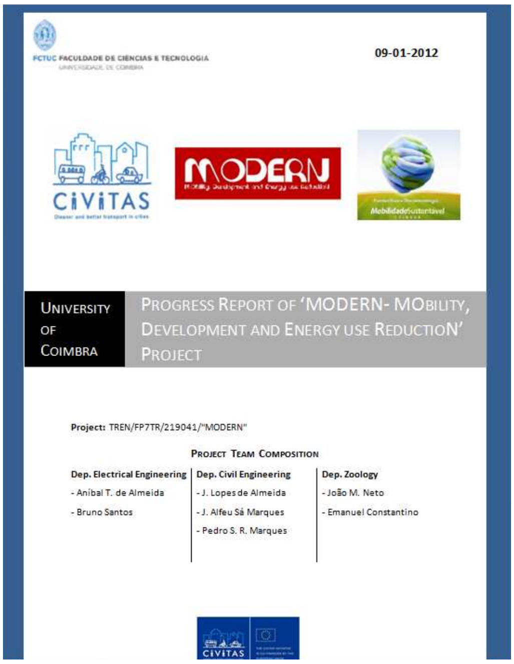
Layout	Number of Units	Units Type	NPV	IRR	Ranking (NPV)
V2	1	VLH 4000-45-4.0	1.222.220 €	8,9%	1 st
V3	2	VLH 4000-45-4.0	1.098.422 €	6,7%	2 nd
V2	1	VLH 4000-45-3.5	808.248 €	7,3%	3 rd

Therefore, the best solution, from an economic point of view, was also identified as layout V2, which is similar to the very successful Millau small hydropower plant in France, in operation since 2007.

The study also analysed the best location for the turbine generator unit installation and the construction requirements. The proposal was to locate in a short channel to be built between the irrigation channel intake and the river area (downstream of the dam). This layout will comprise civil construction works of a similar type to those involved in the new fish ladder, allowing for smaller costs with the project.

Financial issues and institutional arrangements were analysed for the real implementation of the small-hydro in the future. The capital costs for the small hydro are shown to be higher than the initial prediction. So the economic feasibility study, in order to reduce payback time and increase the internal rate of return, takes into consideration positive external factors such as environmental factors (CO2 emissions) and the importance of the project for the city. It was assumed that some funding programs (European, National or Regional) and institutional arrangements could support the initial investment, improving the economic feasibility of the project.

Despite the difficulties in having regular feed-back from the Portuguese Water Authority (INAG), an informal agreement for the authorization of the use of the dam for the production of electric energy for the trolleybus and electric mini-bus transport system was achieved (in a meeting with the President and other members of INAG, the Mayor and the Mobility Councillor of the Municipality of Coimbra, the CIVITAS MODERN site Coordinator and the measure leader and other experts involved in the measure). However, although a substantial amount of effort has been dedicated to the technical, economic and environmental feasibility report, the National Water Authority (INAG) has not yet replied to the administrative request for the addition of the hydropower plant in the Coimbra Dam Bridge. The request was made by the Municipality of Coimbra in the beginning of the CIVITAS MODERN project and in January 2012 a progress report of the project has been sent to the INAG (Fig. 8).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MODERN

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UNIVERSITY OF COIMBRA

PROGRESS REPORT OF 'MODERN- MOBILITY, DEVELOPMENT AND ENERGY USE REDUCTION' PROJECT

Project: TREN/FP7TR/219041/"MODERN"

PROJECT TEAM COMPOSITION

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	- Pedro S. R. Marques	

CIVITAS

Figure 8-Progress report of CIVITAS MODERN project delivered to INAG – National Water Institute

Stage 2: Small-hydro projected basic layout *(June 2010 – October 2012)* - *Although this stage was devoted to the demonstration of the measure, it was also used for the monitoring of results and the support for the demand of the best solution.*

Accordingly, during this stage the budgetary cost of all layouts was computed taking into account the specific unitary construction costs information of the fish ladder in the Coimbra

Dam Bridge, provided by INAG (National Water Institute), as well as considering the cost information obtained from equipment manufacturers. A detailed small hydropower operation computational model was concluded and applied to all possible layouts, in order to estimate the annual revenue of each one (Fig. 9). The detailed small hydropower operation computational model provides a DEMO layout of the Coimbra Dam Bridge equipped with turbine-generator units, namely the overture state of each of the 9 radial gates, the flow in each radial gate, the number of operating turbine-generator units, and respective energy production. This computational model is user-friendly and can be used in normal PC.

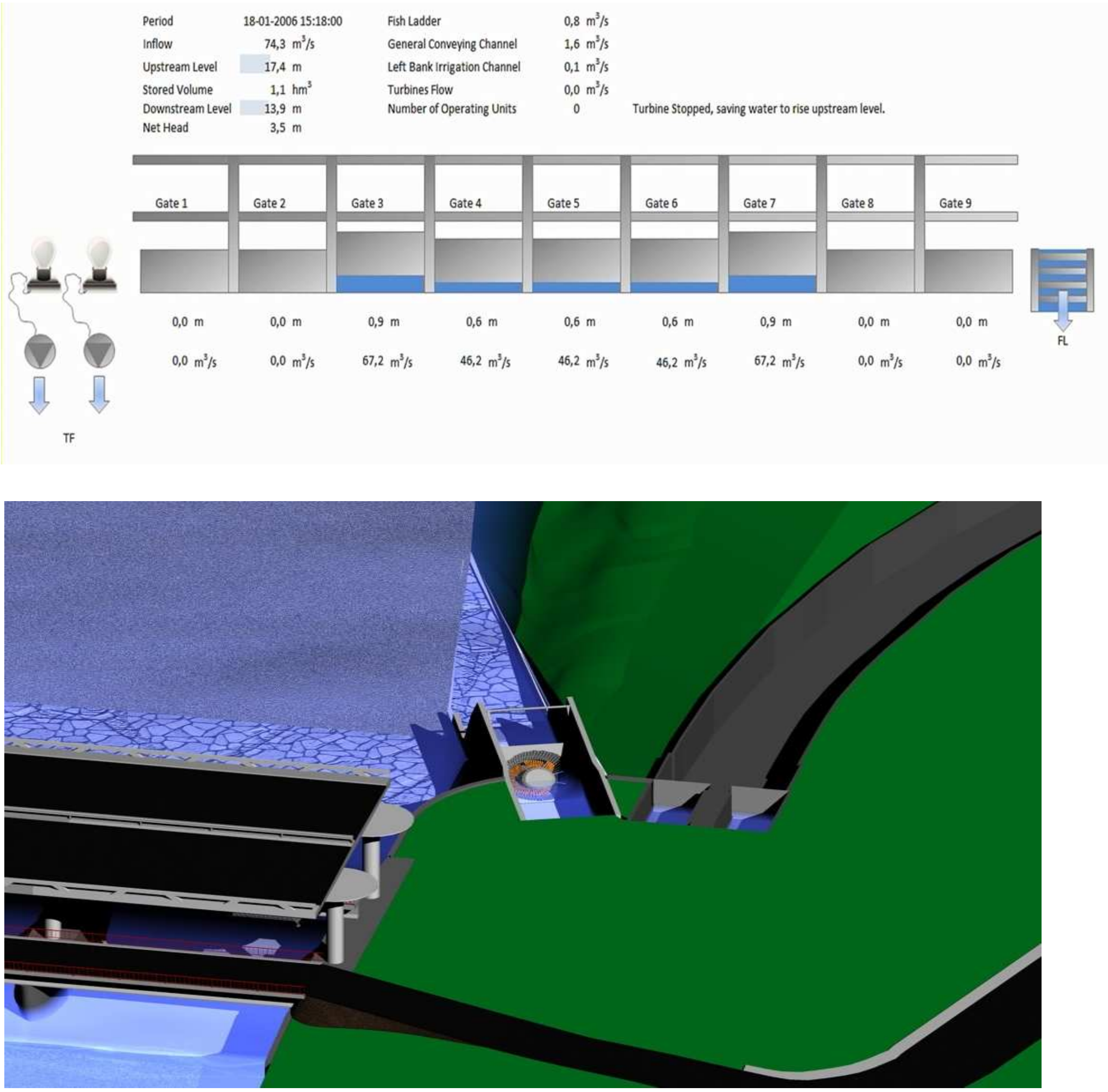


Figure 9-Computer Simulation Model output example (above) and Small Hydro 3D model (below).

Stage 3: Dissemination activities and release of deliverable with the feasibility study *(October 2008 – October 2012) – Despite the fact that this measure is only a study during*

CIVITAS, it had the most media coverage because the population also elected this measure as the most important and welcomed.

The dissemination of the main measure outcomes and technical features predominantly was carried out by the media and presentations in several workshops, seminars and conferences (highlighting the presentation of the CIVITAS measures in the Conference Land Use, Accessibility and Mobility Management organized by EPOMM and IMTT – Portuguese Institute of Mobility and Inland Transportation in Lisbon, 12-14th April 2010 and the measure in the 24th World Electric Vehicle Symposium – EVS24 Norway, 13-16th May 2009) and in the CIVINET Spain and Portugal Forum (Coimbra, 8th June 2011).

Several news articles were published in news papers, magazines and online sites. At the international level, 2 papers were published in indexed academic journals: a revised paper of EVS24 presentation was published in the International Journal World Electric Vehicle Journal, ISSN 2032-6653, Volume 3, December 2009 and the paper entitled "Small-hydropower addition to Coimbra dam-bridge for sustainable urban mobility" was submitted to the journal "Renewable & Sustainable Energy Reviews", Elsevier, and was available online on 16th September 2011.

In June 2012 the final report with the economic, environmental and legal feasibility study was delivered, including the financial engineering and institutional arrangements.

The digital model of the small hydro power generation plant has been developed and used for dissemination activities, which included several presentations (workshops, seminars, CIVINET Spain and Portugal Forum 2011, …), Some dedicated videos with the 3D model version and 4 generic videos that included this model have been also produced and used in presentations, namely in the CIVITAS Forum 2012, or placed on-line (including the CIVITAS website).

B5 Inter-relationships with other measures

The measure does not have any inter-relation with other measures because it is a study.

C Evaluation – methodology and results

C1 Measurement methodology

C1.1 Impacts and Indicators

Table C1.1.1: Indicators

No.	Impact	Indicator	Data used	Comments
1	Operating Revenues	Average Operating Revenues	Total income generated from the small hydro power plant production; Total vehicle-km	Revenues were provided by small-hydro feasibility study
2	Operating Costs	Average Operating Costs	Total operating costs from of electric supply to the trolleybus fleet; Operation and maintenance costs of the small-hydro plant); Total vehicle-km	Costs were provided by SMTUC and small-hydro feasibility study
3	Costs	Capital Costs	Total capital costs spent in setting up the measure	Capital costs were provided by small-hydro feasibility study
4	Awareness	Awareness level	Number of respondents with knowledge of the measure on account of provided information.; Total number of respondents	Awareness level was provided by SMTUC cusom satisfaction survey in the scop of the Quality Management activity of SMTUC
5	Emissions	CO2 emissions	Average CO2 emissions in the supply of 1 MJ of electric energy; Total energy consumption by the Trolleybus fleet; Total vehicle-km	Bibliographic sources
6	Emissions	NOx emissions	Average NOx emissions in the supply of 1 MJ of electric energy; Total energy consumption by the Trolleybus fleet; Total vehicle-km	Bibliographic sources

This measure consists in the elaboration of a feasibility study. The implementation of the measure includes the definition of the methodology to determine the costs and benefits related to the Production of Renewable Energies for Trolleybus Lines of SMTUC, the Urban Public Transport operator in Coimbra, and the estimation of those costs and benefits according to the defined methodology. Without any practical action during the CIVITAS MODERN project, no measureable impacts (apart from the Awareness level) will result from this measure. Therefore, the concept of impact evaluation is not straightforward – only potential impacts of the measure may be derived from the study.

All the chosen indicators reflect the impact of the measure when it will be implemented. The indicators also consider that the energy production of the small hydro plant do not feed directly the fleet of trolley bus and the associated positive income of selling energy will be used for depreciation of the investment and not for increasing the offer of the PT service. For these reason was not chosen indicators related with the fleet performance (fuel mix, fuel efficiency, emissions concerning the SMTUC fleet).

Detailed description of the indicator methodologies:

- **Indicator 1** (*Average Operating Revenues*) – Ratio between the income generated from the power generator in charge of the "Production of Renewable Energies for Trolleybus Lines in Coimbra" divided by the total vehicle-km per year of trolleybus fleet (€/vehicle-km).

  A = B / C

  where: A = Average operational revenue for the small hydro power plant (€/vehicle-km)

  B = Revenues from sale of energy produced in the small-hydro plant (€)

  C = Total vehicle-km of the trolleybus fleet per year (vehicle-km)

  All data are related to the SMTUC Trolleybus fleet. Results from vehicle-kilometres coming from the subtraction of non performed trips data to the scheduled ones. The source is the Excel file where the trips are recorded every day/month/year. The data reliability is maximised due to an accurate data collection among SMTUC records on performed and scheduled trips, which in turn are recorded following reliable procedure: each driver records the corresponding performed/non performed trips; the extension of each trip is known; the number of performed trips recorded by the drivers is validated by the Automatic Vehicle Management (AVM) system.

  The value of sale of energy produced in the small-hydro in the ex-ante situation is zero. Revenues from sale of energy produced in the small-hydro (in relation to the ex-post situation) come from the Progress report of the small-hydro (economical, environmental and legal) feasibility study[1] and from the measure leader. The value is calculated by the product of the estimated annual production (2,6 GWh) of the small hydro plant and a fixed feed-in tariff of 77 €/MWh. The annual production is obtained from the 500 kW hydro turbine configuration in VLH-MJ 2 mode and the feed-in tariff is derived from the Portuguese legislation of renewable energy source production stated in "Decreto-Lei n. º 225/2007", actualised by the 15-10-2010 Contest.

  It is important to stress that that it is not foreseen at short term using the revenues derived from the energy income to increase the PT offer, as well as the increase in the trolley bus network infrastructure or fleet renewal. These revenues will be used only for the depreciation of the small hydro capital costs. For this reason the impact of the small hydro in the tickets sales revenues is not foreseen.

- **Indicator 2** (*Average Operating Costs*) – Ratio between the total operating costs associated with small hydro plant and the total vehicle-km of the trolleybus fleet per year (€/vehicle-km).

[1] This information was included in the in the second year report, in feasibility study.

A = (B + C) / D

where: A = Average operational costs for the power supply to the Trolleybus fleet (€/vehicle-km)

B = Purchase of electric energy from the mains for the trolleybus lines (€)

C = Operation and Maintenance of the small-hydro plant costs (€)

D = Total vehicle-km of the trolleybus fleet (vehicle-km)

All data are related to the SMTUC trolleybus fleet. Results from vehicle-kilometres coming from the subtraction of non performed trips data to the scheduled ones. The source is the Excel file where the trips are recorded every day/month/year. The data reliability is maximised due to an accurate data collection among SMTUC records on performed and scheduled trips, which in turn are recorded following reliable procedures: each driver records the corresponding performed/non performed trips; the extension of each trip is known; the number of performed trips recorded by the drivers is validated by the AVM system.

The value of personnel costs (Operation and Maintenance – O&M) of the small-hydro in the ex-ante situation is zero. The Personnel costs are related with the O&M of the small-hydro (in relation to the ex-post situation) and is 5% of the small hydro plant energy annual revenues. This percentage is considered in the feasibility study and it includes the costs related with personnel for regular maintenance and operation of the plant, spare parts and insurance.

- **Indicator 3** (*Capital Costs*) – Total capital costs expended in setting up the measure (€).

  Expenditures with the purchase of the power generator (€)

  The data about the power generator purchase cost coming from the measure leader and is referenced in the Progress report of the small-hydro (economical, environmental and legal) feasibility study[2].

- **Indicator 4** (*Awareness level*) – Percentage of the users with knowledge of the measure on account of provided information (%).

  A = B / C × 100

  where: A = Percentage of users 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 during customer satisfaction surveys carried out in the scope of the Quality Management System of SMTUC (for more details, see annex dedicated to the customer satisfaction survey) by introducing the following specific question relative to the knowledge of the respondent about the measure – Are you aware about the SMTUC intention in producing renewable energy for trolleybus lines from Coimbra's Bridge-Dam?

[2] This information was included in the in the second year report, in feasibility study.

Indicator 5 (*CO2 Emissions*) – Average CO2 emissions per vehicle-km (g/vehicle-km)

A = B × (C – D)

where: A = Average CO2 emissions per vehicle-km (g/vehicle-km)

B = Average CO2 emissions in the supply of 1 MJ of electrical energy (g/MJ)

C = Total energy consumption by the Trolleybus fleet (MJ)

D = Total energy production by the small-hydro (MJ)

The data about the Average CO2 emissions in the supply of 1 MJ of electric energy is based on bibliographic sources: the Portuguese environment agency (average emissions in electricity production related to each energy source) and the regulatory entity of the Portuguese energy market.

