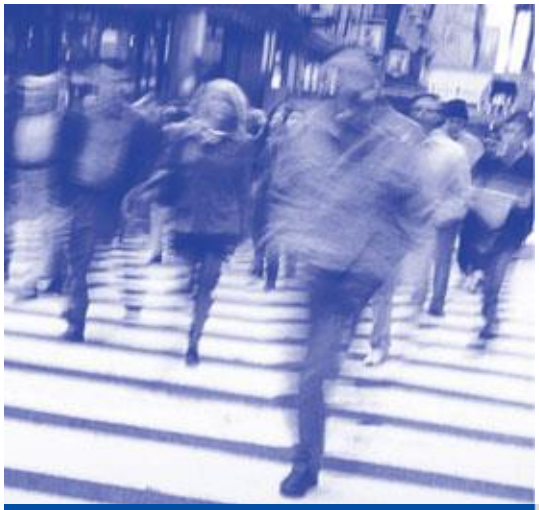

CIVITAS 2020
Cleaner and better transport in cities

DESTINATIONS

Measure Evaluation Result

MAD 7.1 - Electrical vehicles and clean fuels for public transport urban and inter-urban fleet

Project Acronym:	DESTINATIONS
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Executive summary

This measure intended to minimise these negative impacts through the implementation of 4 main actions: 1) demo program to test electric vehicles in public transport fleets, 2) technical visits to electric bus manufacturers' facilities, 3) purchase of 5 mini electric buses and 4) the installation of support systems for public transport fleets. The objective of these actions was to test and evaluate how to drive them and the effects of the transition from a diesel fleet to a more sustainable electric fleet and to test systems that promote more energy efficiency in public transport (PT) and the safety and comfort of PT users. For the promotion of these actions, AREAM was supported by local partners Horários do Funchal (HF - the main public transport operator) and the Regional Secretariat for Economy, Tourism and Culture (SRETC – the Transport Regulator), and with the collaboration of public and private bodies (transport operators, municipalities, hotels, leisure activities, etc.), brands and energy suppliers.

The demonstration program for electric buses in PT fleets was carried out between 2017 and 2020. During this period three electric bus models (mini, midi and standard) were tested in the Madeira Region. Different routes in the Madeira Region were selected, according to the different types of service for the regional PT operators. The chosen routes allowed the connection between: the airport, the harbour, the city centres, hotel shuttle services, culture areas, environmentally sensitive tourist areas, long distance journeys and historical centres. On the basis of the results collected during the tests, three demonstration reports (feasibility studies) were put together, including a complete set of evaluation parameters such as: passengers transported, energy consumption, pollutant emissions, maintenance costs and passenger satisfaction. In parallel, in order to improve knowledge on electrical bus technology, three technical visits to electric bus manufacturers' facilities were organised to see buses in an operational environment.

Following the results of the feasibility studies and the assessment of service needs, HF decided to purchase five mini electric buses that launched the fleet renewal strategy, with alternative financing (funded from the ERDF - Madeira 14-20 Operational Programme).

Complementarily to the electric buses initiative, HF tested innovative solutions with the view to having a more cost-efficient and environmentally friendly daily operation, providing improvements of maintenance sectors, training of bus drivers and better comfort for citizens and tourists. To achieve this, the following systems were installed: an Eco-drive system in 20 buses (Trakm8), a tire pressure management system (Continental) in 50 buses and a predictive system (Stratio) at 41 HF buses. In addition, AREAM and HF installed a photovoltaic (PV) panel system on the roof of two buses, developed by SOLARBUS.

Energy, environment and economic impact data were collected and assessed to perform a proper evaluation of the measure. The data collection depicts both the baseline situation, before the measure implementation and ex-post situation, after implementation. To evaluate the implementation of the 5 mini electric buses in the Madeira Region, the evaluation consisted of the comparison of such vehicle's performance with similar diesel buses, to estimate the energy, environmental and economic benefits of new electric bus technology.

This measure was also very relevant at the political level, as it also led to reinforce the political commitment aiming at the strategic goal of promoting soft modes of transport and improvement of accessibilities at city level. Financially, the measure represented a golden opportunity to raise the attention for fleet renovation. It was easier to finance the planned actions with other types

of external funds and resources. At a cultural level, the fact that citizens became more and more aware of climate change was also an important driver for the introduction of eco-friendly buses and the installation of the needed support systems into the urban PT network.

The measure faced constraints related to the time plan, which was too optimistic at first . Specific activities had to be rescheduled in order to fit the work plan of other DESTINATIONS measures. Due to unexpected delays, several pieces of equipment were purchased at a late stage, reducing the project's eligible amount of funding due to the delayed amortisation of the investment. Regarding the purchase of hybrid/electric buses, the delay was due to the unavailability of technology that would meet the required specifications.

The development and implementation of this measure was an important opportunity to confirm electric mobility as an affordable alternative for collective transport, with environmental and public health benefits for both citizens and visitors.

The measure achieved very positive results during several promoted initiatives. With the electric vehicles' demonstration programme, the PT regional operators were able to test the buses in various conditions, verifying their technical, energy and environmental performance as well as affordability. The specific case of the five mini electric buses, allowed HF to provide a cost effective public service in the city centre, more suited for these areas where the environmental and noise impact needed to be reduced. In addition, the programme allowed the introduction of an intermodal service that connects the city centre and the cruise port of Funchal, providing more quality of life for residents and tourists.

The installation of the auxiliary onboard systems (Eco-drive system, tyre pressure monitoring system, predictive system and the PV solution), contributed to a more cost-effective operation, by reducing the maintenance costs, and improving driving conditions. However, these systems did not contribute directly in the reduction of energy consumption (fuel consumption), since there were changes in other factors that influenced this consumption compared to 2017, namely commercial speed, occupancy rate, etc. On the other hand, the indicator of the perceived quality of driving saw an improvement through the years. Globally, users understood that HF urban fleet is was providing a better service.

A Description

This measure consisted of three pilot tests, including the performance evaluation of the electric buses and test of a series of innovative technological onboard solutions, namely: an eco-drive system, a tyre pressure monitoring system, a fault predictive system, and a photovoltaic solution. The aim was to test and evaluate the transition from a diesel fleet to a more sustainable electric one and to test systems that promote energy efficiency onboard in PT together with improved safety and comfort of PT users.

The demonstration program for electric vehicles in public transport fleets occurred between 2017 and 2020, in which were tested three models of electric buses (mini, midi and standard buses) in Madeira region. To set the demonstration program they was selected different routes in the Madeira Region, according to the different services of the main PT regional operators. The chosen routes allowed the connection between the airport, harbour and city centres, hotel shuttle services, culture areas, environmentally sensitive tourist areas, long distance circuits and historical centres.

Figure 1: Technical visit to TUB, electric buses test.

The first test occurred in December 2017 with the Caetano e-city Gold bus, the second in September 2018 (Madeira) and August 2019 (Porto Santo), with the Karsan jest electric bus and the last in March 2020 with the Karsan Atak electric. To prepare the tests, three feasibility studies in PT and EN were arranged, considering the definition of the following evaluation parameters for circuit operation: passenger's transportation, energy consumption and pollutant emissions, maintenance costs and passenger satisfaction.

Based on the results of the feasibility studies and the service needs, HF purchased five mini electric buses, part of the fleet renovation strategy with alternative financing funds (funded with ERDF, Madeira 14-20 Operational Programme).

In parallel to the demonstration program, three technical visits to the electric manufacture's facilities were organized. The visits involved local stakeholders, visiting the buses in an operational environment to improve their knowledge about the technology.

At a fleet operational level, the main objective of HF was to test and implement several systems to improve the operation with cost-efficient and more environmental performances. Such onboard systems aim also to improve the maintenance performance, the bus driver's relationship and the overall liaison with the population in general. Aligned with this objective, in January 2018 HF initiated the installation of the Eco-drive system in 20 buses (Trakm8) which consists on an on-board equipment to monitor drivers' behaviour, by monitoring several driving parameters, including fuel consumption. In overall, the system intends to improve the driving performance of the bus drivers.

During May 2018, a tire pressure management system (Continental) was installed in 50 buses of HF's urban fleet. The system improves the driving quality and safety of the passengers, as it contributes to reduce costs and to increase energy efficiency of PT operator. The use of correct tire pressure compromises the entire bus operation.

A predictive system (Stratio) was installed in 41 HF buses in May 2019, it detects potential faults early on, and it forecasts possible failures and accelerate root cause analysis. The system collects and extracts insights from the vehicle's data in real-time and communicates possible failures before they happen. The solution is an essential support tool as it decreases vehicle downtime and promotes operational predictability. It allows to prioritize repairs and anticipate breakdowns; it supports the critical maintenance decisions using real time maintenance information such prediction proved to be important to reduce repair and maintenance costs.

AREAM and HF installed a photovoltaic panel solution on the roof of two buses in September 2019, developed by SOLARBUS. This system is very innovative and is in demonstration tests in operational environment (TRL7) in four demonstrating pilots in Norway, Denmark, Chile and Madeira. For the first time is in running in South Europe, with different conditions of solar exposure and demand service, than the other sites.

In this measure AREAM was supported by local partners HF, CMF and SRETC, and mainly collaboration of DRETT (Economy and Land Transportation Authority), public transport operators (SAM, Rodoeste, EACL and Moinho Rent-a-car), municipalities of Porto Santo and Calheta, bus trade companies (Caetano Bus, UIC (karsan representative in Portugal), Irizar, BYD), product and services suppliers (Solarbus, Continental, Stratio and Neves & Neves), HF technicians, drivers and representatives involved in pilot tests and eco-driving training and citizens

A1 Objectives and outputs

City policy level objectives

The measure is in line with the Regional Government Strategy for the promotion of Electric Mobility in the Autonomous Region of Madeira. Also, the results achieved with the savings from the eco-driving, tire pressure, predictive monitoring and photovoltaic systems are in line the Madeira's Sustainable Urban Mobility Plan (SUMP) specific targets, namely: decrease of CO_2 emissions, decrease the energy consumption in transport and improve the quality of the urban environment, public health and safety.

Measure specific objectives

- To implement a demonstration program with an urban electric bus in Madeira
- To carry out a feasibility study of electrical/hybrid buses in Madeira
- To leverage a public transport fleet renewal with low emissions solutions
- To launch an eco-driving programme to promote eco-driving habits among public transport drivers
- To develop a photovoltaic power supply solution for public transport buses
- To test new systems to monitor pressure and temperature of tires
- To improve the daily electricity load diagram imbalance

Outputs[1]

- 3 feasibility studies of electrical/hybrid bus in Madeira in PT and EN languages
- 1 evaluation report of 5 mini electric buses in HF service in PT and EN languages
- 1 technical report of PV system installed in the HF buses in PT and EN languages
- 3 demonstration tests
- 2 promotional videos of demonstration tests
- 20 buses equipped with eco-driving system
- 50 drivers involved in monitoring system and corresponding follow-up of the drivers
- 6 training sessions and at least 200 drivers enrolled and trained
- 50 buses equipped with tire-pressure monitoring system
- 2 bus equipped with PV system
- *41 buses equipped with the predictive system
- ** 5 mini electric buses (co-financed by ERDF funds)

Supporting activities

Within DESTINATIONS project, the following activities were carried out aiming at increase the level of acceptance of citizens, stakeholders and decision makers:

- Regional Government strategy for the promotion of electric mobility in Autonomous Region of Madeira.
- Madeira Move Campaign (awareness raising campaign addressed to citizens and companies).
- Involvement of electric bus manufactures.
- Involvement of photovoltaic systems manufactures.

A2 Inter-relationship with other measures

This measure is linked with other DESTINATIONS measures, as follows:

- **MAD 4.1-** Promote the uptake of clean vehicles by fleet operators – The dissemination of e-mobility among tourism stakeholders, companies and citizens, participation in TV shows, news and newspapers, and Madeira Move Campaign.
- **MAD 7.2** - Attractive Public Transport – The new line “Linha Eco Cidade” launched under MAD 7.2 that connects the city centre with the one of the main gateways of the Region, the port of Funchal, is operated by the five mini electric buses (Karsan).

A3 Target groups and/or affected part of the city or region

This measure targeted different groups of users: citizens and public transport users (residents and tourists), and also the other regional public transport operators.

[1] *Extra-output with DESTINATIONS budget; **Extra-output during DESTINATIONS with other funds

A4 Stakeholders: CIVITAS project partners and other important actors

Stakeholder name	Activities description
DRETT (Economy and Transportation Authority)	The regional transport authority participated during the decision process and the dissemination activities
Municipality of Porto Santo	The Municipality of Porto Santo island participated by providing Information and dissemination campaigns
Public transport operator (HF)	The public transport operator and project partner participated in the decision-making process, in the pilot tests and dissemination activities
Other PT Operators	Other Regional public transport operators participated during the pilot tests, sharing information and dissemination purposes
Bus trade companies	The electric bus manufactures provided all the needed Information and the demos electric buses too.
Consortium: Siemens, CaetanoBus, UIC	The electric bus manufactures provided all the needed information and electric bus supply, as also supported in the pilot tests development
Product and services suppliers	The Manufactures provided all the needed information and electric bus supply
HF technicians, drivers and representatives	The beneficiary's staff performed the pilot's tests and reports validation
Citizens	The main final beneficiary asked for improved service quality
Photovoltaic systems company (Solarbus)	The photovoltaic systems manufacturer provided all the needed information and solutions.
Stratio system company	The stratio solution owner trained and provided the fleet control solutions.
Continental	The tyre pressure management owner. Training and solutions provider
Eco Manager system (Neves & Neves)	The eco manager system owner. Training and solutions provider

Table 1: Stakeholder's involvement

B Measure implementation

B1 Situation before CIVITAS

Over the last 15 years, Madeira Region has witnessed a significant change in the mobility patterns of residents and tourists, with high repercussions on the transport system. In 2001, 27% of residents were using PT as their main transport mode but this figure decreased in 2011 to 21%. These trends come together with an increase of pollution, noise and traffic collisions.

In addition to such trends, several barriers were in place, hampering the evolution towards more sustainable mobility solutions, such as: the lack of credibility of less pollutant technological solutions among PT operators and general users; the high initial cost of electric vehicles comparing with conventional fossil fuels ones; limited market offer for electric buses compared with car; limited autonomy of batteries; high average age of fleets for urban, interurban and tourism too; poor and scattered eco-driving habits. In overall, the city centre registered high level of pollutant emissions and noise during peak hours and in addition to this, all the data confirmed, the high fossil fuel dependency of the entire land transport sector.

HF has quite relevant experience in training sessions in eco-driving, it has started in CIVITAS MIMOSA project as a complement of driver's periodic mandatory trainings. Such training sessions were reinforced under DESTINATIONS considering they affect the overall drivers' performance and preparation, especially due to the topographical specificities of the city.

In addition, the specific hilly land profile of the Region imposes an increased pressure on the bus's performance and materials. Such precondition is being responsible for car's additional exhaust, high maintenance costs, with consequent high fuel consumption and finally air and noise emissions. This situation has significant impacts on the budget and financial sustainability of the public transport operator. Under such circumstances, the implementation of the eco-manager system, the tire pressure monitoring system, the maintenance predictive monitoring system, and the photovoltaic solution can assist and support on minimizing the difficulties imposed by the landscape of Madeira.

B2 Innovative aspects

Use of new technology/ITS - The use of alternative energy sources to reduce fossil fuels, improves environmental performance by reducing pollutant emissions and noise, as well as improves the attractiveness of the touristic image of Madeira Island, which is strongly relates to eco-tourism and respect of natural heritage. Considering the whole public and private bus fleet in Madeira, this action has a huge potential impact to reduce fossil fuel consumption in the Island and decrease the energy dependency.