All data are related to the SMTUC Trolleybus fleet. Results from vehicle-kilometres coming from the subtraction of non performed trips data to the scheduled ones. The source is the Excel file where the trips are recorded every day/month/year. The data reliability is maximised due to an accurate data collection among SMTUC records on performed and scheduled trips, which in turn are recorded following a reliable procedure: each driver records the corresponding performed/non performed trips; the extension of each trip is known; the number of performed trips recorded by the drivers is validated by the GPS/GPRS Operation Support System.

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

A = B × (C – D)

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

B = Average NOx emissions in the supply of 1 MJ of electric energy (g/MJ)

C = Total energy consumption by the Trolleybus fleet (MJ)

D = Total energy production by the small-hydro (MJ)

The data about the Average CO2 emissions in the supply of 1 MJ of electric energy is based on bibliographic sources: the Portuguese environment agency (average emissions in electricity production related to each energy source) and the regulatory entity of the Portuguese energy market.

All data are related to the SMTUC Trolleybus fleet. Results from vehicle-kilometres coming from the subtraction of non performed trips data to the scheduled ones. The source is the Excel file where the trips are recorded every day/month/year. The data reliability is maximised due to an accurate data collection among SMTUC records on performed and scheduled trips, which in turn are recorded following a reliable procedure: each driver records the corresponding performed/non performed trips; the extension of each trip is known; the number of performed trips recorded by the drivers is validated by the GPS/GPRS Operation Support System.

C1.2 Establishing a Baseline

2007 is considered as the baseline, before the start of the study in October 2008 and the release of any news about SMTUC's intention in producing renewable energy for trolleybus lines from Coimbra's Bridge-Dam.

The measure results are obtained from the measure leader, the feasibility study and SMTUC records on indicators 1, 2 and 3 and from the customer satisfaction survey periodically carried out by SMTUC on indicator 4.

Indicators 1, 2 and 3 (Operating Revenues, Operating Costs and Capital Costs):

The transport company SMTUC provided information on both the costs of operating the SMTUC PT system and revenues coming from ticket sales to passengers in relation to the operation of SMTUC transport services. Similarly, SMTUC provided information on the number of passengers as well as the vehicle-km performed both by the trolleybus (and overall) fleet.

For the Operating revenues and the capital costs it was considered that before the implementation of the small-hydro power plant any revenues and capital costs occurred.

For the operating costs was considered that before the referred implementation occurred costs with the purchase of electric energy to supply the trolleybuses fleet (values of the energy purchase and trolleybuses vehicle-km recorded by SMTUC and shown in the table

The results of baseline for each indicator are the following (tables C1.2.1 to C1.2.3).

Table C1.2.1: Baseline operating revenues indicator

Indicators and respective parameters	Ex-Ante values
Operating revenues from the small hydro plant (2007)	0,00 €
Total vechicle-km (2007)	206.797 vkm
Average operating renevues	0,00 €/vkm

Table C1.2.2: Baseline operating costs indicator

Indicators and respective parameters	Ex-Ante values
Total Operationg Costs (2007)	83.204 €
Purchase of electric energy from the mains for the trolleybus lines	83.204 €
Operation and Maintenance of the small-hydro plant costs	0 €
Total vechicle-km (2007)	206.797 vkm
Average operating costs	0,40 €/vkm

Table C1.2.3: Baseline capital cost indicator

Indicators and respective parameters	Ex-Ante values
Total capital cost (2007)	0,00 €

Indicator 4 (Awareness level)

This question was not applied before the launch of the "Feasibility Study" because it was considered that it is non sense to ask people if they know something that still doesn't exist. Thus, it is considered that before something exist awareness is zero because it's impossible to know it.

The Table C1.2.4 shows the results of the baseline for this indicator.

Table C1.2.4: Baseline awarness level indicator

Indicators and respective parameters	Ex-Ante values
Awareness level – users	0 %

Indicator 5 and 6 (Green-house gas emissions – CO2 and NOx)

In order to determine the ex-Ante values for this indicator, the measure leader provided information on the green-house gases emissions related to the measure (trolleybus lines and small-hydro operation). For that purpose, it has been used the available data about the consumption of energy of the trolleybus as well the average emission factor of CO2 and NOx reported from a 2007 data (table 3 and 4 of Annex 3).

The results of baseline for this indicator are shown in the table C1.2.5.

Table C1.2.5: Baseline average emission indicators

Indicators and respective parameters	Ex-Ante values
Average CO2 emissions (ton)	269,29
Average NOx emissions (ton)	0,81

C1.3 Building the Business-as-Usual scenario

The CIVITAS MODERN accelerated the implementation of the feasibility study and without it the implementation of the study would not have take place within a 4 or 5 year period (certainly not within the period of the project).

Without the implementation of the measure (business-as-usual scenario) no changes were likely to occur in the indicator 4 - Awareness level. Therefore, the B-a-U scenario for this indicator equals to the respective Ex-Ante value.

In relation to the indicators 1 - Average Operating Revenues, 2 - Average Operating Costs and 3 - Capital Costs, which were evaluated considering a scenario of real implementation of the measure, the available historic data showing the current trends in these indicators, correspond themselves to the BAU scenario.

Indicator 1 (Average Operating Revenues)

Without setting up the small hydro plant implementation the B-a-U scenario for Average Operating Revenues is considered zero (Table C1.3.1).

It is considered that there are no effects of other factors that have any influence in this indicator. In this case the Business-as-usual is equal to the baseline situation.

Table C1.3.1: BAU Operating Revenues indicator

Indicators and respective parameters	BAU values
Average Operating Revenues (2008)	0,00 €/vkm
Average Operating Revenues (2009)	0,00 €/vkm
Average Operating Revenues (2010)	0,00 €/vkm
Average Operating Revenues (2011)	0,00 €/vkm

Indicator 2 (Average Operating Costs)

Without setting up the small hydro plant the B-a-U scenario for Average Operating Costs is considered the energy costs to feed the trolleybuses (Costs per item and the trolleybuses vehicles-km in the table C1.3.2 and the summary of the BAU Average Operating Costs in the table C1.3.3).

Any costs for the operation and maintenance of the small-hydro has been considered, despite these costs were already incurred, but not by the PT operator (SMTUC).

Table C1.3.2: Costs per item and the vehicles-km in the BAU conditions

Year	A Energy Costs (€)	B Small Hydro Plant O&M Costs (€)	C=A+B Total O&M Costs (€)	D Vehicle-km Trolleybuses vkm	E=C/D Average Operating Costs €/vkm
2000	74.756,00	0,00	74.756,00	222.461,00	0,34
2001	72.587,00	0,00	72.587,00	195.801,00	0,37
2002	66.053,00	0,00	66.053,00	233.873,00	0,28
2003	71.428,00	0,00	71.428,00	235.175,00	0,30
2004	73.852,00	0,00	73.852,00	221.576,00	0,33
2005	75.007,00	0,00	75.007,00	211.555,00	0,35
2006	78.668,00	0,00	78.668,00	210.945,00	0,37
2007	83.204,00	0,00	83.204,00	206.797,00	0,40
2008	75.663,00	0,00	75.663,00	179.565,00	0,42
2009	70.625,00	0,00	80.625,00	147.025,00	0,48
2010	80.457,00	0,00	90.457,00	179.644,00	0,45
2011	93.818,00	0,00	103.818,00	195.507,00	0,48

Table C1.3.3: BAU Operating Costs indicator

Indicators and respective parameters	BAU values
Average Operating Costs (2008)	0,42 €/vkm
Average Operating Costs (2009)	0,48 €/vkm
Average Operating Costs (2010)	0,45 €/vkm
Average Operating Costs (2011)	0,48 €/vkm

Indicator 3 (Capital Costs)

The capital costs related to the installation of the power generator is considered in the year of setting up the measure (2008). Therefore, without the implementation of the measure, the capital costs would be as before. It is considered that there are no effects of other factors that have any influence in this indicator. In this case the Business-as-usual is equal to the baseline situation (Table C1.3.4).

Table C1.3.4: BAU Capital Costs indicator

Indicators and respective parameters	BAU values
Capital Costs (2008)	0 €
Capital Costs (2009)	0 €
Capital Costs (2010)	0 €
Capital Costs (2011)	0 €

Indicator 4 (Awareness level – users)

The change in the Awareness level – users related to SMTUC's intention in producing renewable energy for trolleybus lines from Coimbra's Bridge-Dam is obtained after setting up the measure (i.e. after the "start of the study" in October 2008 and the release of news about SMTUC's intention in producing renewable energy for trolleybus lines from Coimbra's Bridge-Dam). Therefore, if this measure wasn't implemented, the Awareness level – users would be as before. It is considered that there are no effects of other factors that have any influence in this indicator. In this case the Business-as-usual is equal to the baseline situation.

Therefore, the results of BAU scenario for this case (Table C1.3.5) are equal to the baseline.

Table C1.3.5: BAU awarness level indicator

Indicators and respective parameters	BAU values
Awareness level – users (2008)	0 %
Awareness level – users (2009)	0 %
Awareness level – users (2010)	0 %
Awareness level – users (2011)	0 %

Indicator 5 and 6 (Green-house gas emissions – CO2 and NOx)

The change in the Green-house gas emissions related to the installation of the power generator is obtained after setting up the measure. Therefore, without the implementation of the measure, the Green-house gas emissions would be as before. It is considered that there are no effects of other factors that have any influence in this indicator. In this case the Business-as-usual is equal to the baseline situation. It was considered the impact resulting of the change in the energy source from the usual production at national level to the local small-hydro production. The emissions were related to the energy used to feed the SMTUC trolleybuses and were obtained from the emissions factor of CO2 and NOx reported from a 2011 monthly data series (table 3 of Annex 3) and the energy consumption of the trolleybuses recorded by SMTUC (Table 4 of Annex 3)

The tables C1.3.6 and C1.3.7 show the results of BAU scenario for the emissions.

Table C1.3.6: BAU CO2 emissions indicator

Indicators and respective parameters	BAU values
Average CO2 emissions (2008)	236,48 (ton)
Average CO2 emissions (2009)	202,35 (ton)
Average CO2 emissions (2010)	228,89 (ton)
Average CO2 emissions (2011)	239,94 (ton)

Table C1.3.7: BAU NOx emissions indicator

Indicators and respective parameters	BAU values
Average NOx emissions (ton) (2008)	0,71
Average NOx emissions (ton) (2009)	0,61
Average NOx emissions (ton) (2010)	0,69
Average NOx emissions (ton) (2011)	0,72

C2 Measure results

The results are presented under sub headings corresponding to the areas used for indicators – economy, energy, environment, society and transport.

C2.1 Economy

In the same way as for the baseline, the results of the indicators for the situation after implementing the measure were obtained. Indicators 1 - Average Operating Revenues, 2 - Average Operating Costs and 3 Capital Costs were evaluated considering a scenario of real implementation of the measure during CIVITAS MODERN. The table C2.1.1 shows the small-hydro implementation scenario considered.

Table C2.1.1: Measure implementation timeline

Year	Stage
2008	Purchase and Installation of the power generator
2009	Operation of the small hydro power plant
2010	
2011	

The tables C2.1.2 and C2.1.3 show the data obtained relative to the operating revenues. This indicator is calculated taking in consideration the revenues coming from the sale of the energy produced in the small-hydro to the national grid per the vehicle-km in SMTUC trolleybus fleet. The revenues results of the annual energy production obtained in the feasibility study (2,6 GWh) and the feed-in tariff (0,077 €/kWh).

Table C2.1.2: Operating revenues coming from the energy produced in the small-hydro

Year	A Annual Small Hydro Plant Production (GWh)	B Feed-in tariff (€/kWh)	C= A/B Revenues Small Hydro (€)	D Vehicle-km - Trolleys (vkm)	**E=C/D Operating Revenues (€/vkm)**
2001	0	-	0,00	195.801	**0**
2002	0	-	0,00	233.873	**0**
2003	0	-	0,00	235.175	**0**
2004	0	-	0,00	221.576	**0**
2005	0	-	0,00	211.555	**0**
2006	0	-	0,00	210.945	**0**
2007	0	-	0,00	206.797	**0**
2008	0	-	0,00	179.565	**0**
2009	2,6	0,077	200.000,00	147.025	**1,36**
2010	2,6	0,077	200.000,00	179.644	**1,11**
2011	2,6	0,077	200.000,00	195.507	**1,02**

Table C2.1.32: Ex-Post Operating Revenues indicator

Indicators and respective parameters	Ex-Post Values
Average operating revenue (2009)	1,36 €/vkm
Average operating revenue (2010)	1,11 €/vkm
Average operating revenue (2011)	1,02 €/vkm

The table C2.1.4 show the data obtained from SMTUC relative to costs related to the trolley buses lines and the costs concerning the small-hydro operation and maintenance.

Table C2.1.43: Costs per item and total operating costs

Year	Energy Costs (€)	Small Hydro Plant O&M Costs (€)	Total O&M Costs (€)	Vehicle-km Trolley vkm	O&M costs / vkm €/vkm
2009	70.625,00	10.000,00	80.625,00	147.025,00	0,55
2010	80.457,00	10.000,00	90.457,00	179.644,00	0,50
2011	93.818,00	10.000,00	103.818,00	195.507,00	0,53

The table C2.1.5 summarize the Ex-Post Operating Costs

Table C2.1.5: Ex-Post Operating costs indicator

Indicators and respective parameters	Ex-Post Values
Average operating costs (2009)	0,55 €/vkm
Average operating costs (2010)	0,50 €/vkm
Average operating costs (2011)	0,53 €/vkm

The capital costs were obtained in the feasibility study and was considered that the implementation of the small-hydro took place in 2008 and no other investments will occur in the subsequent years (Table C2.1.6).

Table C2.1.6: Ex-Post capital costs indicator

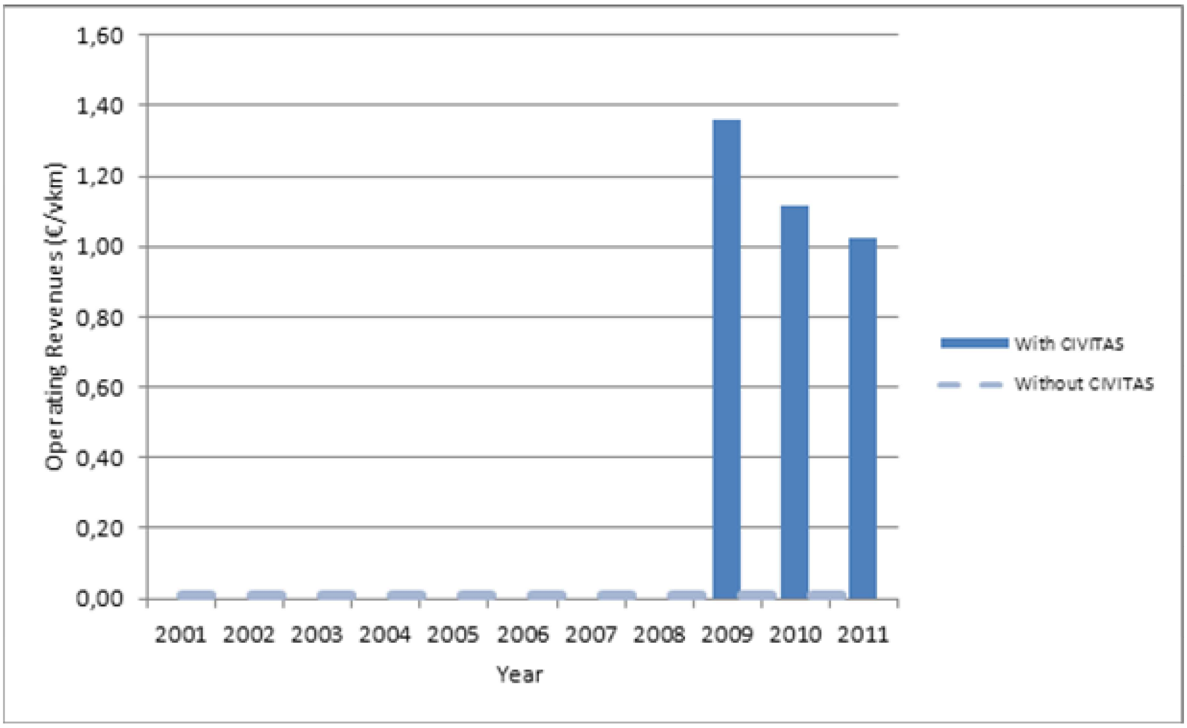
Indicators and respective parameters	Ex-Post Values
Total capital cost (2008)	1.700.000 €
Total capital cost (2009)	0 €
Total capital cost (2010)	0 €
Total capital cost (2011)	0 €

The table C2.1.7 summarises the results of indicators 1, 2 and 3.