The installation of photovoltaic system on the top of the buses was also very innovative. The main goal was to achieve the reduction of energy consumption of the urban fleet, allowing greater ecological and economic efficiency of the service. The innovation is related with the solar energy that is collected and feeds the auxiliary electrical equipment and charge the batteries of the buses. In such way it was minimized the overload of the motor induced by the alternators for the production of electric energy. As a consequence, for those same purposes, the PV system tested, allows a reduction of the fuel consumption. It's important to refer that in the buses are installed several ITS systems, which are critical for the operation of the service, (such as ticketing and the others) and they have not entirely negligible electric consumption.

The use of such solution in vehicles was recent activity. This application was firstly tested in Norway by Nettbuss, a bus company which registered a reduction of fuel consumption of around 5%. In March, in the city of Santiago, Chile, the test of these equipment's began. HF joins to the pioneer's public transport operators which use solar energy for the benefit of the environment and population.

B3 Technology development

This measure integrates various types of innovative technologies, such as electric vehicles, control systems to monitor driving style, tire pressure monitoring systems, the photovoltaic system installed on the buses to feed the bus auxiliary systems and maintenance predictive monitoring system. All the implemented/tested solutions required quite intense research work.

Considering that the Madeira Region is characterized by a challenging topographic reality, which is very demanding for buses performance, the diesel technology is often seen as the best and the only option on the market with higher power and torque. Under such circumstances, the local partners analysed the several options available on the market and choose to proceed by testing three different models of electric buses (mini - Karsan Jest Electric, midi - Karsan Atak Electric and standard buses - Caetano e.City Gold) to evaluate which would be more suitable. The tests intended to assess and reinforce the technical feasibility of electric buses operating in different land profiles, some of them very demanding for bus, and to support local actors in defining a strategy for the decarbonization of the PT sector.

As for the support systems, HF performed an exhaustive research work to choose the best solution to monitor the driving style, the tire pressure systems, and the predictive monitoring system. They were examined several potential solutions available on the market and established several contacts with the solutions suppliers to assess the viability of each alternative. Each option was appraised under HF's operation prism, considering also the variables of the future needs for maintenance, calibrations and training.

Considering solar energy was being implemented also in transportation sector, the local partners analysed the solutions available on the market which use solar energy in busses. Local partners started different contacts with possible solutions suppliers to understand the feasibility of a pilot test. At last, the local partners found the SOLARBUS solution, which was also under tests in other EU regions. After the collection of all the relevant information, HF and AREAM decided to proceed with the pilot of such solution in Madeira.

B4 Actual implementation of the measure

The implementation of this measure was composed by 4 different main actions, duly described below.

Demonstration program for electric vehicles in public transport fleets

A demonstration program, coordinated by AREAM, with the support of DRETT and HF, was planned to assess the technical and economic feasibility of three 100% electric buses. The vehicles tested in Madeira and Porto Santo Islands were of different sizes and capacities. Following the tests with the buses, studies were carried out.

Figure 2: Demonstration test in March 2020

E.City Gold, Caetanobus

In December 2017, the e.City Gold bus, manufactured by Caetanobus, with low floor, 12m length and a capacity of 88 passengers it was tested in three public transport operators in Madeira and Porto Santo (HF, SAM and Moinho) including also urban and interurban services. The study revealed that the bus is technically feasible, cost-effective and environmentally advantageous in relation to diesel and natural gas fuelled buses and it has suitable power and torque for the required level of passengers' demand. In all cases the bus performed successfully the planned services. During the test, it was also identified some main limitations (excessive dimension for some routes, limited battery capacity and reduced distance from the chassis to the ground).

Jest Electric, Karsan

In September 2018 and August 2019, it was tested the Jest Electric a bus manufactured by Karsan. The test was run by two public transport operators in Madeira and Porto Santo (HF and Moinho) operating also a touristic transport service in Rabaçal natural reserve. It is a low entry vehicle, 5,8m long, with a capacity of 22 passengers. The bus performed well the tests ran by HF, Moinho and in Rabaçal, showing suitable power and torque and proving to be technically feasible.

The demonstration test of the **Karsan Jest Electric in Madeira island** (in September 2018) was aimed to evaluate the technical feasibility of electric buses operating in the centre of Funchal city and on the *Rabaçal* path. Such test was important to support local actors in defining a strategy for the decarbonization of the public transport sector in urban centres as well as in environmentally protected areas. It was tangible that the battery capacity of the vehicle (test vehicle equipped with a 33-kWh battery) could be a handicap in a real operation condition. Also, the capacity of energy regeneration of the regenerative braking system proved to be low and it should be optimized and adapted to the route and service provided. In such way it is possible to optimize the vehicle's energy performance.

The demonstration of the **Karsan Jest Electric in Porto Santo island** (August 2019) was organized to promote electric mobility in the public transport system. The electric minibus was operated by Moinho Rent-a-Car and carried out the passenger transport service. In this case

the battery capacity of the vehicle (test vehicle equipped with 88 kWh battery) shown enough autonomy to cover between 200 and 250 km.

Atak Electric, Karsan

In March 2020, the Atak Electric bus, from Karsan, was tested by the PT operators in Madeira Island (low entry bus, 8m length and capacity for 52 passengers). The bus performed well the tests ran by HF, demonstrating suitable power and torque and proving to be technically feasible, identifying that it can circulate in approximately 70% of the routes. This bus was going to be tested in the interurban services, but due to mandatory confinement imposed by COVID-19 the scheduled tests were cancelled.

All three buses performed well the planned services, demonstrating suitable power and torque for the required level of passengers' demand. The main limitations were the dimension and the distance of the chassis from the ground, which prevented its circulation in some roads, and consequently in some routes. The smaller vehicle with greater approach and departure angles, revealed to be a better choice to increase the diversity of services to be carried out.

The battery capacity was another limitation felt during the tests. To prepare the technical specs to purchase the vehicles it is necessary to take in account an increase of the battery capacity or adopting fast charging infrastructures in some terminals, or the combination of both, to grant a continuous operation.

To disseminate the buses' demonstration actions, public communications initiatives were carried out and buses were garnished with images depicting a green urban environment and the DESTINATIONS project logos. To involve public opinion, free rides were opened to residents and tourists. In this scope, two promotional videos were developed and AREAM and HF participated in local TV shows to explain better the experiences and the campaigns launched and the advantages of electromobility. The videos were disseminated and promoted on the DESTINATIONS YouTube channel, AREAM's website and YouTube channel.

Technical visits to electric bus manufacturers' facilities

To improve knowledge about electrical technology three technical visits were organized, involving local stakeholders, to visit electric bus manufacturers' facilities and buses in an operational environment: BYD (China) in June 2018; CaetanoBus (Portugal) in October 2018 and IRIZAR (Spain) in November 2018.

The technical visits were carried out following several contacts with the manufacturers of e-charge stations for e-buses, which materialized into meetings with Irizar to gather information on electric buses and on e-charging systems for electric buses (Jema).

The meeting with Caetanobus involved the participation of Siemens staff to gather information about charging process and stations, including available pantographs in the market. It was also assessed the compatibility of different batteries and electric buses on the market. HD and AREAM developed a study on the required charging infrastructure for electric buses on the routes of the pilot test, as a feasibility study for the electrification of two routes of HF with the installation of the pantograph chargers' station.

Acquisition of five mini electric buses

In July 2019, HF purchased five mini electric buses Jest Electric, like the ones previously tested in Madeira under the demonstration program. The new buses started their operation on the route “Linha Eco Cidade”, a PT service that circulates in the city core, linking the historic zone to the touristic area and also connecting the city centre with the cruise port. These buses revealed to be especially suitable to serve these sensitive areas, where the environmental and noise impacts must be reduced. The purchase was co-financed by ERDF EU funds.

Figure 3: Karsan mini electric bus

AREAM analysed the data collected during 12 months of operation (October 2019 - September 2020) of the five mini electric buses in the service “Linha Eco Cidade. An evaluation report was carried out to assess the viability of mini electric buses in that service compared to diesel buses, namely the energy, environmental and economic impacts and period of return on investment.

Installation and acquisition of support systems

Eco-Drive system – Trakm8

In January 2018 HF initiated the tests and calibration in 20 regular buses and followed 6 eco-drive training sessions for 200 drivers. To support and improve the implementation of the eco drive program 50 drivers were involved to use the monitoring system and corresponding follow-up of the drivers. The main goal of HF was to improve the performance of the drivers, having continuous drivers’ training and eco drive follow up. In such was it was possible to monitor drivers’ actions in real time and access to detailed reports of their driving performance.

All the information was available in the web portal and in a mobile application that enabled the HF training team to check the situation at any place including inside the bus. The system allows to monitor drivers’ behaviour in real time. During this test phase, the HF training team was able to provide information about idle time, excessive speed and where it happened. In addition, the app provides more valuable information to prepare and adapt each the training sessions.

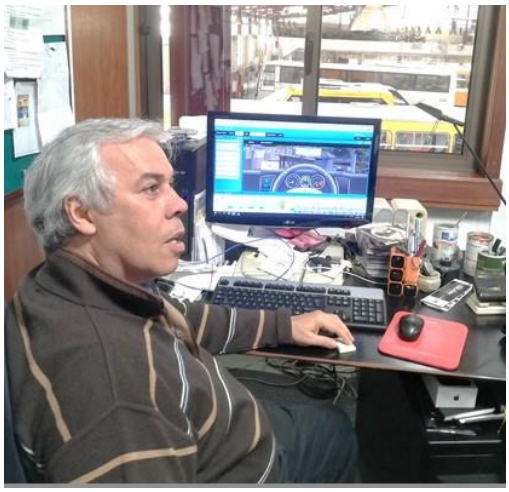

Figure 4: Trakm8 system

Although, technical constraints were identified from the beginning, related with the short distance routes, relevant numbers of driving stops. This fact is related with the service being tested in areas with very narrow streets and steep gradients, with atypical conditions, therefore not suitable for evaluation.

After the installation of the solution, HF informed the bus drivers that the system was in a test and improvement phase. This approach with drivers resulted in two different reactions. On one hand, some drivers accepted the new monitoring system and they were enthusiastic about the new chance to improve their performances. On the other hand, some drivers did not accept

such control, so they didn't present the key to start the monitoring session; some of them even tried to destroy the onboard consoles to boycott the control system.

The system faced problems related to union issues regarding driver's personal information and to the fact that some drivers were blaming the company of excessive control of the bus drivers. The solution led to several operational and legal constraints and a full successful implementation of the measure was partially compromised.

Tire Management System - Continental

In May 2018 started the gradual installation of the sensors in the bus's tyres (in total installed in 50 buses). The buses were equipped with six tyre pressure sensors, mounted onto the inner lining of a tyre to collect data. The installation of sensors followed a logic of opportunity to minimize the human resources and the immobilization time of the buses. The installation occurred when the vehicles were replacing tyres.

A 4-yard reader station receives the data from the tyre sensors within a yard and transmits it via cellular connection to the backend. The reader stations were installed at the fleet's washing bay. Through the web portal it is possible to proactively monitor tyre conditions on all vehicles.

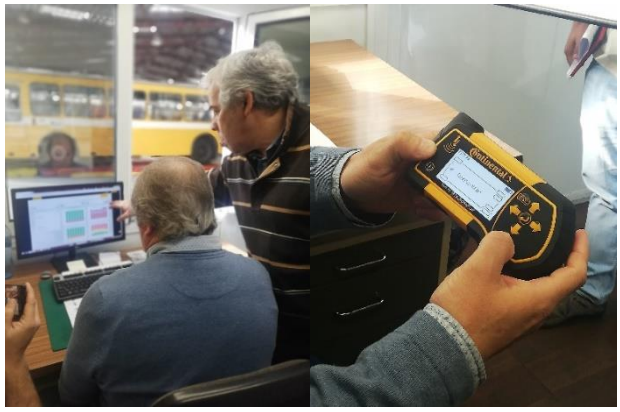

Figure 5: Tire Management system in operation

The first two months of operation were essential to adapt the system to Madeira specific land profile and to HF service reality. Besides the training sessions, it was necessary to configure and parametrize the system. Several interactions with the system supplier were required.

The tire pressure management system brought significant benefits for the operation, once driving safely is directly related to the condition of the tyres. Buses with under-inflated tyres cause higher fuel consumption, increase their carbon dioxide emissions and cost more money. In addition, it was possible to detect other possible problems as the temperature of the tyre, possible problems with the brakes, and, indirectly related, identify fewer steering malfunctions.

In general, the main benefits were related to the enhancement of the lifetime of the tyre, although, not in all cases, this extension was due to the system. It was possible to understand that the change/update of the brand of the tyre, contributed also to such enhancement.

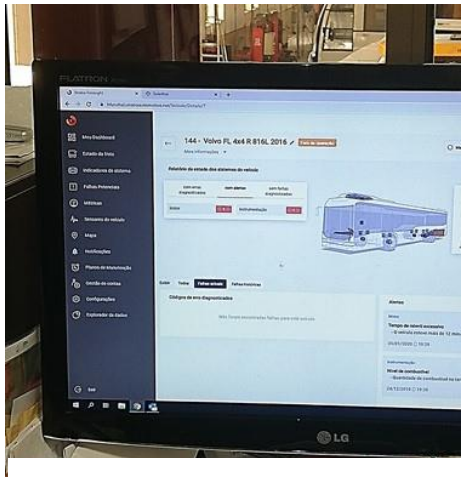

Figure 6: Stratio system

Predictive Maintenance Monitoring System – Stratio

In May 2019, it was installed in 41 buses the equipment capable of collecting and securely streaming in real-time high-density vehicle data. The solution allowed the early fault detection enabling decreased vehicle downtime and operational predictability and the real-time monitoring of the remaining useful life of parts and systems, reducing

repair and maintenance costs. It was necessary to calibrate the alerts of the system, considering the specificities of the Madeira roads, and the type of buses.

This tool was very useful for the maintenance department once it allowed to prioritize repairs and anticipate breakdowns, making data-backed decisions that reduced repair and maintenance costs. In some cases, when a serious alert was triggered during a service, the bus returns immediately to the bus station avoiding accidents or bigger mechanical damages on the bus.

PV support system - SOLARBUS

HF in partnership with AREAM carried out an assessment of the photovoltaic existing solutions and identified a Norwegian solution from SOLARBUS as the most interesting and with the most promising results. Hence, the company SOLARBUS visited HF to present the company and the products.

In September 2019, the SOLARBUS manufacturer installed the photovoltaic system on the roof of two buses to start the pilot tests. AREAM and HF prepared a communication campaign to be placed on the buses with the solution installed, mentioning that the bus used solar energy. It was also prepared and published an article to disseminate on regional and national media such innovative solution.

Figure 7: Bus with photovoltaic power system

During the demonstration phase, AREAM collected information and analysed the data gathered during nine months of demonstration (January-September 2020). A technical report was prepared to evaluate the viability of the system considering the energy, environmental and economic impacts including also the return-on-investment period. In the evaluation was analysed the most adapter power's panels to the needs of the auxiliary on board electrical equipment.

The information was gathered through the charge controller installed on the two buses. This equipment performs the communication of electricity data production with a monitoring platform through wi-fi when the bus arrives at the bus station.