Table C2.1.7: Summary of the indicators impact

Indicator	Before (date)	B-a-U (date)	After (date)	Difference: After –Before	Difference: After – B-a-U
1. Average Operating Revenues	0,00 €/vkm (2007)	0,00 €/vkm (2008) 0,00 €/vkm (2009) 0,00 €/vkm (2010) 0,00 €/vkm (2011)	1,36 €/vkm (2009) 1,11 €/vkm (2010) 1,02 €/vkm (2011)	1,36 €/vkm (2009) 1,11 €/vkm (2010) 1,02 €/vkm (2011)	1,36 €/vkm (2009) 1,11 €/vkm (2010) 1,02 €/vkm (2011)
2. Average Operating Costs	0,00 €/vkm (2007)	0,42 €/vkm (2008) 0,48 €/vkm (2009) 0,45 €/vkm (2010) 0,48 €/vkm (2011)	0,42 €/vkm (2008) 0,55 €/vkm (2009) 0,50 €/vkm (2010) 0,53 €/vkm (2011)	0,42 €/vkm (2008) 0,55 €/vkm (2009) 0,50 €/vkm (2010) 0,53 €/vkm (2011)	0,00 €/vkm (2008) 0,07 €/vkm (2009) 0,05 €/vkm (2010) 0,05 €/vkm (2011)
3. Capital Costs	0,00 € (2007)	0,00 € (2008) 0,00 € (2009) 0,00 € (2010) 0,00 € (2011)	1,700.000,00 € (2008) 0,00 € (2009) 0,00 € (2010) 0,00 € (2011)	1,700.000,00 € (2008) 0,00 € (2009) 0,00 € (2010) 0,00 € (2011)	1,700.000,00 € (2008) 0,00 € (2009) 0,00 € (2010) 0,00 € (2011)

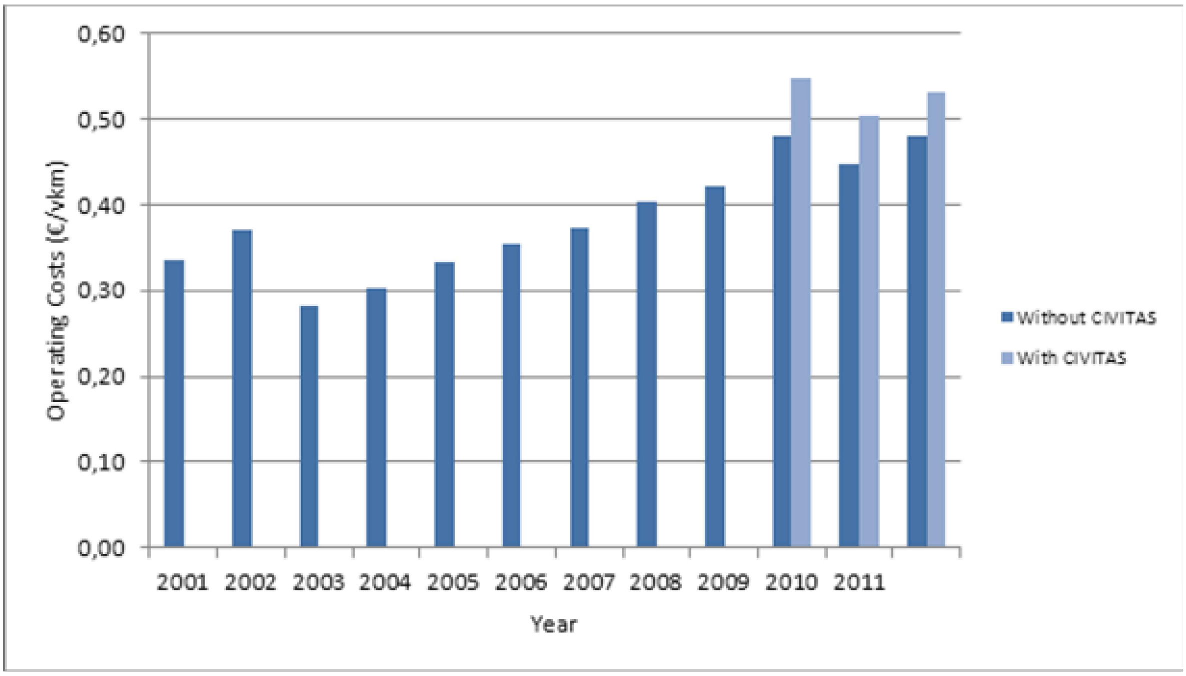
The graph C2.1.1 shows the evolution of average operating revenues (€/vkm) with the implementation of CIVITAS MODERN measure and the evolution of this indicator according to the B-a-U scenario (Without CIVITAS).



Graph C2.1.1 - Operating Revenues - trend without CIVITAS (BAU) and results with CIVITAS.

With the implementation of CIVITAS MODERN measure it is obtained 200 k €/year with the revenues of selling all the energy produced in the small-hydro, contributing to an increase in the overall operating revenues.

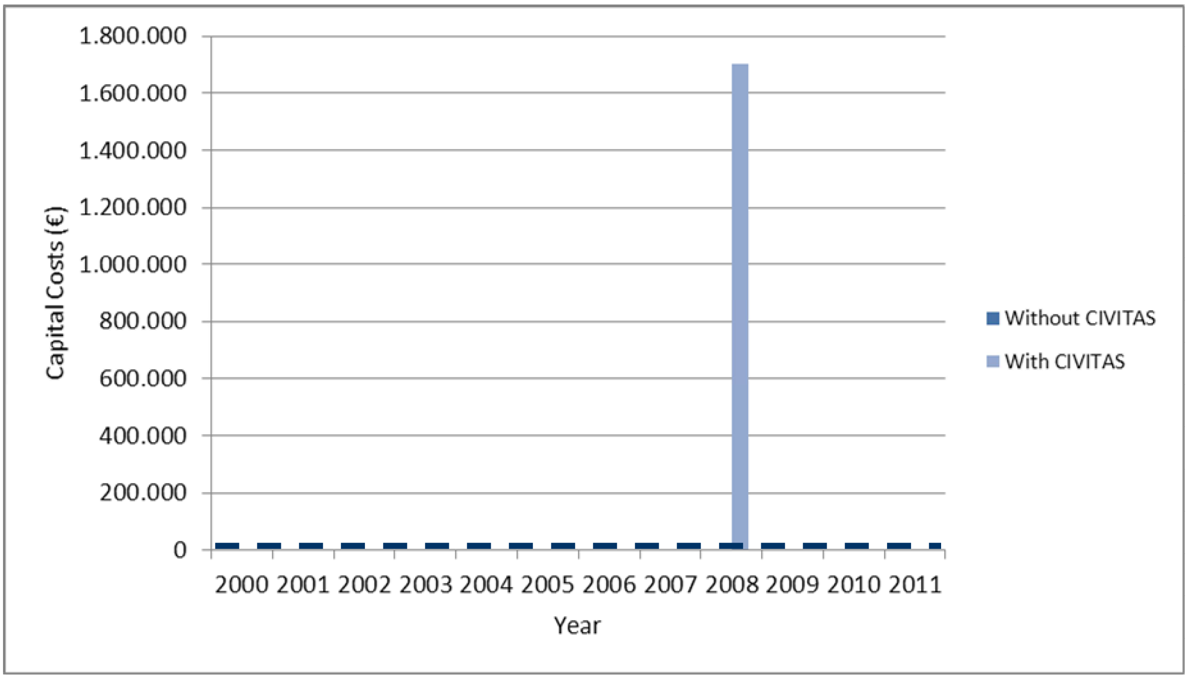
The graph C2.1.2 shows the evolution of average operating costs (€/vkm) With CIVITAS and the evolution of this indicator according to the B-a-U scenario (Without CIVITAS).



Graph C2.1.2 - Operating Costs - trend without CIVITAS and results with CIVITAS.

With the implementation of CIVITAS MODERN project, there is an increase on the operating costs due to the costs of operation and maintenance of the power generator which represents about 5% of the value of the revenues of selling the energy produced in the small-hydro.

The graph C2.1.3 shows the evolution of capital costs (€) With CIVITAS and the evolution of this indicator according to the B-a-U scenario (Without CIVITAS).



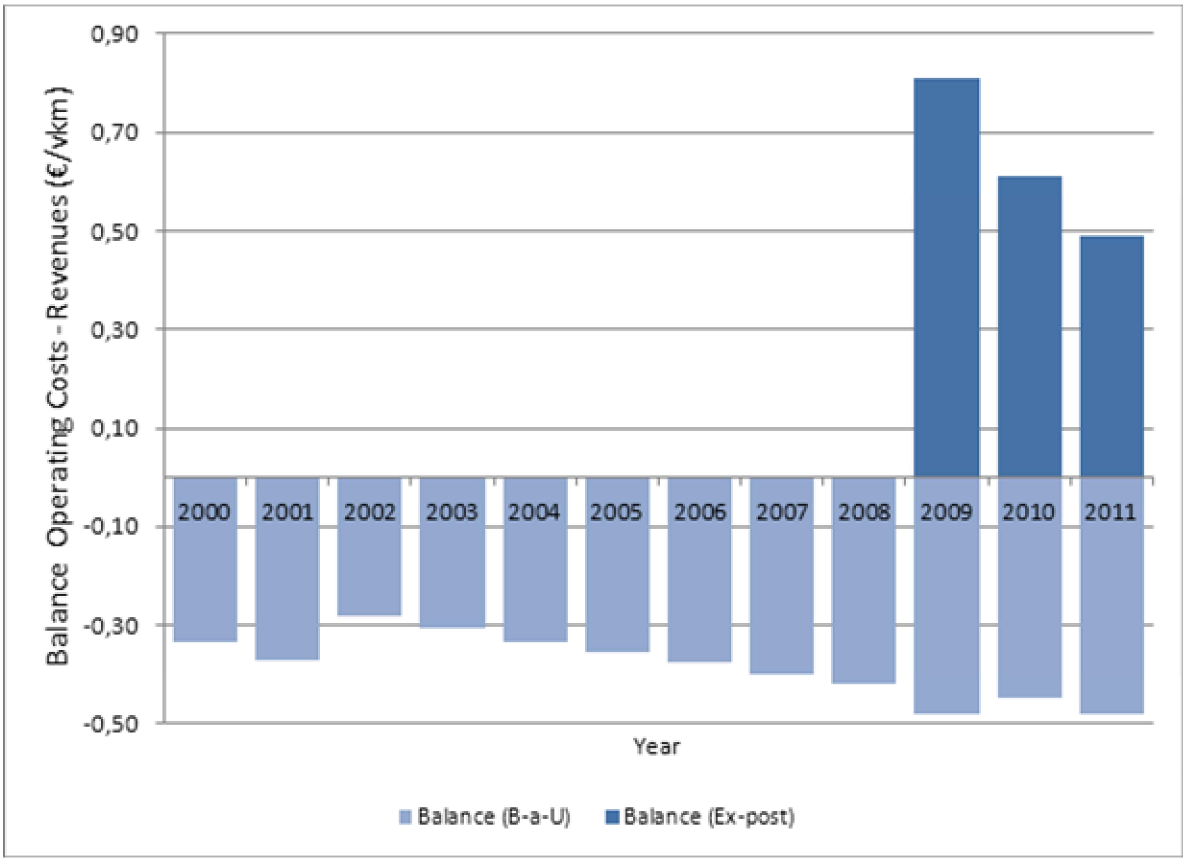
Graph C2.1.3 -Capital Costs - trend without CIVITAS and results with CIVITAS

In summary, the indicator 1(average operating revenues) associated with the small hydro plant reveals a generated income related to the revenue of selling the produced electrical energy to the grid after operating the plant (2009). As expected, the indicator 2 (average operating costs) reflects an extra costs related to the Operation and Maintenance (O&M) of the plant. Indicator 3 (Capital Costs) reflects the investment in 2008 for the small hydro plant. The table C2.1.8 shows the balance between indicator 1 and 2. Analysing the difference between the scenario ex-post and B-a-U it is possible to conclude that the measure revealed itself to be efficient since there are surpluses given by the difference between the average operating revenues and the average operating costs.

Table C2.1.8: Balance between average operating revenues and costs

Year	Difference: After – B-a-U (€/vkm)		
	Average Operating Revenues (A)	Average Operating Costs (B)	**Balance (A-B)**
2007	0,00	0,40	**-0,40**
2008	0,00	0,42	**-0,42**
2009	1,36	0,55	**0,81**
2010	1,11	0,50	**0,61**
2011	1,02	0,53	**0,49**

The balance of the operating revenues and costs from 2000 to 2011 for the B-a-U and Ex-post scenario is illustrated in the following histogram (Graph C2.1.4).



Graph C2.1.4 - Balance of the B-a-U scenario and Ex-post results

By analysing the figure it is possible to observe that in the B-a-U scenario the balance between revenues and costs are negative due to the fact that the implementation of the CIVITAS measure are not previewed. Observing the Ex-post scenario it is possible to perceive the impact of the measure on the balance between revenues and costs by changing the trend from negative to positive, i.e., the revenues obtained with selling the small hydro energy production to the grid generates a surplus when compared with the operating costs associated with the small hydro plant. Due to this fact it is possible to conclude that the introduction of the measure has a positive impact in financial terms.

Besides this economical evaluation it is also important to stress that the investment in the small hydro plant will have a simple payback period of 12 years. This value is based on the feasibility study in which values are expressed in the following table.

Table C2.1.9: Summary of the pay-back period

Investiment (M€)	1,7
Production (MWh)	2.600
Feed-in tariff (€/MWh)	77
Annual revenues (M€)	0,20
Simple Pay-back	**8,5**

C2.2 Society

To assess the knowledge towards the changes specific questions were added to the customer satisfaction survey to PT users - *Are you aware about the SMTUC intention in producing renewable energy for trolleybus lines from Coimbra's Bridge-Dam?* (according to the indicator definition). In this way, it has been obtained the results of the indicator after implementing the measure in 2009. The table C2.2.1 shows the results of indicator 4.

Table C2.2.1: Ex-post awareness level users

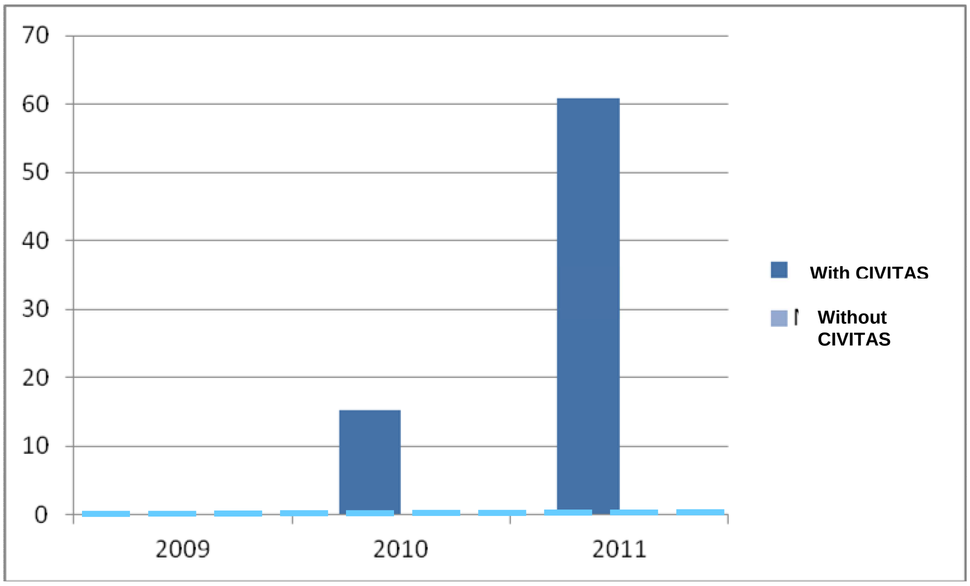
Indicators and respective parameters	Ex-Post values
Awareness level users (2010-03-23 a 2010-03-29)	15%
Awareness level users (2011-03-29 to 2011-04-04)	61%

The table C2.2.2 shows the results of the indicator:

Table C2.2.2: Ex-post awareness level balance

Indicator	Before (date)	B-a-U (date)	After (date)	Difference: After –Before	Difference: After – B-a-U
1. Awareness level – users	0 % (2009)	0 % (2010) 0 % (2011)	15 % (2010) 61 % (2011)	15 % (2010) 61 % (2011)	15 % (2010) 61 % (2011)

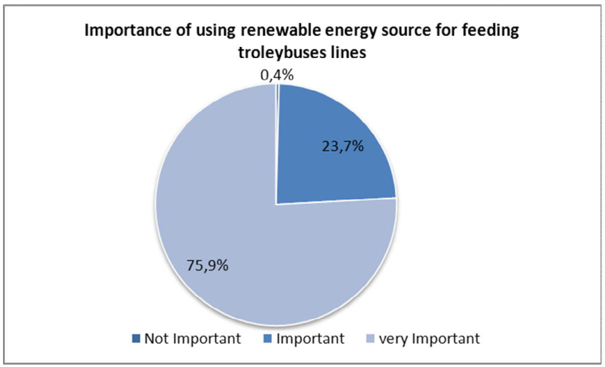
The next graph shows the evolution of the Awareness Level (%) With CIVITAS and the evolution of this indicator according to the B-a-U scenario (Without CIVITAS).