Figure 8: Solarbus.pro monitoring system

C Impact evaluation

C1 Evaluation approach

Expected impacts and indicators

Impact category	Impact indicator	Impact indicator 2	Unit of measure
Energy	1 - Energy mix in PT fleet	Energy consumption	MWh
		Fossil fuels (diesel)	%
		B7 biodiesel	%
		Electricity	%
Energy	2- Use of RES in PT fleet	Sustainable electricity	MWh
		Sustainable B7 biodiesel	
		PV system (solar production)	
Energy	3 - Energy consumption	HF urban Fleet	Lt/100km
		2 bus - PV panel	Lt/100km
		5 mini electric buses	MWh
		3 demonstration tests	MWh
Environment	4 - CO_2 emissions avoided	2 bus - PV panel	t
		5 mini electric buses	t
		3 demonstration tests	t
Environment	5 - CO emissions avoided	2 bus - PV panel	kg
		5 mini electric buses	kg
Environment	6 - NOx emissions avoided	2 bus with PV panel	kg
		5 mini electric buses	Kg
Environment	7 - PM emissions avoided	2 bus with PV panel	Kg
		5 mini electric buses	Kg
Economy	8 - Maintenance costs	HF urban Fleet	€/100km
Economy	9 – Operating costs	5 mini electric buses	€/100km
Transport	10 - Perception of quality of driving	Quality of driving	qualitative

Table 2: Expected impact and indicators

Method of measurement

Impact indicator	Method*	Frequency (Month)			Target Group	Domain (demonstration area or city)
		Baseline	During	After		
1 - Energy mix in PT fleet	DC	M12	n.a.	M49	PT operators	Madeira
2 - Use of RES in PT fleet	E	M12	n.a.	M49	PT operators	Madeira
3 - Energy consumption	DC	M16	M28	M40	PT operators	Madeira
4 - CO_2 emissions avoided	E	M12	n.a.	M49	PT operators	Madeira
5 - CO emissions avoided	E	M12	n.a.	M49	PT operators	Madeira
6 - NOx emissions avoided	E	M12	n.a.	M49	PT operators	Madeira
7 - PM emissions avoided	E	M12	n.a.	M49	PT operators	Madeira

8 - Maintenance costs	DC	M16	M28	M40	PT operators	Madeira
9 – Operating costs	DC	M35, M36 and M37	n.a.	M37 and M38	PT operators	Madeira
10 - Perception of quality of driving	S	M12	M28	M40	PT passengers (tourists)	Madeira

*(Data collection (DC), Estimation (E), Survey (S)

Table 3: Method of measurement

Detailed description of the indicator methodologies

1 - Energy mix in PT fleet – HF was responsible for collecting data for this indicator and AREAM performed the data processing. The indicator considers the annual energy consumption per source of energy (example: litres diesel, kWh of electricity (electric buses), B7 biodiesel-mandatory biodiesel incorporated with conventional gasoil in 7% volume by the HF PT fleet. The data was all converted to MWh using IPCC (Intergovernmental Panel on Climate Change) energy conversion factors.

2 – Use of RES in PT fleet – HF was responsible for collecting data for this indicator and AREAM performed the data processing. The indicator considered the renewable energy incorporated in energy consumption per source of energy:

Sustainable electricity is a renewable energy in electricity consumed by the five mini electric buses in service between October 2019 and September 2020. In off-peak hours (night) the electricity integrates about 80% of energy from of hydro, wind and solid urban waste. In the baseline situation (2016) the value is zero because electric buses did not exist.

Sustainable B7 biodiesel is the mandatory biodiesel incorporated with conventional diesel in 7% volume. The volume of incorporated biodiesel is a renewable energy as it comes from a culture used in a sustainable way that results in a neutral balance of emissions.

For the PV system (solar production), the data was obtained through electricity data production presented in the monitoring platform, it was considered the solar production between January and September 2020.

3 - Energy consumption - HF was responsible for collecting data for this indicator and AREAM performed the data processing. The indicator considered the energy consumption per the 4 actions performed in the scope of this measure:

For the entire **HF urban fleet**, where the needed information was extracted from the internal databases (kms driven, fuel consumption, maintenance and operational costs) and AREAM calculated the energy estimation. The data considered the energy consumption per 100 km.bus before (baseline) and after the implementation (2019).

For the **two HF buses with PV systems**, the needed data was extracted from the internal databases (kms driven, fuel consumption, maintenance and operational costs) and AREAM calculated the energy estimation. The data considered the energy consumption per 100 km.bus before (baseline) and after the implementation (2019).

For the **five mini electric buses**, it was used the same data extracted from HF internal databases for the realized service (kilometres) between October 2019 and September 2020.

The baseline corresponds to the energy consumption of the five Mercedes Vario with the same service (kilometres) of the five mini electric buses Karsan.

The information for the **three demonstration tests** was provided by public transport operators involved in the demonstration tests (HF, SAM, Moinho Rent-a-car and Municipality of Calheta) through daily record sheets used for the demonstration days where they were recorded daily consumption of electricity and electricity that was charged. The baseline corresponded to the average energy consumption of diesel buses (specific consumption was provided by public transport operators involved) considering equivalent service (kilometres) to the realized in demonstration tests.

4, 5, 6, 7 - CO_2, CO, NOx, PM emissions avoided - HF was responsible for collecting data of energy consumption and AREAM performs the data processing. The estimation of avoided emissions was performed using IPCC CO_2 emission factor of diesel. Such calculation models adopted by the EC (Copert) for diesel buses (for the others pollutants) and EMEP/EEA air pollutant emission inventory for the electric buses.

This indicator considers the CO_2 emissions avoided, through the impact of the two buses with photovoltaic panels between January and September 2020, according the information provided for the production of electric energy, taking into account the indication of Solarbus system, in which it was indicating that for each kWh of solar photovoltaic production it is possible to save about 1 liter of diesel.

This indicator considered the five mini electric buses Karsan. The indicator considered the kilometres performed by the five mini electric buses between October 2019 and September 2020, and estimation considers that they replaced services that were performed by the five Mercedes Vario (diesel buses).

The CO_2 emissions avoided indicator also estimated the impact of three demonstration tests using consumption data from indicator 3 - Energy consumption, compared with the diesel buses.

8 - Maintenance costs - HF was responsible for collecting data for this indicator, by extracting the needed information from the internal databases. This indicator was measured considering the maintenance costs per 100km (consumable materials and costs with workforce) for the entire HF urban fleet in order to evaluate the impact of the actions implemented under this measure (Ecomanager system, tire pressure system, photovoltaic system, the five mini electric buses and the predictive monitoring system).

9 – Operating costs - HF was responsible for collecting data for this indicator, by extracting the needed information from the internal databases. This indicator was calculated considering the kms performed, the maintenance and operating costs with the five diesel Mercedes Vario buses that circulated between July and September 2019 along on the new “Linha Eco Cidade” (for baseline data), substituted in September 2019 by the five mini electric buses, for which it was considered costs between September and October 2019 (for ex-post evaluation).

10 - Perception of quality of driving - HF was responsible for collecting data for this indicator. The indicator evaluates the perception of quality of services affected by the actions carried out under the measure. The data was collected through surveys addressed to tourists at the airport of Madeira, that experienced the PT service. It was asked the tourists to rate the “Quality of Driving” in a scale 1 to 5 (1-very poor;5-very good). The surveys were applied in 2017, 2018 and 2019.

The Business-as-Usual scenario

Without DESTINATIONS project, there would continue to exist no electric buses in the PT fleets in the Madeira Region. On the other side, there would remain a general lack of liability in the technology experienced in recent past. DESTINATIONS project had an important role to build and reinforce the credibility of e-bus technology and its dissemination among decision makers and PT operators. The pilot tests carried out, which have strengthened the political commitment with a long-term sustainable strategy.

For the indicators 1 - Energy mix in PT fleet, 2 - Use of RES in PT fleet and 3 - Energy consumption, the BAU scenario considered the data collection regarding energy consumption from specific consumption information for the HF urban bus fleet between 2013 and 2015, using a tendency linear line. There was no data for 2016.

If the five mini electric buses would have not been bought, the BAU scenario would be the “Linha Eco Cidade” remaining with considerable operation costs from one side, as contributing for high emissions and noise pollution on the city centre of Funchal, area of operation of the service.

A BAU scenario was not possible to establish for indicator 4, 5, 6, 7 - CO_2, CO, NOx, PM emissions avoided, because the avoided emissions were achieved through the implementation of actions to be developed within the scope of this measure, however, we emphasize that the non-implementation of the actions would keep the emission levels of urban service or it would even increase due to the rise of the average age of the PT urban fleet.

For the indicator 8 - Maintenance costs it was not possible to perform a BAU projection as there were several external variables that did not allow to establish such scenario.

As for the indicator 9 – Operating costs it was possible to establish a BAU scenario considering the operation costs of the five Mercedes Vario under operation in the “Linha Cidade”.

None BAU is feasible for indicator 10 - Perception of quality of driving. Nevertheless, without DESTINATIONS, despite no significative improvement achieved, it is believed that the quality of driving would have worst results.

C2 Measure results

Impact category	Impact indicator	Impact indicator 2	Unit of measure	Baseline	Ex-Ante	Ex-Post
Energy	1 - Energy mix in PT fleet	Energy consumption	MWh	37.248	-	37.379
		Electricity	%	0%	-	0,014%
		Fossil fuels (diesel)	%	93,81%	-	93,80%
		B7 biodiesel	%	6,19%	-	6,18%
Energy	2- Use of RES in PT fleet	Sustainable electricity	MWh	0	77	11,9
		Sustainable B7 biodiesel		2.330	-	2.312
		2 bus - PV panel	kWh	0	1.680	210,1
Energy	3 - Energy consumption	HF urban Fleet	Lt/100km	61,6	55,9	63,6
		2 bus - PV panel	Lt/100km	57,4	-	63,2
		5 mini electric buses	MWh	116,4	-	14,6
		3 Demonstrations tests	MWh	15,8	-	2,3
Environment		2 bus - PV panel	T	0	0,4	0,6
		5 mini electric buses	T	0	35,7	29,1

	4 - CO_2 emissions avoided	3 Demonstrations tests	T	0	87,1	3,1
Environment	5 - CO emissions avoided	5 mini electric buses	Kg	0	-	7,9
Environment	6 - NOx emissions avoided	5 mini electric buses	Kg	0	-	11,7
Environment	7 - PM emissions avoided	5 mini electric buses	Kg	0	-	1,6
Economy	8 - Maintenance costs	HF urban Fleet	€/100km	29,48	21,69	29,14
Economy	9 – Operating costs	5 mini electric buses	€/100km	62,81	31,41	28,1
Transport	10 - Perception of quality of driving	Quality of driving	qualitative (1-poor; 5- very good)	3,93	4,32	4,10

Table 4: Measure results

C2.1 Energy

1- Energy mix in PT fleet

This indicator is related to the energy consumption. It registered an increase of 0,34% between 2017 and 2019 in urban fleet of HF. Electricity was introduced in the fleet mix as a result of the introduction of the five Karsan jest electric in September 2019, about 5,18 MWh of electricity being consumed between September and December 2019, representing only 0,014% of the fleet energy mix.

Impact indicator	Unit of measure	2013	2014	2015	2017 (Baseline)	2019 (Ex-post)	Variation [%] 2017-2019
Energy consumption	MWh	40.250	38.580	38.256	37.248	37.379	+0,34%
Electricity	%	0%	0%	0%	0%	0,014%	+0,014%
Fossil fuels (diesel)	%	93,81%	93,81%	93,81%	93,81%	93,80%	-0,01%
B7 biodiesel	%	6,19%	6,19%	6,19%	6,19%	6,18%	-0,01%

Table 5: Evaluation of energy mix in HF PT fleet

2- Use of RES in PT fleet

The indicator is related with use of RES in PT fleet. The decrease of 0,34% of **sustainable B7 biodiesel** between 2017 and 2019 in the HF's urban fleet, was because biodiesel is integrated into diesel and its consumption increased between 2017 and 2019.

The use of **sustainable electricity** increases 11,9 MWh (80% of electricity consumed comes from RES), between October 2019 and September 2020 by the five Karsan jest electric.

The use of the PV systems in the two buses allowed to produce about 210,1 kWh of RES electricity between January and September 2020.

3- Energy consumption

HF urban fleet

The indicator related with the energy consumption registered an increase of 2,4% between 2017 and 2019 among the urban fleet. Only the buses equipped with the Ecomanager solution had a decrease of 4,8%. It is not correct to directly assess average consumption since there may have been changes in other factors that influenced this consumption compared to 2017, namely commercial speed, occupancy rate, change in services, etc.

Bus typology with equipment	2017	2018	2019	Var. 2017-2019
Pre-Euro no equipment	63,98	66,93	66,86	4,5%
Euro I no equipment	66,13	66,62	67,85	2,6%
Euro II no equipment	61,52	61,12	61,50	0,0%
Euro I with Eco Manager	63,77	65,87	66,96	5,0%
Euro II with Eco Manager	62,88	60,59	59,87	-4,8%
Euro II with Tyre Pressure	60,77	60,87	61,61	1,4%
Euro V with EcoManager e SolarBus	58,96	58,11	63,23	7,2%
Euro V with EcoManager, Tyre Pressure e STRATIO	62,42	62,43	63,97	2,5%
Euro V with Stratio	59,39	59,20	61,06	2,8%
Euro V with SolarBus	57,39	55,51	60,74	5,8%
Euro V with Tyre Pressure e STRATIO	61,42	60,75	62,68	2,1%
Euro V with Stratio Mercedes	26,79	28,00	29,13	8,8%
Euro VI with Stratio	64,25	63,36	64,51	0,4%
Euro VI with Stratio Mercedes	0	0	16,82	0%
Total	62,07	62,83	63,56	2,4%

Table 6: Monthly average fuel consumption per bus type and per 100km (L/100km)

If DESTINATIONS would have not been implemented, the HF PT fleet would continue to register a continuous increase of the energy consumption (L/100km). This tendency is strongly related to the ageing of the HF PT fleet. With DESTINATIONS it was possible to mitigate such degradation trend, achieving lower energy consumption in 2018 and 2019. These results will be expanded beyond DESTINATIONS considering HF's fleet renovation strategy, with the acquisition of 5 electric minibuses in 2019 and continued with 30 standard buses Euro VI. acquire between 2020 and 2021

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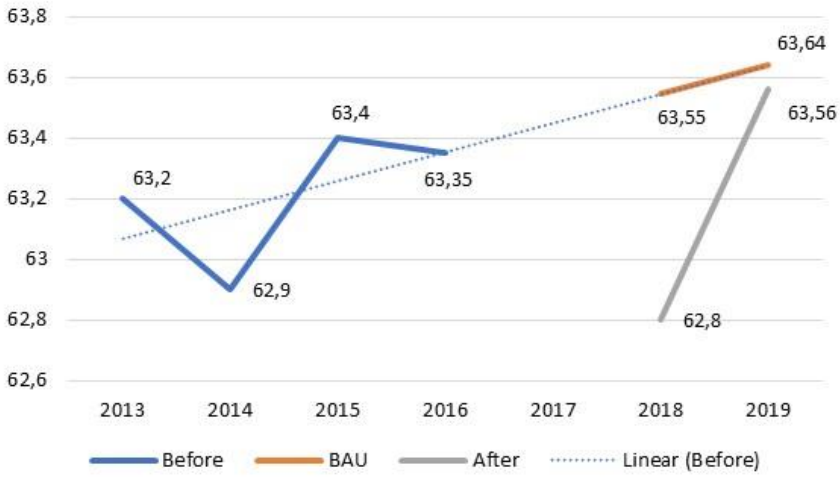

Figure 9: Average fuel consumption per 100km (L/100km) per year, before DESTINATIONS, after and BAU scenario

It was not considered on this projection the energy consumption of 2017 because the values were considered an outlier, not in line with the values of the past years.

Two bus - PV panel

The indicator related with the energy consumption of the two buses with PV registered an increase of 5,8% between 2017 and 2019. This variation may be related to several external factors, namely the type of services they were providing, increased traffic and increased occupancy rate.