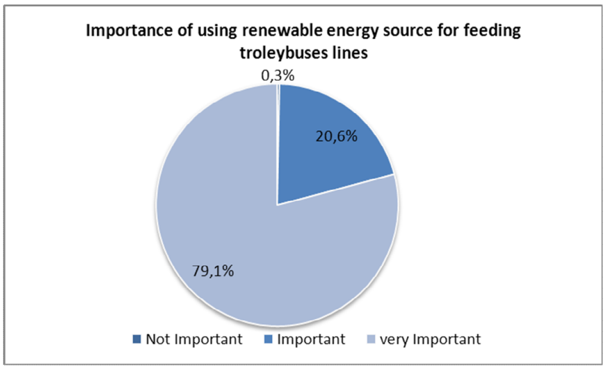


Graph C2.2.1-Awarness Level with CIVITAS and without CIVITAS

This evolution shows that the awareness level increased steadily along with the implementation of the measure (more rapidly from 2010-2011 than from 2009-2010 due the increase in the media coverage).

In addition a survey was developed in order to assess the acceptance level. A question related to the importance of using renewable energy sources to feed the trolley bus lines was introduced into the yearly customer satisfaction survey to PT users. Meanwhile, the impacts on society did not included the acceptance level because the measure had an initial high social media impact which did not allow for the assessment of the ex-ante data for this indicator (the first survey was conducted in 23-29 March 2010). The results of these surveys demonstrated a high acceptance level and it improved between 2010 and 2011, as it is shown in the Graph C2.2.2.





Graph C2.2.2- Renewable energy introduction acceptance level of PT users

C2.3 Environment

Indicator 5 and 6 (Green-house gas emissions – CO2 and NOx)

In order to determine the ex-Post values for this indicator, the measure leader provided information on the green-house gases emissions related to the measure (trolleybus lines and small-hydro operation). For that purpose, the available data about the consumption of energy of the trolleybus and the average emission factor of CO2 and NOx reported from a 2011 monthly series data as well as the total production of renewable energy at the small-hydro has been used.

The ex-post emissions reduction corresponds to the difference between the emissions due the energy production in the small-hydro (zero emissions) and the comparatively emissions for the same energy production at national level. According the feasibility study the foreseen energy production will be 9.360.000 MJ per year. So with the emission factors for the greenhouses gases incurred in the energy production at national level (table C2.3.1) we obtain the reduction in the emissions per year with the implementation of the small-hydro power generator (table C2.3.2).

Table C2.3.1: Emission factor for the greenhouse gases incurred in the global electricity production (at national level)

Average CO2 emissions incurred in electricity production (g/MJ)	99,4
Average NOx emissions incurred in electricity production (g/MJ)	0,30

Table C2.3.2: Ex-post average CO2 emissions

Indicators and respective parameters	Ex-Post values
Average CO2 emissions (ton) – 2008	+ 236,48
Average CO2 emissions (ton) – 2009 / 2010 / 2011	-930,38
Average NOx emissions (ton) – 2008	+ 0,71
Average NOx emissions (ton) – 2009 / 2010 / 2011	-2,81

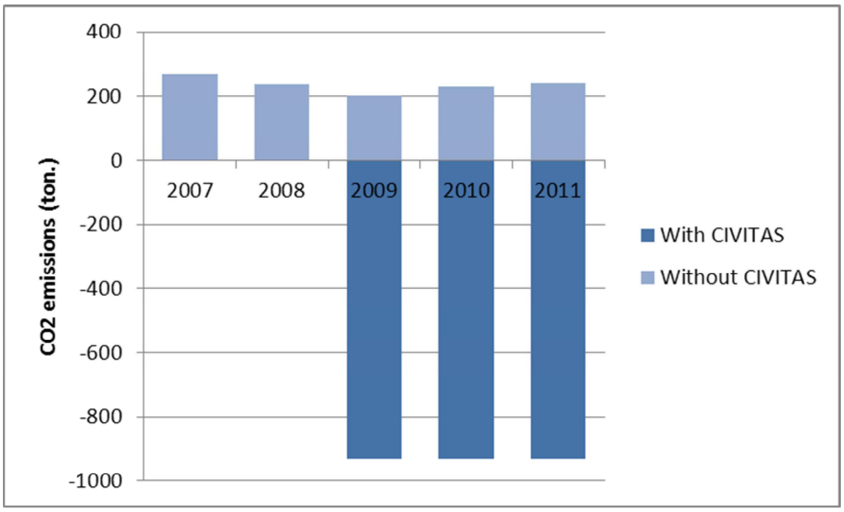
These results (negative emissions) show that the production of renewable energy at the small-hydro largely exceeds the consumption of energy of the trolleybus lines. Thus, the measure contributes to an reduction of GHG emissions at national level.

The table C2.3.3 sumarises the results of the indicators.

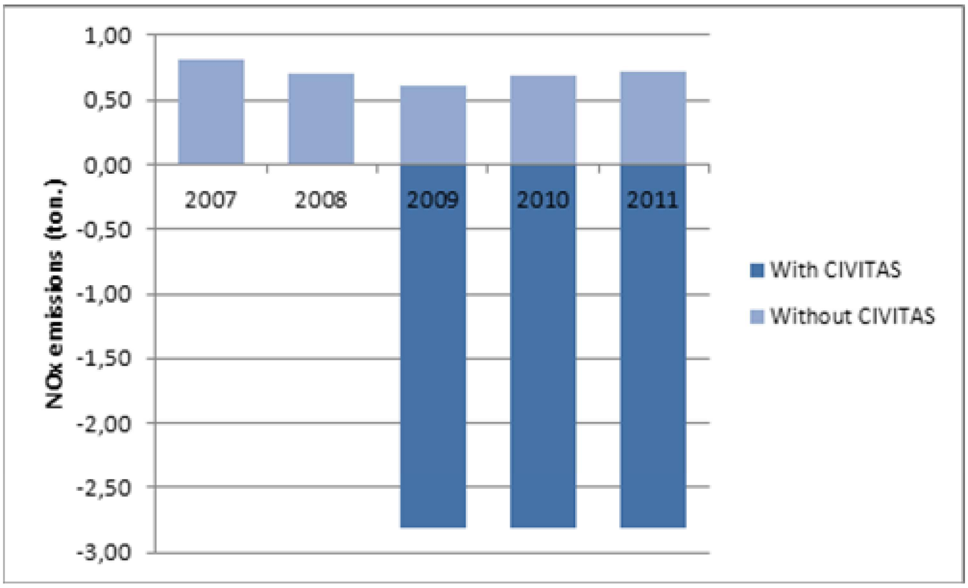
Table 2.3.3: Ex-post average CO2 emissions balance

Indicator	Before (date)	B-a-U (date)	After (date)	Difference: After –Before	Difference: After – B-a-U
2. CO2 emissions	239,98 ton (2007)	236,48 ton (2008) 202,35 ton (2009) 228,89 ton (2010) 239,98 ton (2011)	236,48 ton (2008) -930,38 ton (2009) -930,38 ton (2010) --930,38 ton (2011)	0 ton (2008) -930,38 ton (2009) -930,38 ton (2010) -930,38 ton (2011)	0 ton (2008) -1132,73 ton (2009) -1159,27 ton (2010) -1170,32 ton (2011)
3. NOx emissions	0,81 ton (2007)	0,71 ton (2008) 0,61 ton (2009) 0,69 ton (2010) 0,72 ton (2011)	0,71 ton (2008) -2,81 ton (2009) -2,81 ton (2010) -2,81 ton (2011)	0 ton (2008) -2,81 ton (2009) -2,81 ton (2010) -2,81 ton (2011)	0 ton (2008) -3,42 ton (2009) -3,50 ton (2010) -3,53 ton (2011)

The graphs C2.3.1 and C2.3.2 show the evolution of the CO2 emissions (ton) and NOx (ton) With CIVITAS and the evolution of these indicators according to the B-a-U scenario (Without CIVITAS).



Graph C2.3.1 -CO2 emissions – trend without CIVITAS and results with CIVITAS



Graph C2.3.2 -NOx emissions B-a-U with CIVITAS and No CIVITAS

These graphs show that the measure has a significant positive impact in terms of emission abatement. Indeed, the operation of the small-hydro generates an amount of energy significantly higher than the energy consumption of the trolleybus fleet.

C3 Achievement of quantifiable targets and objectives

No.	Target	Rating
1	**To make a technical project and economical, environmental and legal feasibility study to implement an electric energy production system (small-hydro) inserted in the already existing Coimbra Dam-bridge (Producing at least 0,75 GWh per year).** The study has been carried out and the feasibility was demonstrated with an energy production of 2,6 GWh per year (that largely exceeds the initial objective)	★★★
2	**To release a digital model of the small hydro** The digital model was delivered including a 3D version	★★
3	**To carry out awareness campaigns of the benefits of future self-production of electricity to supply the trolleybuses lines of the Urban PT operator (SMTUC)** This measure had a high media coverage with several pieces in magazines, newspapers and TV. In the scientific community the measure also had a very positive impact, since it was presented in 3 international conferences and a publication in the International Journal World Electric Vehicle Journal, ISSN 2032-6653, Volume 3, December 2009 and another paper entitled "Small-hydropower addition to Coimbra dam-bridge for sustainable urban mobility" was submitted to the journal "Renewable & Sustainable Energy Reviews", Elsevier, and is available online since on 16th September 2011.	★★★
4	**To contribute to the reduction of emission of greenhouse gases at national level** Since the energy production is higher than expected (0,75 GWh) then the emissions were largely reduced (1.170 ton of CO_2, 3,53 ton of NO_x)	★★★
NA = Not Assessed O = Not Achieved ★ = Substantially achieved (at least 50%) ★★ = Achieved in full ★★★ = Exceeded		

C4 Up-scaling of results

The scenario considered about installing a power station at the existing dam to produce electric energy for trolleybus lines in Coimbra is not object of up-scaling because no other means to produce renewable electric energy to the trolleybus lines in Coimbra are currently available to STMUC.

C5 Appraisal of evaluation approach

The evaluation strategy of this measure sought to focus on a number of indicators across the areas of economy, energy, environment and society, which were to be measured in different ways.

The idea of direct feeding of trolleybus by the energy produced at the Coimbra power station initially considered was abandoned because in technical and economic terms was not recommended. For this reason it was introduced a solution based on feed-in tariff and selling all the produced energy to the electrical grid. Also SMTUC will not use the surplus in energy (and revenues) in the increase of the offer in the trolleybus PT network in a first stage but for the payback of the investment. For this reason it is not expected changes at short time in the operational revenues coming from ticket sales and consequently this item was not considerate nor the global operational costs of SMTUC.

In the new scenario, the only energy and environment impacts resulting from the production of electricity at the small-hydro occur at national level. <u>For these reason was not chosen indicators related directly with the SMTUC fleet (fuel mix, fuel efficiency, GHG emissions). Instead of this approach it was evaluated the impacts of CO_2 and NO_x emissions generated in the well (Portuguese electrical power generation system).</u>

C6 Summary of evaluation results

The key results are as follows:

- **Increase of operating revenues** – Average Operating Revenues are expected to increase as result of the implementation of the measure because it will be introduced a new income to the company related with production of renewable energy production. A. With the implementation of CIVITAS MODERN measure it is estimated a revenue of 200 k€/year by selling all energy production (2 600 MWh) associated with a feed-in tariff scheme.

- **Small increase of operating costs** – After the measure implementation period, the Operating Costs are likely to have a small increase related with the O&M costs. The O&M costs are estimated to be 5% of the annual receipt of energy production. It is estimated an increase of 0,05€/vkm with the introduction of the measure.

- **Additional capital Costs** – The implementation of the measure have an initial capital cost of 1.700 k€. It is estimated that this investment has a simple pay-back period of 8,5 years, which is considered cost effective in terms of other investments in small hydro plants.

- **Positive financial balance** – The implementation of the measure generates a positive balance between average operating costs and revenues, giving a financial surplus. It is estimated that with the implementation of the measure the average balance between 2009-2011 is 0,64 €/vkm. This surplus it will contribute the company to enhance the environment and energy efficiency performance.

- **Positive energy balance and GHG emissions abatement** – The results of the measure allows that the production of renewable energy at the small-hydro is expected to largely exceed the energy consumption of the trolleybus lines. This means that the operation of the small-hydro would have a significant positive impact in terms of greenhouse gas emission abatement at national level once it generates an amount of energy significantly higher than the energy consumption of the trolleybus fleet.

- **Positive awareness impact and stimulation of the R&D activities** – The results of the measure had a high media coverage with several pieces in magazines, newspapers and TV. In scientific community the measure also had a very positive impact, since it was presented in 3 international conferences and generates publications for the scientific energy and environment community.

C7 Future activities relating to the measure

The real implementation of the small-hydro power plant in the future is forecasted. For this purpose will continue the search for opportunities for financial and partnership arrangements. As soon as the funding is decided a final project for the power plant will be made and provided to the INAG – Portuguese Water Institute – to allow for the quick start of the small-hydro implementation.

During the first years the revenues of the energy sold will be used mainly in the depreciation of the small-hydro implementation and in the energy supply of the trolleybus and electric mini-bus fleet. After the payback period the surplus in energy sold will be used for renewing the fleet.

D Process Evaluation Findings

D.1 Deviations from the original plan

The deviations from the original plan comprised:

- **The direct electric feed of the trolleybus traction lines was not considered, but rather the study centred on the sale of the energy to the national electricity grid** – The original plan considered that the electric energy produced in the small-hydro would be used to directly feed the trolleybus traction lines. But this solution had many disadvantages: very high capital costs for the energy transformation; strong irregularity of the Mondego river flow which could cause peaks in the energy supply (including periods of insufficient feed of trolleybuses system, namely during the summer); loss of the surplus of energy, mainly during the night period (in which trolleybuses don't run) and during the major part of the days of the year (that the foreseen energy production must higher than the trolleybuses and electric mini-buses energy consumption). So all the parts agreed to consider that the energy produced in the small-hydro would have to be sold to the electricity grid of EDP – the Portuguese electricity supplier – and the revenues applied in the electric dimension of the public transportation system in Coimbra.
- **A detailed small hydropower operation computational model has been developed instead of the construction of a small-hydro scale model plant** – The original plan had foreseen the construction of a physical scale model of the small-hydro, but these models are more frequently used for the building projects of the dams and in the Coimbra's case the dam was already built. For this reason, it the decision was to develop of a detailed small hydropower operation computational model, which provides a DEMO layout of the Coimbra Dam Bridge equipped with turbine-generator units. This approach is more useful for the objectives of the study, because the model allows for the immediate monitoring of the overture state of each of the 9 radial gates, the flow in each radial gate, the number of operating turbine-generator units, and the respective energy production. This model is also more portable, which is more convenient for dissemination activities.
- **The achievement of the technical feasibility had a delay of 8 months** – The reply of the Portuguese Water Authority (INAG) and some other governmental departments to the administrative procedures and requests for data was quite sluggish, which delayed the first part of the study that had the objective of assess the technical feasibility of the measure. In any case this delay was totally recovered in the other parts of the measure.

D.2 Barriers and drivers

D.2.1 Barriers

<u>**Preparation phase**</u>

- **Barrier 1.1 – Technological Barrier** – The hydrological analysis to the available flows for the production of electric energy shows a strong irregularity of the Mondego River. This feature could produce peaks in the energy supply and periods in which the energy produced is lower than that consumed by the trolleybuses (namely in the summer). The direct electric feed of the trolleybus traction lines couldn't absorb these fluctuations nor the surplus energy production that occurs during large part part of the year and during the evening period in which trolleybuses don't run. This technology also implies high capital costs for the energy transformation.

- **Barrier 1.2 – Technological Barrier** – More technical constraints occurred than originally foreseen, namely the above mentioned irregularity of the Mondego River flow, the limited space available in the existing dam bridge, the need for carefully analysing the impacts in the fish-pass, and the impossibility of achieving the maximum flow rates without the risk of flooding. These constraints forced the study of several layouts for the power plant implementation. Also for this reason a physical scale model of the small-hydro isn't the optimal solution to model and to monitor the several layouts for the power plant. Also the physical model could be too expensive in comparison with the benefits received. These models are more frequently used for the entire modulation of the dam, but in Coimbra's case the dam was already built.

<u>Implementation phase</u>

The measure was only a study, so no implementation phase was foreseen during CIVITAS. Nevertheless, the following barriers could be critical reasons for the initial decision to carry out only a feasibility study during CIVITAS instead of implementing the measure:

- **Barrier 2.1 – Financial Barrier** – The idea of using the existing dam located in the city centre to feed the trolleybus traction lines happen only during the last period of the preparation for the CIVITAS call. For this reason it was impossible to have time to develop a preliminary study to assess the feasibility of the measure, mainly at the financial level, and to find funding for its actual implementation. So SMTUC decided to avoid the risk of an unsuccessful implementation and opted to carry out the only the feasibility study, involving the University of Coimbra for this purpose.
- **Barrier 2.2 – Institutional Barrier** – The reply of the Portuguese Water Authority (INAG) and some other governmental departments to administrative procedures and requests for data was quit sluggish, revealing long periods without receiving any feed-back. INAG has not yet replied to the administrative request for the addition hydropower plant in the Coimbra Dam Bridge. The request was made by the Municipality of Coimbra at the beginning of the CIVITAS MODERN project.