PV systems were installed in September 2019, and by the end of 2019 they were not being monitored correctly. The energy production of the PV panel between January and September of 2020 in buses 408 and 419, considering information provided by Solarbus, are shown below.

Due to the context of COVID-19, the two buses circulated little between March and September 2020, which led to low energy production, lower than the winter months, for which the availability of sun is much lower. To overcome this problem, a correction factor was used between March, and September according to the monthly data from Funchal presented in the atlas of sun exposure on the island of Madeira.

Month	Correction factor		PV Production (kWh)			
			Bus 408		Bus 419	
	408	419	Real	With correction factor	Real	With correction factor
January	0,83	1,00	17,8	15,6	16,6	16,50
February	1,00	1,20	18,7	18,7	12,2	19,82
March	1,36	1,63	8,9	25,4	5,5	26,91
April	1,66	2,00	10,9	31,1	13,5	32,94
May	1,66	2,00	11,8	31,2	9,9	32,98
June	1,64	1,97	13,6	30,7	8,3	32,46
July	1,64	1,97	10,1	30,8	11,9	32,54
August	1,61	1,93	12,4	30,1	8,7	31,85
September	1,47	1,77	10,8	27,6	8,5	29,23
October	1,13	1,36		21,25		22,48
November	0,84	1,01		15,69		16,61
December	0,73	0,87		13,59		14,38
Total		-	115,0	291,8	95,1	308,7

*Bus 408-Real PV Production in February and multiplication by the correction factor
*Bus 419-Real PV Production in January and multiplication by the correction factor

Table 7: PV production between January and September of 2020

SOLARBUS, indicates that for each kWh of solar photovoltaic production it is possible to save about 1 litre of diesel. Hence, the PV production achieved, allowed to avoid at least 210,1 litres of diesel (115,0 kWh from bus 408 and 95,1 kWh from bus 419), that could reach 600,5 litres between January and December if the buses maintained the service carried out in January and February, with a correction factor related with the greater solar radiation compared to the winter months.

Five mini electric buses

Between October 2019 and September 2020, the five mini electric buses substituted the previous five diesel buses, which were operating on the “Linha Eco Cidade” during August 2019. In this period, the five mini electric buses performed 38.608 km, with a consumption of 14,6

MWh, with the average consumption of 37,8 kWh/100 km, **reduction of 87% comparatively of diesel buses (101,8 MWh, less 11 337 litres of diesel).**

	km	Consumption l/100km	Consumption kWh/100km	Energy consumption MWh
Diesel Mercedes vario	38.608	29,37	301,5	116,4
DESTINATIONS Karsan	38.608	-	37,8	14,6
Impacts	-	-	- 263,7	- 101,8

Table 8: Energy consumption impacts of the introduction of five mini electric buses comparatively of diesel buses.

Three demonstration pilot tests

Considering the service performed in the demonstration pilot tests and the reference energy consumption of similar diesel buses with the same service, it was calculated the avoided energy consumption by the three demonstrations tests. In total it **was avoided 13,5 MWh (-86%) with the electric buses demonstrations**.

Three demonstration pilot tests	Diesel Bus	DESTINATION Electric buses	Avoid energy	
Energy consumption	15,8 MWh	2,3 MWh	13,5 MWh	- 86%

Table 9: Energy consumption impacts of the demonstration of electric buses comparatively of diesel buses.

The DESTINATIONS ex post indicators of the demonstration tests were lower than expected, since in the calculations made in the project proposal were considered tests during 360 days of tests in a standard bus (12m bus).

C2.2 Environment

4- CO_2 emissions avoided

2 bus - PV panel

The PV production allowed to **avoid 0,6t of CO_2 emissions** as a result of the reduction of 210,1 litres of diesel, which could reach 1,2t of CO_2 emissions if the buses maintained between March and September 2020 the same service performed in January and February, with a correction factor related to the higher solar radiation compared to the winter months.

Five mini electric buses

Between October 2019 and September 2020, the five mini electric buses replaced the previous 5 diesel buses who were operating in the “Linha Eco Cidade” in August 2019. In this period, the five mini electric buses **reduced CO_2 emissions by 29,1 t compared to diesel buses (-93%)**.

	km	Energy consumption MWh	CO_2 emissions tonnes
Diesel Mercedes vario	38.608	116,4	31,1
DESTINATIONS Karsan	38.608	14,6	2,0
Impacts-CO_2 avoided	-	101,8	29,1

Table 10: CO_2 emissions impacts of the introduction of mini electric buses comparatively of diesel buses.

Three demonstrations tests

With the 3 demonstration pilot tests it was **avoided 3,1 t CO_2 emissions**, a reduction of 75% compared to similar diesel buses considering the same service performed.

	Energy consumption MWh	CO_2 emissions tonnes
Diesel buses	15,8	4,2
DESTINATIONS- Electric buses	2,3	1,1
Impacts-CO_2 avoided	13,5	3,1

Table 11: CO_2 emissions impacts of the demonstration of electric buses comparatively of diesel buses

5- CO emissions avoided

Five mini electric buses

Between October 2019 and September 2020, the five mini electric buses achieved a **reduction of 91% (-7,9kg) of CO emissions** compared to the five diesel buses (Mercedes Vario) that operated on the "Linha Eco Cidade" in August 2019, as presented in Table 12.

6- NOx emissions avoided

Five mini electric buses

Between October 2019 and September 2020, the five mini electric buses achieved a **reduction of 61% (-11,7kg) of NOx emissions** compared to the five diesel buses (Mercedes Vario) that operated on the "Linha Eco Cidade" in August 2019, as presented in Table 12.

7- PM emissions avoided

Five mini electric buses

Between October 2019 and September 2020, the five mini electric buses achieved a **reduction of 56% (-1,6kg) of PM emissions** compared to the five diesel buses (Mercedes Vario) that operated on the "Linha Eco Cidade" in August 2019, as presented in Table 12.

		Energy consumption MWh	CO emissions kg	NOx emissions kg	PM emissions kg
Diesel Bus	Mercedes vario	116,4	8,7	19,2	2,9
DESTINATIONS	Karsan jest eletric	14,6	0,8	7,5	1,3
	Impacts- avoided	101,8	7,9	11,7	1,6

Table 12: CO, NOx and PM emissions impacts of the introduction of mini electric buses comparatively of diesel buses

C2.3 Economy

8 - Maintenance costs

The 1,1% reduction of the operational costs between 2017 and 2019 was a positive achievement and it results from the implementation of the several systems. Although the results could not be assessed individually per system as they were installed in different type of buses (EURO I, II, V, VI) that were operating in different orographic conditions. This approach was chosen to perform a wide evaluation on the network, covering the several types of buses and conditions.

	2017	2018	2019	Var. 2017-2019
Pre-Euro no equipment	31,51	26,05	22,51	**-28,6%**
Euro I no equipment	26,97	27,13	28,96	7,4%
Euro II no equipment	26,87	34,46	30,23	12,5%
Euro I with Eco Manager	23,06	29,59	20,51	**-11,1%**
Euro II with Eco Manager	34,62	21,76	29,96	**-13,4%**
Euro II with Tyre Pressure	27,71	27,96	27,29	**-1,5%**
Euro V with EcoManager e SolarBus	20,52	50,66	31,25	52,2%
Euro V with EcoManager, Tyre Pressure and STRATIO	29,51	37,40	35,02	18,7%
Euro V with Stratio	25,95	31,37	55,87	115,3%
Euro V with SolarBus	19,75	17,42	60,22	204,9%
Euro V with Tyre Pressure and STRATIO	34,55	39,25	28,46	**-17,6%**
Euro VI with Stratio	22,83	35,50	65,81	188,2%
Euro V with Stratio mercedes	22,51	28,01	52,44	133,0%
Euro VI with Stratio mercedes	0	0	5,00	0%
Total	**29,48**	**30,80**	**29,14**	**-1,1%**

Table 13: Monthly average maintenance costs per bus type and per 100km

9 – Operating costs

It was possible to achieve very good results in what regards the operating costs under “Linha Eco Cidade” through the substitution of the five diesel Mercedes Vario buses by the five mini electric buses. Considering the same monthly average number of kms performed by the diesel buses (1.148kms), during the initial period of operation of the mini electric buses, it was estimated a reduction of 55% of the operation costs. The initial period of operation required adjustments and calibration of the involved equipment and, also, specific training for the maintenance team and bus drivers, which justified the considerable value of the operation costs (consumables and workforce).