<u>Operation phase</u>

The measure was only a study, so no operation phase was foreseen during CIVITAS, Accordingly, and as described in the barrier 1.2, a digital model of the dam, the turbines and the small hydro power generation has been developed for the demonstration and dissemination of the measure. Thus this task can be considered the integration of the operation phase. No important barrier occurred, but the institutional barrier described for the implementation phase (2.2) also influenced the development of the digital model due the difficulty brought on by the unavailability of timely data. This problem didn't avoid the conclusion of the model before the foreseen date, but caused delays that hindered the conclusion of this work sooner, (with less efforts spent on human resources and allowing more time for demonstration).

D.2.2 Drivers

Preparation phase

- **Driver 1.1 – Financial Driver** – This feasibility study needed a great deal of research in several areas and critical issues were analysed, namely those that could have impacts at the environmental and safety level. For this reason the costs foreseen for the study have a significant value that only could be covered with the availability of CIVITAS funds.

- **Driver 1.2 – Involvement, communication Driver** – Despite this measure only consisting of a study during CIVITAS, it received the most media coverage because the population also elected this measure as the most important and welcomed. The reasons for this involvement of the population of Coimbra (and of the personnel responsible for the study) were mainly the innovation of the measure and the possibility to have an environmentally friendly use of the dam.

Implementation phase

The measure was only a study, so no implementation phase was foreseen during CIVITAS. Nevertheless the following driver helps catalyse the possibility of real implementation of the measure:

- **Driver 2.1 – Financial Driver** – The possibility using the revenues from the sale of the surplus energy produced in the existing dam for the feeding of the trolleybus traction lines, mainly because the capital costs will be smaller due to the fact that the dam already exists.

Operation phase

The measure was only a study, so no operation phase was foreseen during CIVITAS, However, as referred to for the barriers, a digital model of the dam has been developed and it can be considered that this activity was integrated in the operation phase. The following driver occurred in this phase:

- **Driver 3.1 – Technological Driver** – The high quality of the digital model allowed for identifying the best solutions and reaching faster conclusions, namely about the specifications and location for the energy power generation system: Equally important, the digital model also served as a good instrument for the dissemination activities.

D.2.3 Activities

Preparation phase

- **Activities 1.1 – Technological Activities** – Taking into consideration that the technology for the energy supply, based on the direct electric feed of the trolleybus lines, wasn't advisable due to the irregularity of the energy production in the small-hydro and the possibility of frequently surpassing the needed energy production (barrier 1.1), it was considered that the energy produced in the small-hydro will be sold to the public electricity grid of EDP and the revenues will be used in the electric part of the public transportation system in Coimbra.

- **Activities 1.2 – Technological Activities** – The physical scale model of the small-hydro isn't the best solution to model and to monitor the different layouts for the power plant (barrier 1.2). For this reason the development of a detailed small hydropower operation computational model, which provides a DEMO layout of the Coimbra Dam Bridge equipped with turbine-generator units, was chosen as the best option. This approach is more useful for the objectives of the study and more convenient for the dissemination activities. The occurrence of delays caused by the technical constraints referred to in barrier 1.2 was avoided by involving experts of several areas in the study, taking advantage of the availability of the CIVITAS funds (driver 1.1) and the fact that these experts are highly motivated (driver 1.2).

Implementation phase

The measure was only a study, so no implementation phase was foreseen during CIVITAS.

Operation phase

The measure was only a study, so no operation phase was foreseen during CIVITAS. Nevertheless, the use of the digital model of the small hydro power plant for demonstration and dissemination actions could be included in this phase. The following activity is highlighted:

- **Activities 3.1 – Involvement, Communication Activities** – Taking advantage of the driver 3.1 several tests with the digital model have been carried out and the model has been used in several presentations (workshops, seminars, CIVINET Spain and Portugal Forum 2011, …), Some dedicated videos with the 3D model version and 4 generic videos that included this model have been also produced and used in presentations, namely in the CIVITAS Forum 2012, or placed on-line (including the CIVITAS website).

D.3 Participation

D.3.1 Measure partners

- **Measure partner 1 – University of Coimbra (UC); University; Leading role**

  The University was responsible for the development of the technical, environmental, economic and financial feasibility study to implement a renewable energy production (small-hydro power plant) in an existing local river dam, using this electricity to supply Coimbra's trolleybus and electric minibus fleet.

  They also made some laboratorial tests in an open flume channel and developed a computational simulation model used to test the hydraulic operational aspects connected to hydropower addition and to evaluate electric energy production revenue.

  Accordingly, the University carried out all the research and technical development activities in the measure and also participated in some dissemination actions, namely with the release of papers that were published in indexed international journals as well as the presentation of the measure in several international conferences and workshops. They demonstrated a great interest and involvement in the measure.

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

The Municipality assisted the University and the SMTUC in the activities made in order to increase the involvement in the measure of some governmental departments, namely the Portuguese Water Authority (INAG). Since October 2011 the Municipality has also been responsible for the dissemination of the MODERN project of Coimbra.

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

While responsible for the dissemination activities for the first three years of the MODERN project of COIMBRA, PRODESO also provided some support in the dissemination and promotion of this measure, including the assistance of SMTUC in the organization of the CIVINET Spain and Portugal Forum where the small-hydro project was presented.

- **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.

- **Measure partner 5 - Serviços Municipalizados de Transportes Urbanos de Coimbra (SMTUC); Public transport company; Occasional participant**

SMTUC is the partner that will benefit from the measure if the small-hydro project is implemented and the revenues of the energy produced will be used in the trolleybus and electric mini-bus fleets. For this reason they also have an important role in the collection and release of data concerning the public transport service.

SMTUC also assisted the University and the Municipality in the activities in order to increase the involvement in the measure of some governmental departments, namely the Portuguese Water Authority (INAG).

Additionally, SMTUC organized some events where the measure was presented, namely the CIVINET Spain and Portugal, and participated in several events for its dissemination.

D.3.2 Stakeholders

- **Stakeholder 1 – Portuguese population –** The measure had a great interest and involvement of the population in general, supported by important media coverage. As the main beneficiaries of this measure, at the environmental or mobility level, the inhabitants of Coimbra are pushing for the real implementation of the small-hydro.

- **Stakeholder 2 – Portuguese Water Authority (INAG – Instituto da Água) –** INAG is responsible for the management of the national water issues, including the Mondego River, and the owner of the existing river dam where the implementation of the small-hydro is foreseen. They provided some data about the dam and the Mondego River and participated in some meetings, which also involved the University, the Municipality and the SMTUC, with the objective of having a greater involvement of the national departments.

- **Stakeholder 3 – Portuguese Electric Energy Supplier (EDP – Electricidade de Portugal) –**EDP will be an important part of business if the measure is implemented because it is expected that the supply of electric energy for the trolleybus and electric mini-bus fleet will be made with the revenues of the sale of the electric energy produced in the small-hydro plant to EDP. So preliminary informal contacts occurred, but a higher involvement in the future to evaluate the possibility of partnerships in this project is expected.

- **Stakeholder 4 – Media** – This measure was the best covered by the media and it was frequent for people to associate the CIVITAS project to the implementation of the small-hydro in Coimbra for the (indirect) supply of the trolleybus and electric mini-bus fleet. The media has been a channel for the dissemination and promotion of the measure and all the events organized in Coimbra had the participation at least of the local media with several news articles published (in the international events the specialised media also participated, namely the magazines "Transportes em Revista" e "Água e Ambiente").

The specialised international journals "World Electric Vehicle Journal" and "Renewable & Sustainable Energy Reviews" have published papers of the small-hydro project.

- **Stakeholder 5 – Electric Vehicle Portuguese Association (APVE – Associação Portuguesa do Veículo Eléctrico)** – Taking into consideration that the electric energy produced in the small-hydro will be also used for the electric mini-bus system (if the measure is implemented in the future), the APVE demonstrated great interest in this project and assisted the University and SMTUC in some dissemination activities, with special emphasis on the presentation of the measure in the 24th World Electric Vehicle Symposium – EVS24 (Norway, 13-16th May 2009).

D.4 Recommendations

D.4.1 Recommendations: measure replication

- **To sell the energy to the public grid is better than the direct feeding of the vehicles used in the public transport system –** The measure replication will be not easy because it is difficult to find similar conditions in other cities: an existing river dam (major capital costs already made), located in the centre of the city (local production which avoids energy transport losses), for the production of renewable electric energy for the use in the electric part of the transport system. If similar conditions are available avoiding the direct electric feed of the fleet is recommended because the costs of energy transformation could be high and irregularities could occur in the energy production that will affect the transport system (peaks or insufficient energy production) or a surplus of unused energy production can occur. As in Coimbra's case, it would be better to consider the sale of the energy to the public grid and the use of the revenues for the electric part of transport system.

- **Possibility of environmental and technical constraints** – In this kind of projects the anticipation of analysing possible constraints, mainly at the environmental level (impacts on the biodiversity, consequences in case of flooding), but also at dam specifications level (including the space for the turbines and generator and the flood rates available), is recommended. The involvement of experts of several different fields is also advisable (in Coimbra's case, the University also involved experts in zoology to study the issues linked to the fish passage)

- **Special attention must be given to the administrative / legal procedures** –The processes of licensing and request for authorisations could be longer and complicated than initially predicted, so they must be started as soon as possible. If negotiations with entities are needed, some anticipation could be also important - as the case in Coimbra (the demand for meetings with the Portuguese Water Authority (INAG) and the request for the small-hydro implementation were made at the beginning of the CIVITAS MODERN project). The involvement of the Municipality in the activities of viability and strengthening of the communication channels with national authorities could be very important (in Coimbra's case the Mayor and the Mobility Councillor attended 2 meetings with the decision-makers at INAG).

- **The capital costs for the implementation of the small-hydro could be significant, so it is recommended to consider the external benefits, as well as the availability of funding programs and institutional arrangements.** – Despite the dam already being built, as the case of Coimbra, the capital costs for the small-hydro could be significants (1.700 thousand euros in Coimbra). It is recommended that the economic feasibility study, in order to reduce payback time and increase the internal rate of return, take into consideration positive external factors such as environmental issues and the importance of the project for the city (the measure will contribute for an reduction of 930 tons per year in the CO2 emissions and 2,79 tons per year in the NOx emissions, but these values could be augmented when the revenues of the surplus energy production is applied in the increase of the offer of trolleybus services). Some funding programs (European, National or Regional) and institutional arrangements could also support the initial investment, improving the economic feasibility of the project.

D.4.2 Recommendations: process

- **It is recommended to motivate the staff and involve experts of several fields to face eventual constraints due the complexity of this kind of projects –** The involvement of experts from several fields is recommended in this kind of project in order to deal competently and promptly with the different constraints that can occur. The University of Coimbra used this technique with success, taking advantage of the funds available and the fact that these experts are highly motivated by the innovation and media coverage of the measure. Despite some critical technical barriers – i.e., the strong irregularity of the flow rate of the Mondego river, the impossibility of achieving the maximum flow rate without the risk of flooding, the difficulties in solving the problems with the fish passage, the space constraints due the fact that the dam was already built, the higher costs of the technology needed for the small-hydro, and the delay in the reply for request to some national departments - the University of Coimbra concluded the feasibility study on time and with great quality and outcomes.

ANNEX 1 Average Operating Costs Data

The next table shows the data obtained obtained from SMTUC relative to operating costs for the trolley buses lines:

Table 1: Operating Costs related to the purchase of energy to suply the trolleybuses fleet and for the operation and maintenance of the small-hydro

Year	A Energy Costs (€)	B Small Hydro Plant O&M Costs (€)	C = A+B Total O&M Costs (€)	D Vehicle-km Trolley vkm	E=C/D O&M costs / vkm €/vkm
2000	74.756,00	0,00	74.756,00	222.461,00	0,34
2001	72.587,00	0,00	72.587,00	195.801,00	0,37
2002	66.053,00	0,00	66.053,00	233.873,00	0,28
2003	71.428,00	0,00	71.428,00	235.175,00	0,30
2004	73.852,00	0,00	73.852,00	221.576,00	0,33
2005	75.007,00	0,00	75.007,00	211.555,00	0,35
2006	78.668,00	0,00	78.668,00	210.945,00	0,37
2007	83.204,00	0,00	83.204,00	206.797,00	0,40
2008	75.663,00	0,00	75.663,00	179.565,00	0,42
2009	70.625,00	10.000,00	80.625,00	147.025,00	0,55
2010	80.457,00	10.000,00	90.457,00	179.644,00	0,50
2011	93.818,00	10.000,00	103.818,00	195.507,00	0,53

Source: SMTUC

ANNEX 2 Small-hydro feasibility study Data

The next table shows the data obtained from the feasibility study in relation to the small-hydro:

Table 2: Outputs of the smal-hydro feasibility study

Layouts		V2-1T
Turbines Type		VLH-4000-4.0
Estimated cost of small-hydro (M€)		1,7
Annual Revenue (M€)	DL 225 / 2007 (average of 35 years)	0,14
	15-10-2010 Context (average of 45 years)	0,2
Annual energy (GWh)		2,6

University of Coimbra, Progress report of the small-hydro (economical, environmental and legal) feasibility study

In relation to the Annual Revenues it has been considered the 15-10-2010 Context (which corresponds to an average of 200.000,00 €/year).

Additionally, the measure leader provided information in relation to the Personnel costs (maintenance and operation) of the small-hydro. According to this information, the Personnel costs (maintenance and operation) of the small-hydro correspond to an average of 5% of the Revenues comming from the sale of energy produced in the small-hydro (which corresponds to an average of 10.000,00 €/year).

ANNEX 3 Green-house gas emissions data

The next table shows the data obtained from the measure leader in relation to the average emission factor of CO2 and NOx reported from a 2011 monthly serie data:

Table 3: Emission factor for the green gases incurred in the global electricity production (at national level)

Average CO2 emissions incurred in electricity production (g/MJ)	99,4
Average NOx emissions incurred in electricity production (g/MJ)	0,30

The table 4 shows the data obtained from SMTUC in relation to the energy consumption of the trolleybus fleet per year:

Table 4: Evolution of the offer (vkm) and the energy consumption in the SMTUC trolleybus lines and emissions related to the energy production

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Total vehicle-km (Vkm)	222.461	195.801	233.873	235.175	221.576	211.555	210.945	206.797	179.565	147.025	179.644	195.507
Total energy consumption (kWh)	770.220	709.633	769.038	840.190	833.136	771.833	748.164	752.556	660.845	565.474	639.637	670.518
Total energy consumption (MJ)	2.772.792	2.554.679	2.768.537	3.024.684	2.999.290	2.778.599	2.693.390	2.709.202	2.379.042	2.035.706	2.302.693	2.413.865
Total costs with the electricity consumption (€)	74.756	72.587	66.053	71.428	73.852	75.007	78.668	83.204	75.663	70.625	80.457	93.818
kWh / Vkm	3,4623	3,6243	3,2883	3,5726	3,7600	3,6484	3,5467	3,6391	3,6803	3,8461	3,5606	3,4296
CO2 (ton)	275,62	253,94	275,19	300,65	298,13	276,19	267,72	269,29	236,48	202,35	228,89	239,94
NOx (ton.)	0,83	0,77	0,83	0,91	0,90	0,83	0,81	0,81	0,71	0,61	0,69	0,72
€ / kWh	0,0971	0,1023	0,0859	0,0850	0,0886	0,0972	0,1051	0,1106	0,1145	0,1249	0,1258	0,1399
€ / vkm	0,3360	0,3707	0,2824	0,3037	0,3333	0,3546	0,3729	0,4023	0,4214	0,4804	0,4479	0,4799

1kWh =3,6 MJ

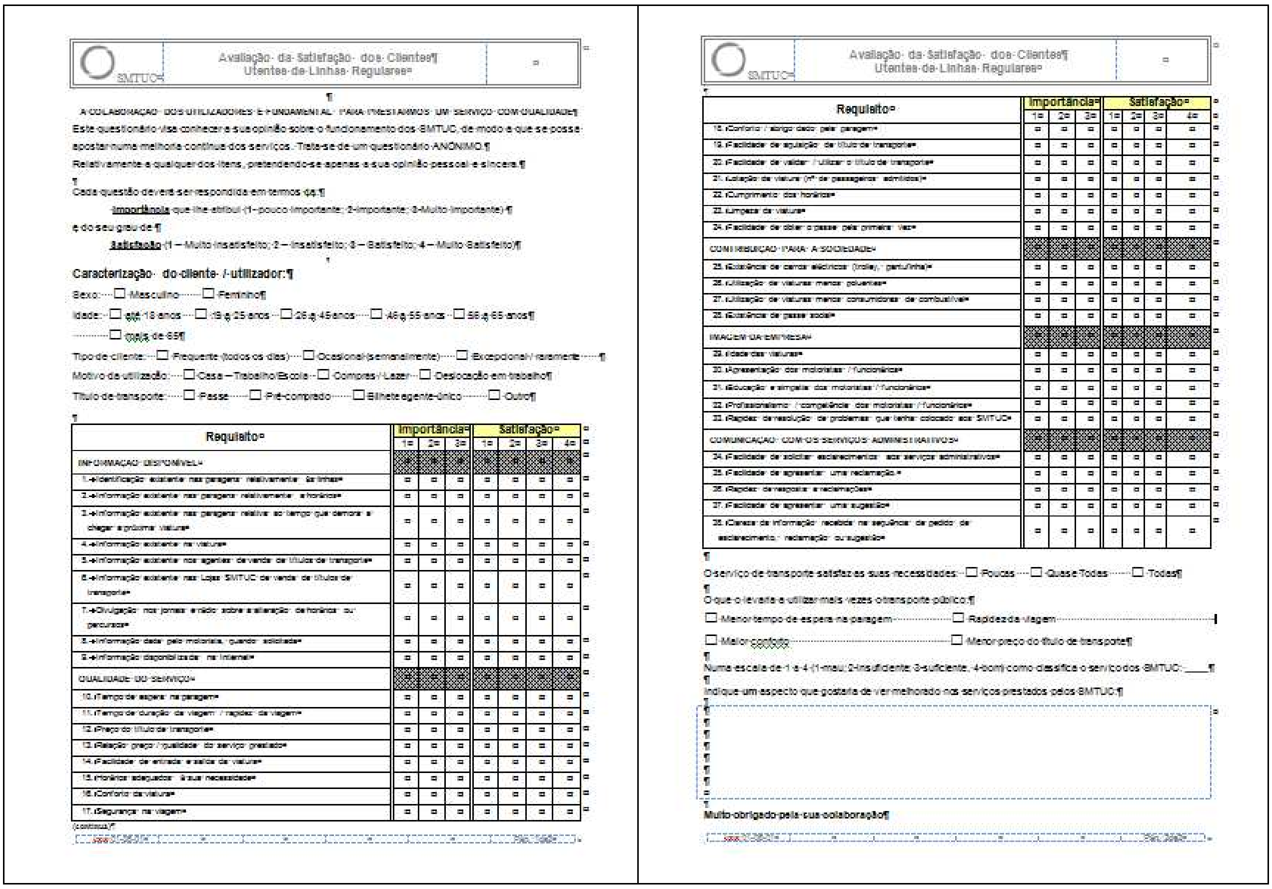
The table 5 shows the data obtained from the feasibility study in relation to the total annual production of renewable energy at the small-hydro.

Table 5: Energy production in the small-hydro power generator

Total energy produced by the power generator (MJ/year)	9.360.000

ANNEX 4 Quality Survey

ANNEX 4.1 Questionnaire model


Avaliação da Satisfação dos Clientes
Utentes de Linhas Regulares

Requisito | Importância | Satisfação

Avaliação da Satisfação dos Clientes
Utentes de Linhas Regulares

Requisito | Importância | Satisfação

Muito obrigado pela sua colaboração

ANNEX 4.2 Structure and questions

The questionnaire starts with 4 questions related to the interviewee – Sex, Age (<18, 19-25, 26-45, 56-65, >65),type of client (frequent, occasional, exceptional/rare use), motive of the trip (home-work/school, shopping/leisure, in service), type of ticket (pass, single ticket bought on the selling point, single ticket bought on the vehicle, other).

The main part of the questionnaire is composed of 38 specific questions related to various items related to 5 areas of the service (1-Available information, 2-Quality of service, 3-Contribution to society, 4-Image of the company, 5-Communication with the administrative services) and a specific global customer satisfaction question that resume quality of service. In each question the people interviewed express a judgement choosing between very satisfied – satisfied – unsatisfied – very unsatisfied and about the importance of each of the 38 items choosing between very important – important – low importance.

Each question is assessed in terms of importance given (1-Not important, 2-Important, 3-Very Important) and level of satisfaction (1-Very Dissatisfied 2-Dissatisfied 3-Satisfied 4-Very Satisfied) of the user in relation to the respective item.

AVAILABLE INFORMATION
1. Identification of existing lines at stops
2. Information at stops about timetables
3. Information at stops about the waiting time until the next vehicle
4. Information inside the vehicle
5. Information at ticket selling points
6. Information at SMTUC ticket selling shops
7. Disclosure of information in the newspapers and radio about timetable or routes changing[3]
8. Information given by the driver, upon request
9. Information available on the Internet
QUALITY OF SERVICE
10. Waiting time at stop
11. Trip duration / speed of travel
12. Price of the ticket
13. Relation Price / Quality of the service
14. Ease of entry and exit of the vehicle
15. Adjustment of the timetable to your needs
16. Comfort of the vehicle
17. Safety during the trip
18. Comfort / protection given by the stop shelter
19. Ease of ticket purchase
20. Ease of ticket validation / utilization
21. Capacity of the vehicle (nr. of passengers allowed)
22. Compliance with the timetable
23. Cleanliness of the vehicle

[3] This question was eliminated on the 2010 and 2011 surveys.

24. Facility in obtaining the travelcard for the first time
CONTRIBUTION TO SOCIETY
25. Existence of electric vehicles (trolleybuses, electric mini-buses)
26. Utilization of less polluting vehicles
27. Utilization of less fuel consuming vehicles
28. Existence of social travelcard
IMAGE OF THE COMPANY
29. Age of the vehicles
30. Presentation of drivers / staff
31. Education and friendliness of the drivers / staff
32. Quality of driving performance of SMTUC drivers[4]
33. Professionalism / competence of the drivers / staff
34. Quickness in the resolution of problems you may have submitted to SMTUC
COMMUNICATION WITH THE ADMINISTRATIVE SERVICES
35. Facility in requesting clarifications to the administrative services
36. Facility in submitting a complaint.
37. Response quickness in respect to complaints
38. Facility in presenting a suggestion
39. Clarity of the information obtained in response to a request for information, complaint or suggestion

The questionnaire concludes with 5 questions in relation to the respondent's general attitude towards the service supplied by SMTUC:

1. The transportation service meets your needs (1-Few, 2-Nearly all, 3-All)

2. What would make you consider using public transportation more often (1-Shorter waiting time at stops, 2-Higher speeds, 3-Increased comfort, 4-Lower price of the ticket)

3. How do you rate the SMTUC service on a scale of 1 to 4 (1-bad, 2-poor, 3-sufficient, 4-good)

4. Indicate a point you would like to see improved in the SMTUC service:

[4] This question was not included on the 2009 survey.

ANNEX 4.3 Customer satisfaction survey results

Quality of service is measured by means of customer satisfaction survey periodically carried out by SMTUC:

The survey is repeated 1 time a year and is carried out to customers on face to face interviews on board of the SMTUC busses.

The sample is drowned on the basis of the lines used by the passengers, i.e., the number of interviewees chosen in each line is defined according to the demand of the line relative to the overall SMTUC demand.

The dimension of the sample is defined according to the specifications of the quality management auditors which supervise the all process in line with the ISO9001 standard.

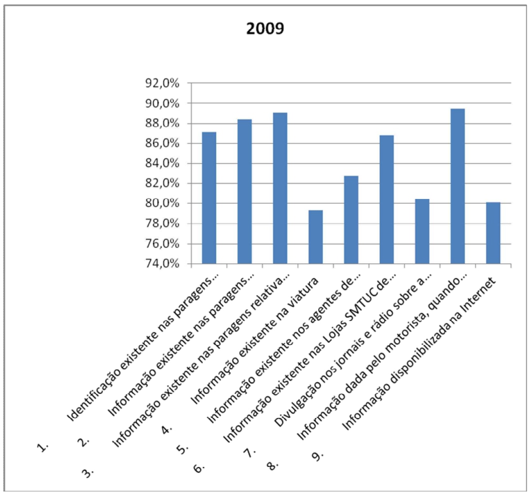
The quality management auditors considered 500 interviews as (a minimum) suitable to assess quality evaluation by PT passengers in Coimbra. However, SMTUC volunteered to go above this number. Thus, the following number of interviews and valid answers were achieved:

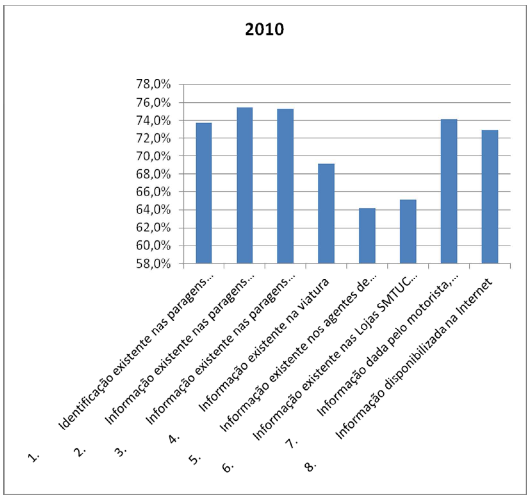
In 2009 it was defined a sample of 1000 interviews and it was obtained 984 valid answers

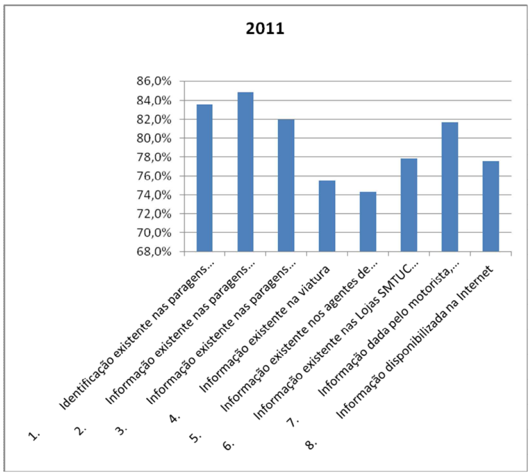
In 2010 and 2011 it was defined a sample of 750 interviews and it was obtained 750 valid answers due surveys with errors were rejected and repeated.

The folowing graphs show the several results of the susveys

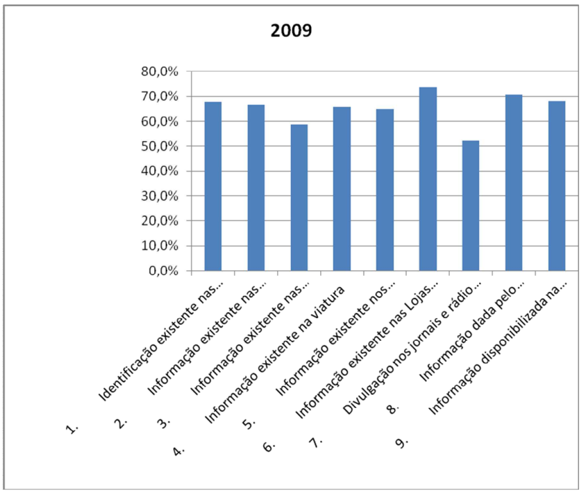
Importance given to the Available Information

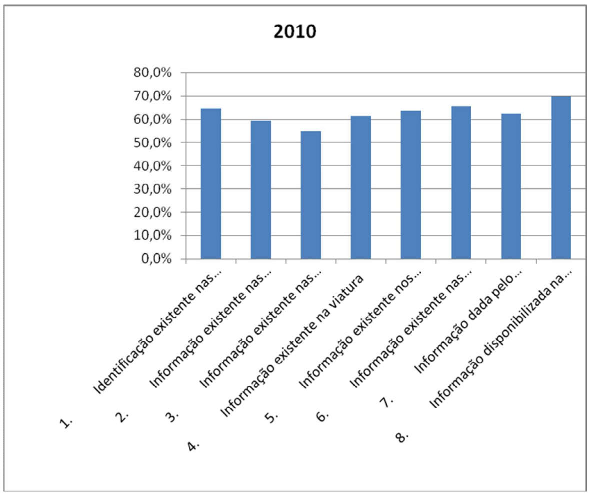


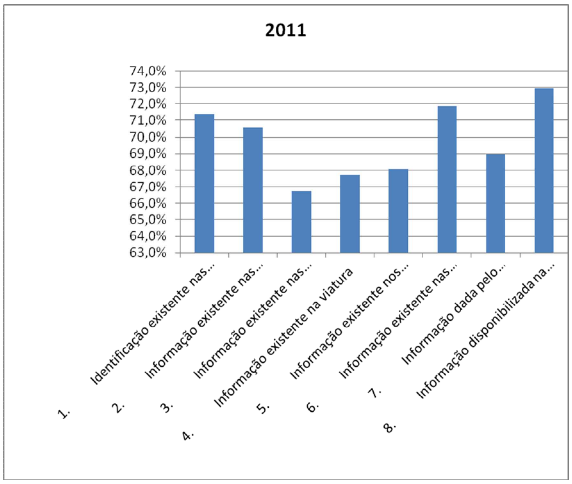


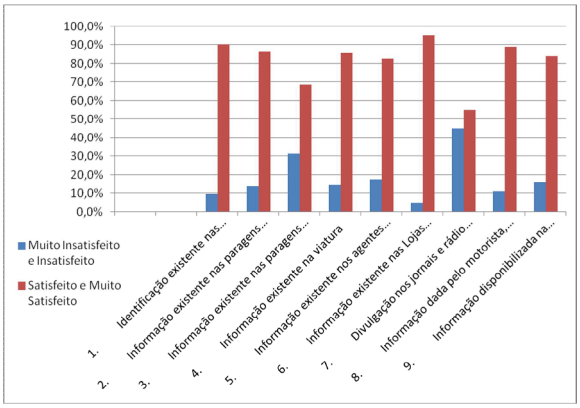


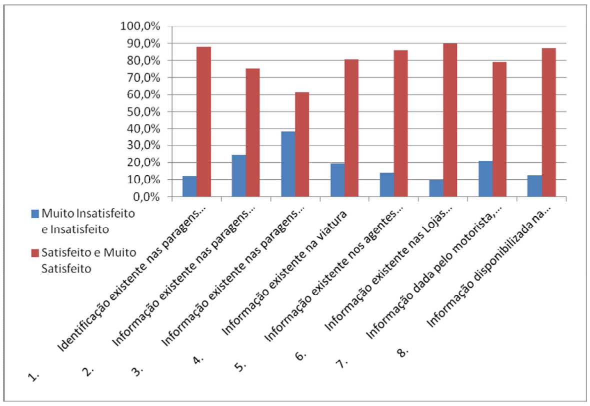
Level of satisfaction in relation to the Available Information

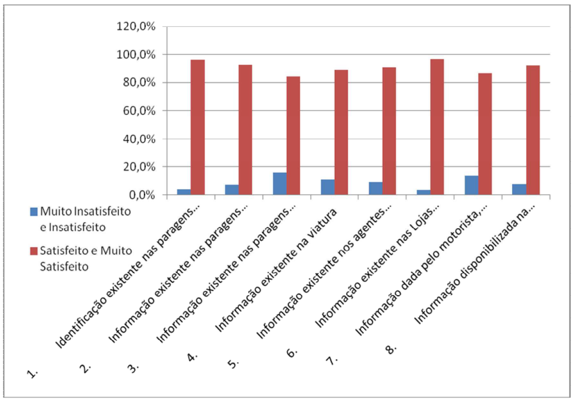




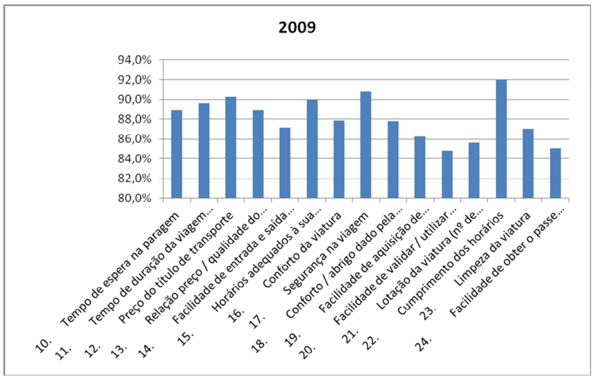


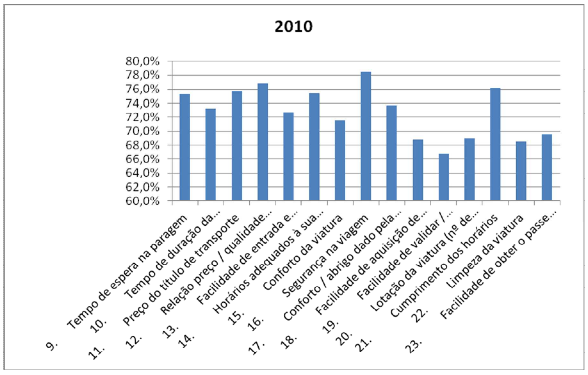


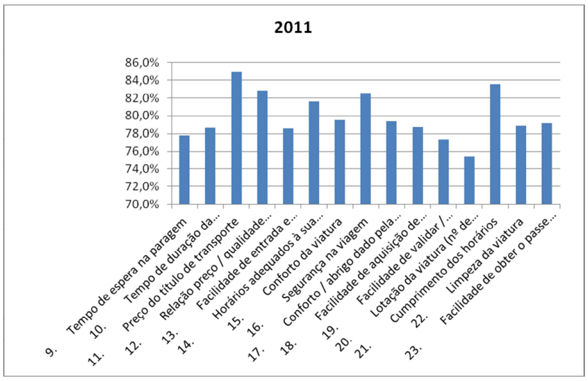




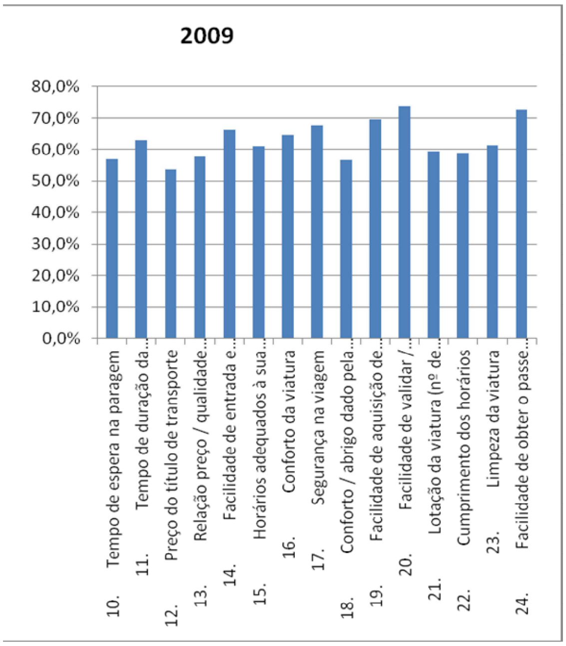
Importance given to the Quality of Service

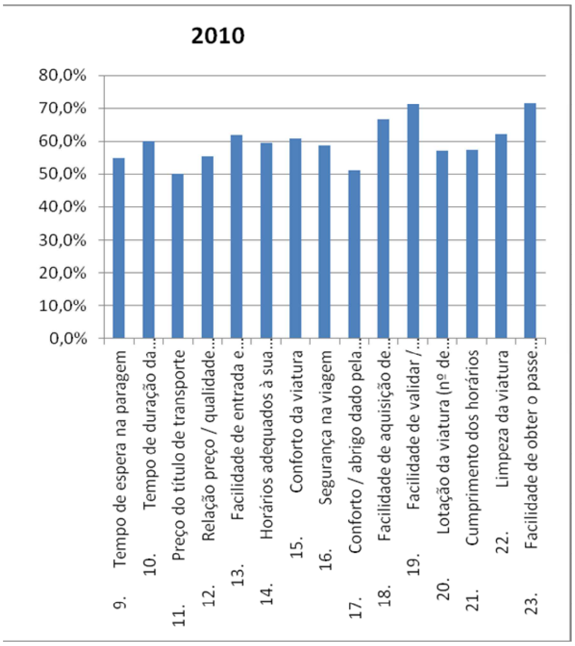


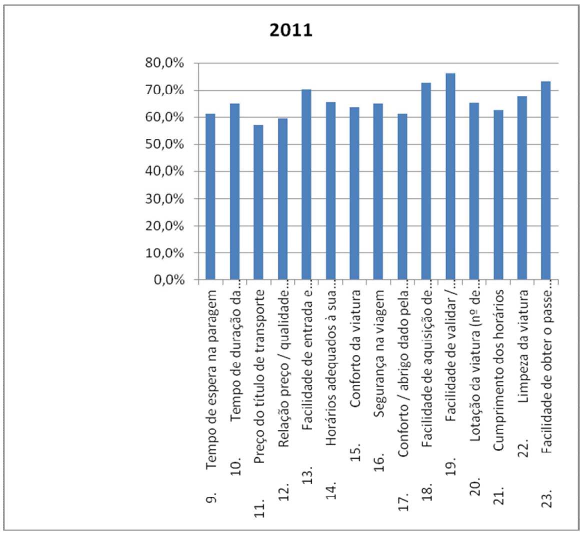


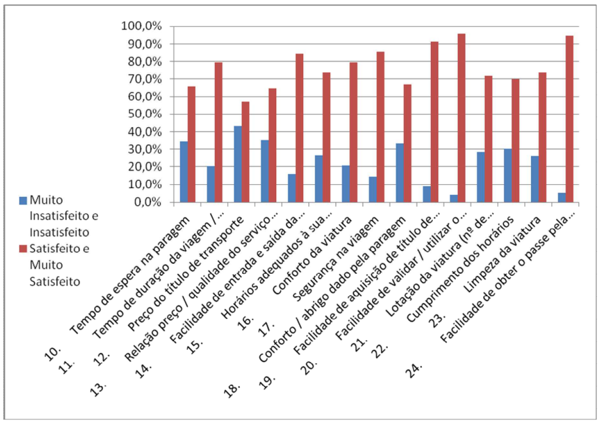


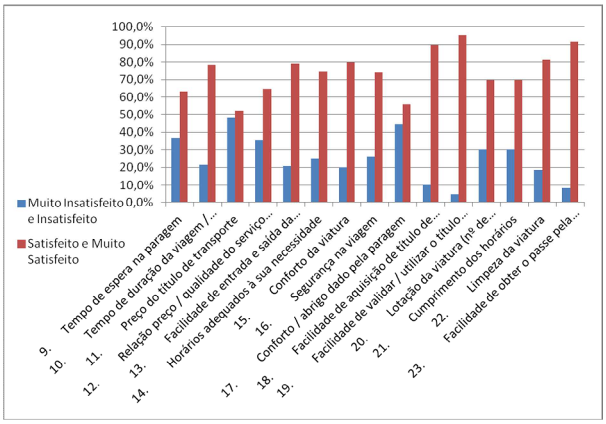
Level of satisfaction in relation to the Quality of Service

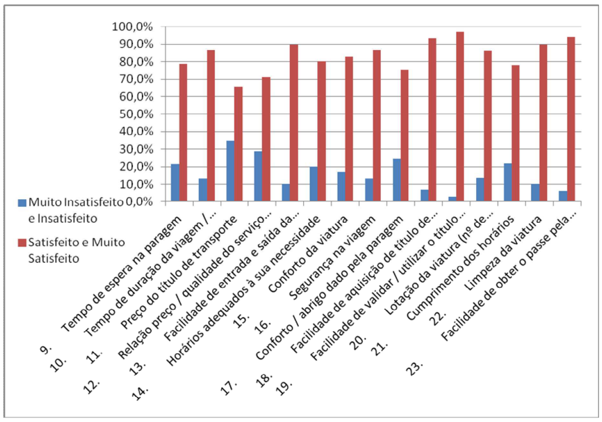




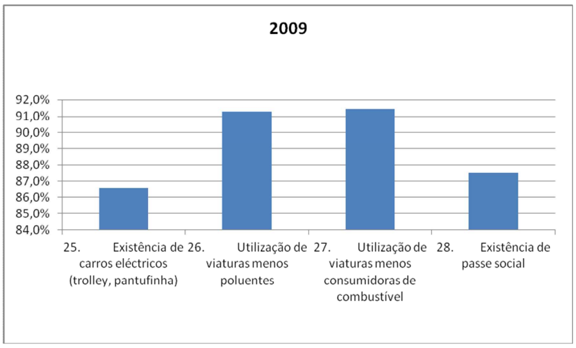


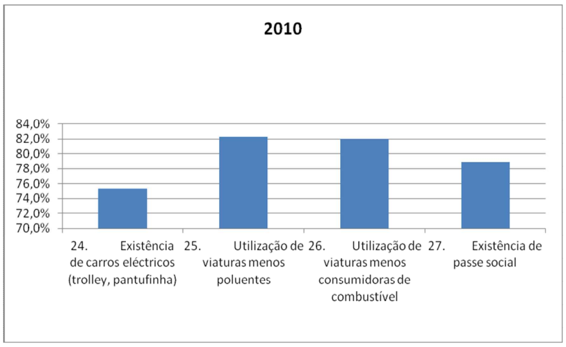


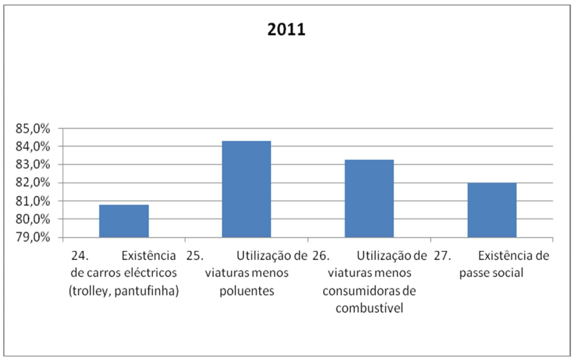




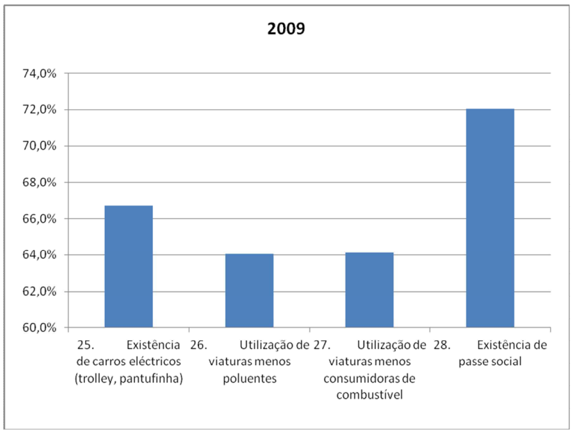
Importance given to the Contribution to Society

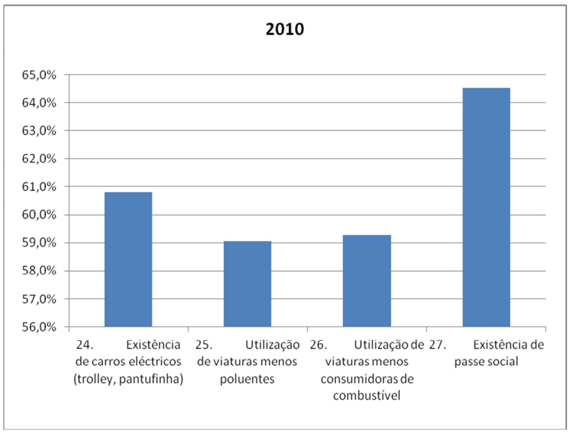


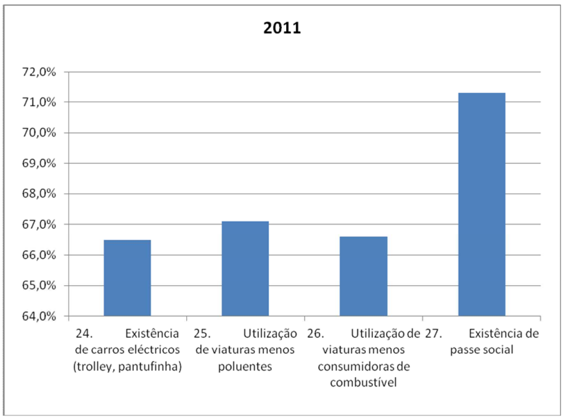


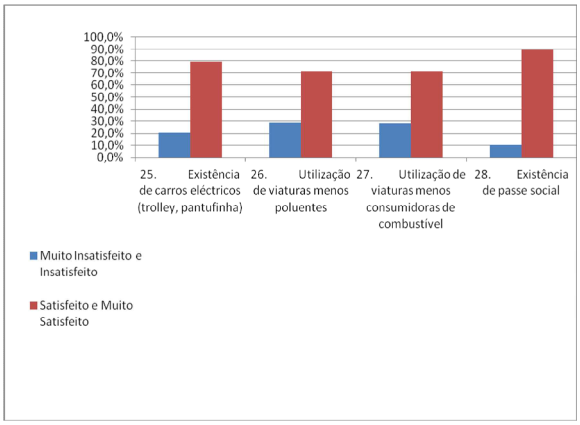


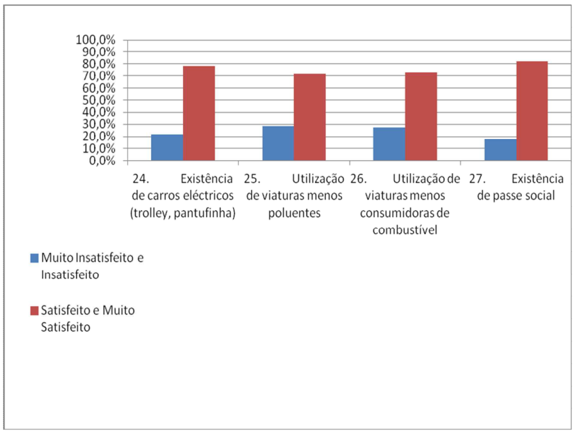
Level of satisfaction in relation to the Contribution to Society

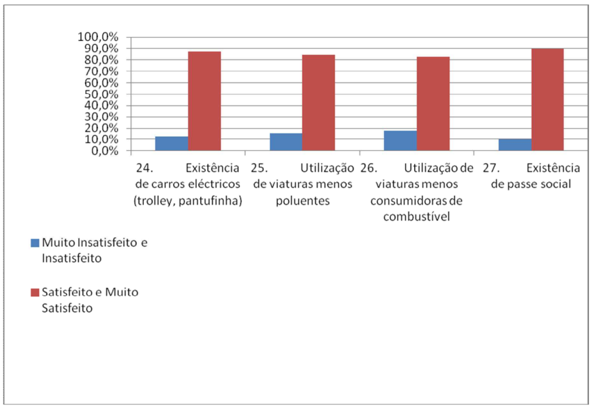




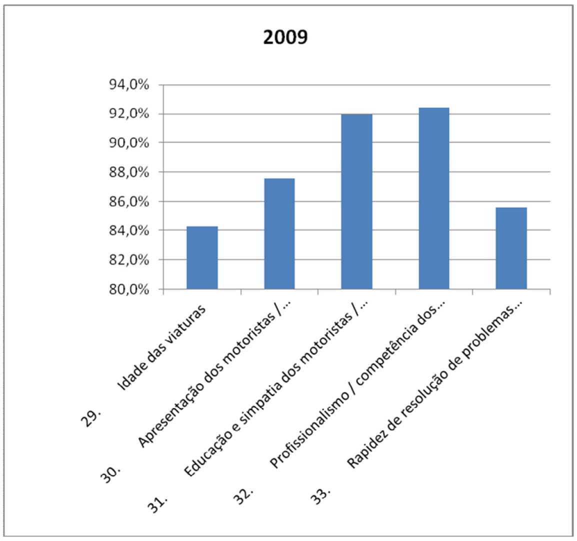


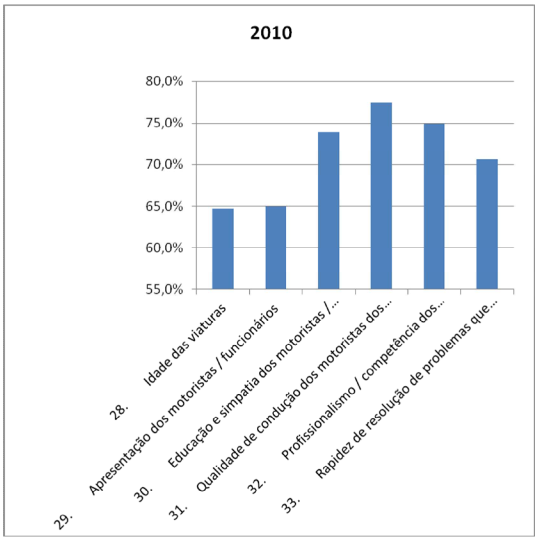


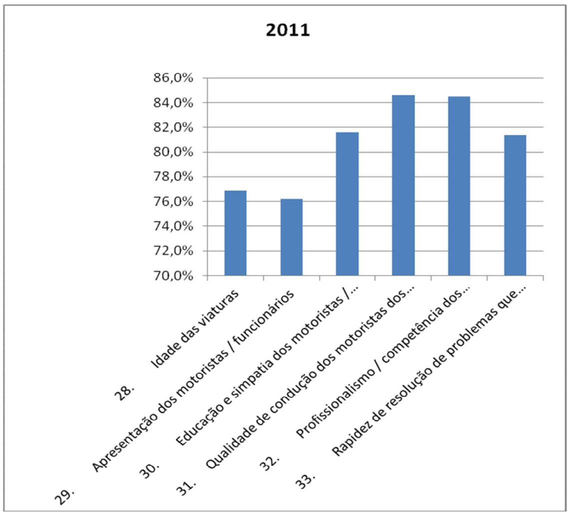




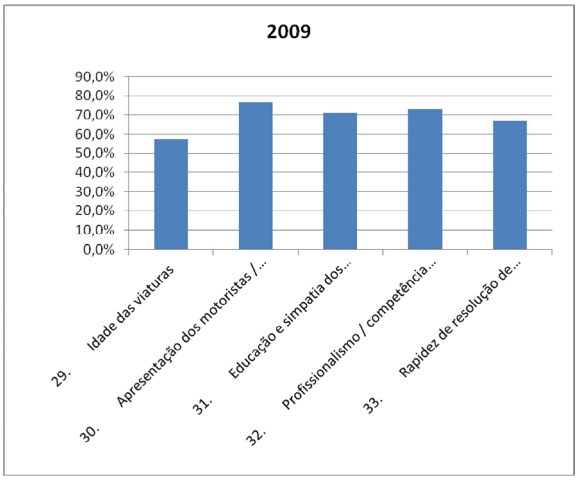
Importance given to the Image of the Company

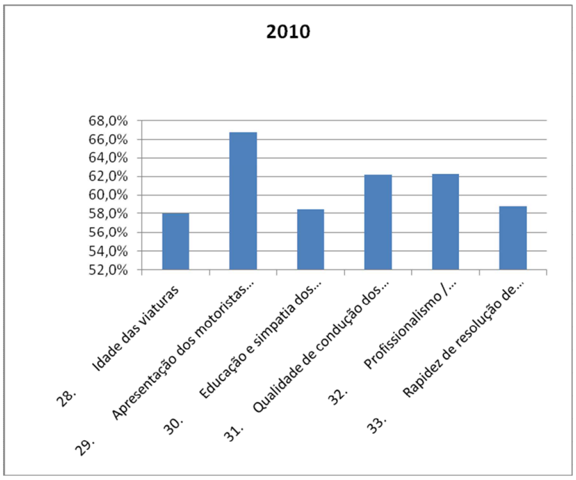


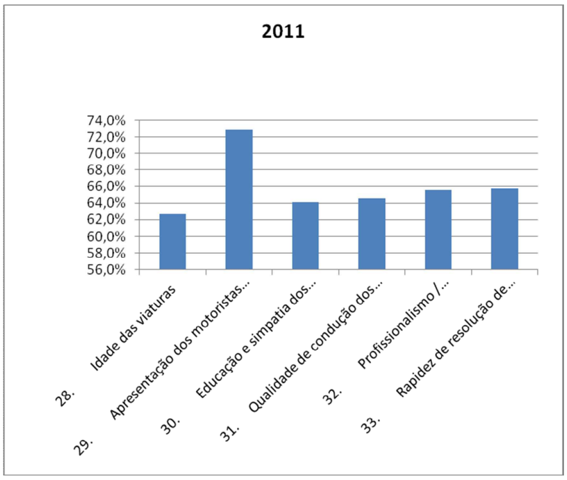


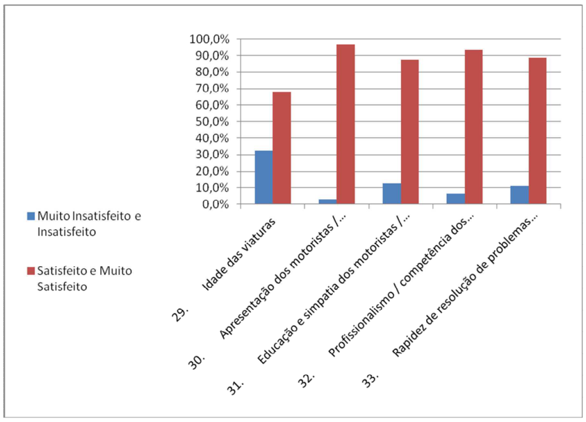


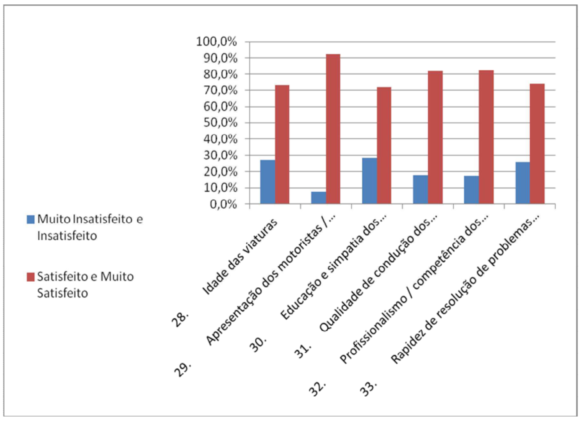
Level of satisfaction in relation to the Image of the Company

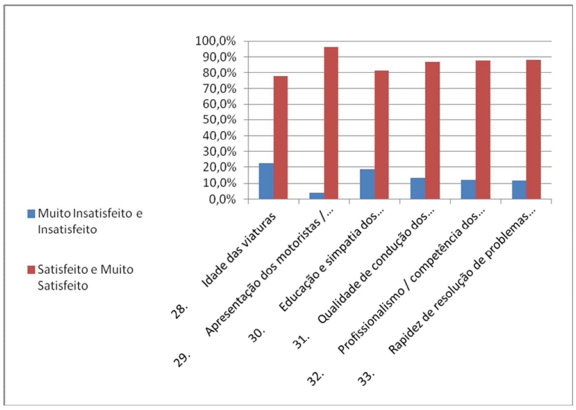




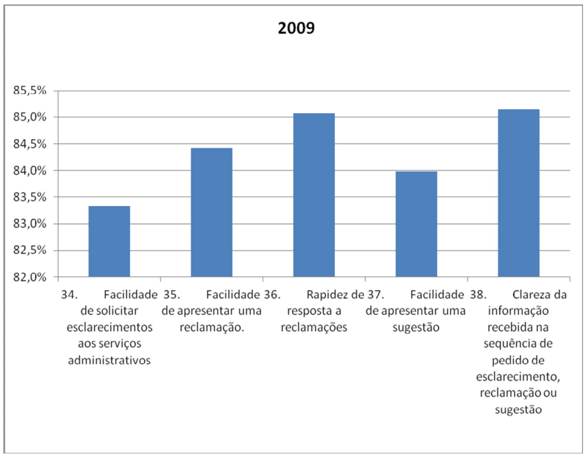


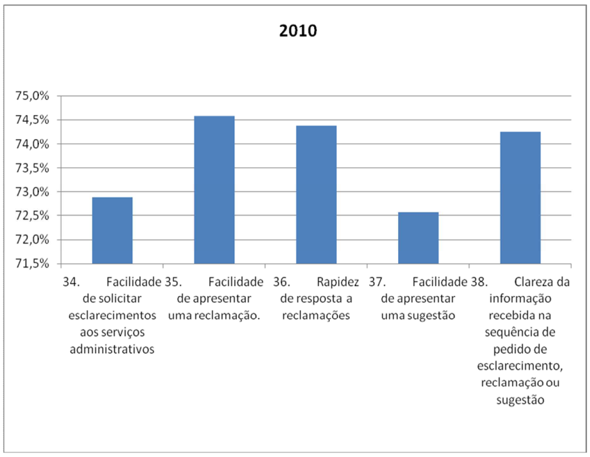


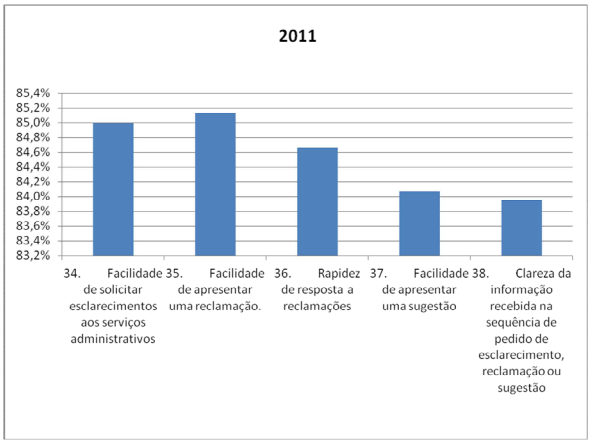




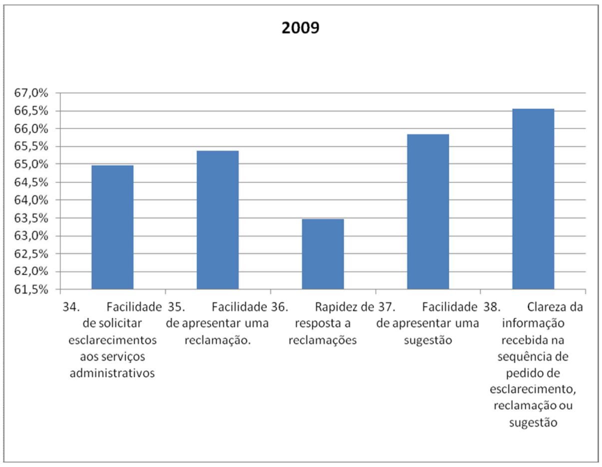
Importance given in relation to the Communication with the Administrative Sevices

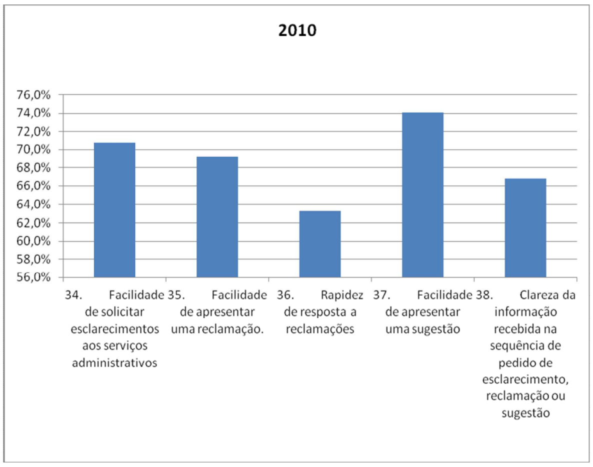


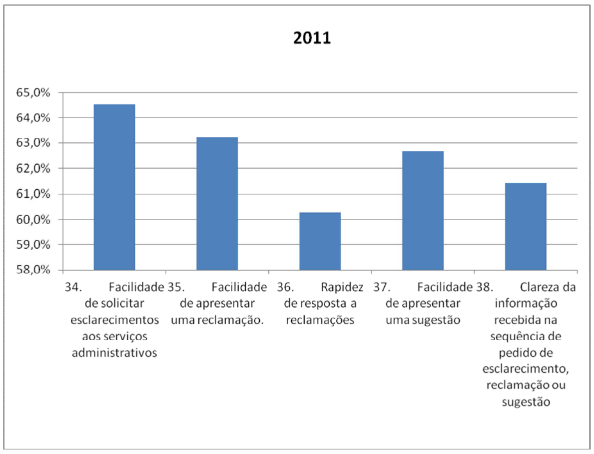


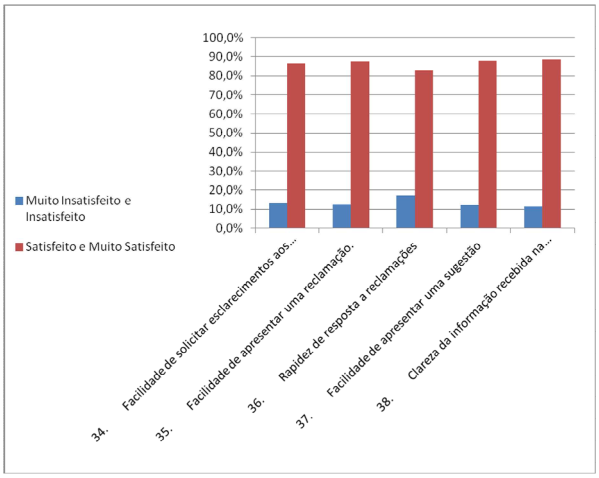


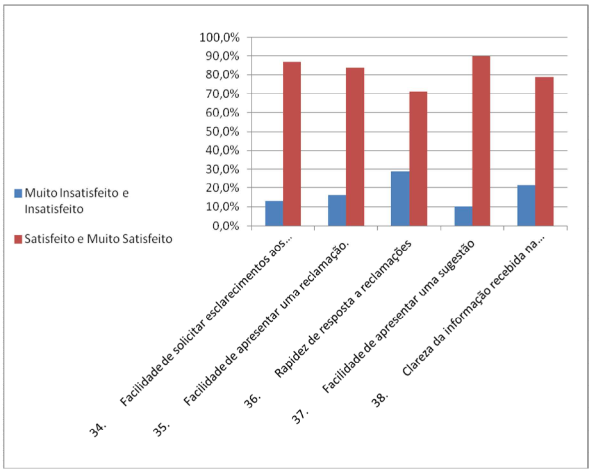
Level of satisfaction in relation to the Communication with the Administrative Sevices

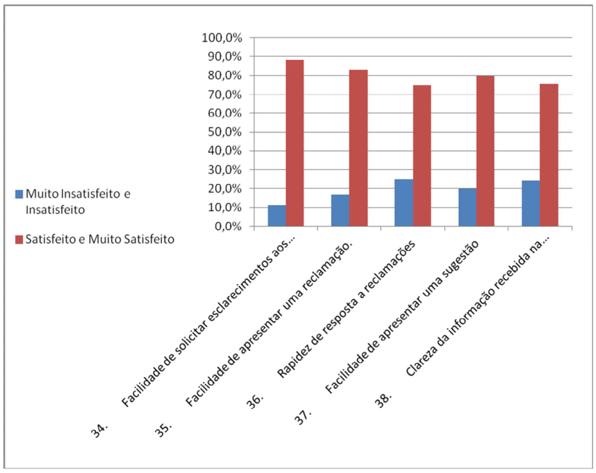






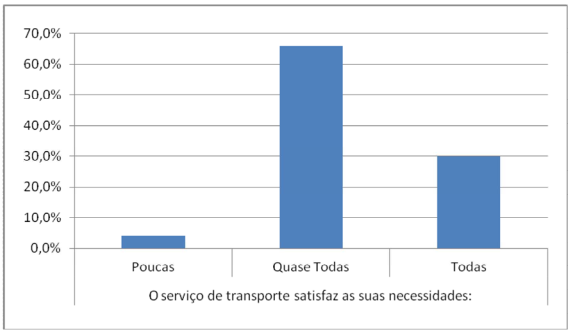




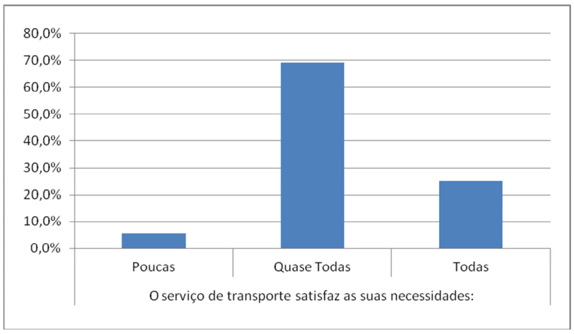


Results of the question "The transportation service meets your needs?"

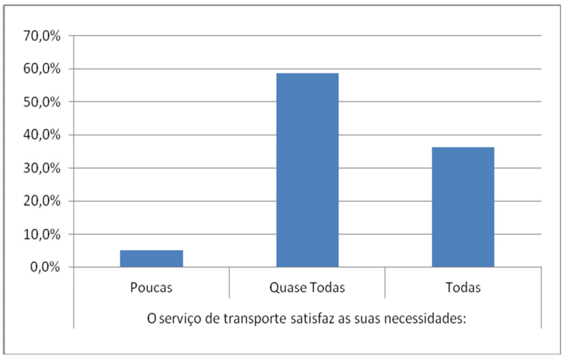
2009



2010

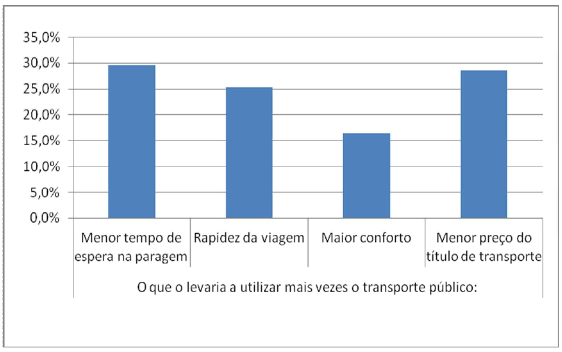


2011

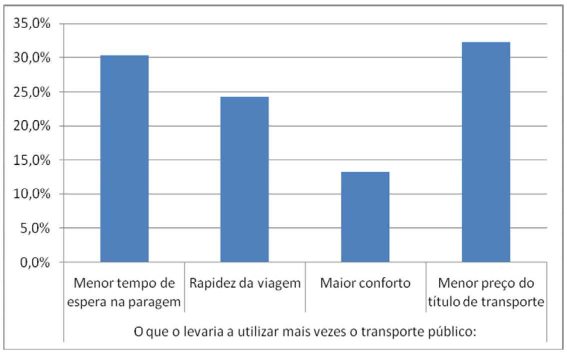


Results of the question "What would make you consider using public transportation more often?"

2009



2010



2011