During December 2019, it was estimated that the Karsan buses registered an average decrease of 74% on the operation costs, when compared with diesel Mercedes Vario, with considerable inferior values on maintenance (consumables and workforce).

	Distance (month)	Fuel consumption	Energy consumption	Fuel	Energy	Consumable materials	Workforce	Total operation costs	Operation costs per 100km	Var. with Diesel
	Kms	Lt.	kWh	€	€	€	€	€	€	%
Diesel Mercedes Vario*	1.148	315,3	3.238,0	281,6	0	374,0	65,5	721,1	62,8	-
Mini eletric Karsan **		0	413,0	0	33,04	39,4	248,7	322,78	28,1	**-55%**
Mini eletric Karsan***		0		0	33,04	0	154,0	187,04	16,3	**-74%**

*(Jul, Ago, Set 2019); **(Set, Out, Nov 2019); *** (Dec. 2019)

Table 14: Monthly average operation costs

If the five mini electric buses would have not been bought, the “Linha Eco Cidade” would remain with considerable operation costs from one side, as contributing for higher emissions and noise pollution on the city core of Funchal.

C2.3 Transport

10 - Perception of the driving quality

The perceived quality of driving between 2017 and 2019 had an increase of 4,3%. This result reflets the efforts made by HF to improve the service through the implementation of the Ecomanager solution that initiated tests in January 2018 and, complementarily, with the several trainings provided to the bus drivers (under measure MAD6.3). At the beginning, the Ecomanager solution was well accepted and considered as an improvement tool by the 50 bus drivers. Although, followed few months of implementation and tests, HF had to deal with the non-accept of the solution among some drivers, some of them even tried to sabotage the equipment.

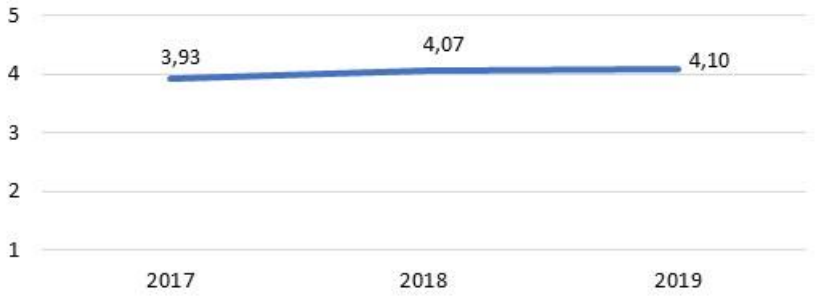

Figure 10: Perceived quality of driving

C3 Quantifiable targets

No	Target	Rating
1	Less CO_2 emissions - 105 tCO_2, 89%.	★
2	Less energy consumption - 348 MWh, 79%	★
3	Less noise	★★
4	Use of cleaner and alternative fuels - 76,6 MWh	O
5	80% - Renewable energy during night time	★★
6	* Decrease of 5% on the maintenance costs	O
7	* Improvement of 5% on the quality of driving	★★
8	* Decrease of 50% of the operating costs with the five mini electric buses	★★★
NA = Not Assessed O = Not Achieved ★ = Substantially achieved (at least 50%) ★★ = Achieved in full ★★★ = Exceeded		

* New target, not in GA

Table 15: Assessment of quantifiable targets

The targets from 1 to 5 were planned in the grant agreement, and the targets 6 to 8 were defined during the measure development.

The target 1 and 2 were substantially achieved. The target 1 achieved a reduction of 32,8 t CO_2 (less 90% comparatively to diesel bus, with the support of the PV system, the demonstrations tests and the five mini electric buses). Target 2 achieved a reduction of 101 MWh (less 85% comparatively to diesel bus, with the support of the demonstrations tests and the five mini electric buses).

These two targets did not achieve better results because, from one side despite the PV systems having 9 months of operation for evaluation, during 7 of them the buses ran a reduced service. From the other side, despite the five mini electric buses had 12 months of operation for evaluation, throughout 7 of them the buses performed a reduced service, of about 50% less. In the demonstration tests, around 360 days of testing were considered in the GA and during the project, approximately 60 days were carried out. For the Eco-Drive system and the Tire Management System it was not possible to assess the reduction of energy consumption and CO_2 emissions since there may have been changes in other factors that influenced this consumption compared to 2017, namely commercial speed, occupancy rate, change in services, it is not possible to assess the reduction in energy consumption and CO_2 emissions.

The target 3 was achieved in full, as the electric buses introduced in the HF fleet contributed to the reduction of noise pollution, mainly in the urban centre, a place where pedestrian circulation is higher and where many citizens and tourists spend most of the time. According to a scientific article (Sven Borén, 2016, Preferences of Electric Buses in Public Transport; Conclusions from Real Life Testing in Eight Swedish Municipalities) diesel bus emit in acceleration 72 dBA (0-56 km/h) and electric bus 62,8 dBA, less 14,7%. In idle mode the diesel bus can emit 90 dBA, and the electric bus in this condition has zero noise.

The target 4 was not achieved, reaching 11,9 MWh of RES. The lower impact is referred to the following factors: the photovoltaic panel system started to produce energy in January, and the five mini electric buses begin to circulate in October 2019, with an initial reduced use. These two actions were interrupted due to the COVID-19 and the use of cleaner and alternative fuels was influenced by the resulting adjustments to the public transport service

The target 5 was achieved in full. The indicator was related to the charging of the five mini electric buses in off-peak hours (between 11 pm and 6 am), benefiting from cheaper energy cost and about 80% of the electricity in the network coming from RES.

Target 6 was not achieved as it was possible to accomplish only a 1,1% of decrease on the maintenance costs of the entire HF urban fleet, instead of 5%. These results are explained by the fact of the solutions were installed in different types of buses, operating under different land profile conditions. Other fact that contributed to a below par result was related to the learning process of the new hired drivers, with less efficient driving skills. On the other hand, the traffic constrains provoked by the frequent civil works in the urban are contributed to increase the operating costs.

The target 7 was considered to be achieved with an increase of 4,3%. This result was reached with the implementation of the Ecomanager solution installed on January 2018 and, complementarily, with the support of the several trainings for the bus drivers (under MAD6.3).

Target 8 was Exceeded once it was achieved a decrease of 55% on the operating costs with the substitution of the five diesel buses by the five mini electric buses. These results could be

extended on the following months considering that the initial costs of the five mini electric costs included costs of calibration and training of the maintenance workers and bus drivers. In December 2019 it was achieved, as a result, an average reduction of 74% of the operating costs.

C4 Up-scaling of results

The promotion of electric vehicles in the renewal of the PT fleet are activities to continue in the coming years. If these initiatives would be roll-out to the entire urban fleet (150 buses), it would contribute to the improvement of the energy and environmental indicators of the PT fleet and to save energy and maintenance costs for the companies, contributing also to reduce overall dependency on fossil fuels.

According to the Karsan Atak Eletcric demonstration test carried out in March 2020, it was possible to assess that this bus can perform about 70% of HF urban service network (where the bus dimensions are suitable to the land profile). This is a good indicator to take into account for future fleet renewal strategies and action plans.

Impact category	Impact indicator	Unit of measure	Assumptions	Likely results
Energy	Energy consumption	MWh energy consumption	The energy consumption of the HF urban fleet is 37.379 MWh. Substituting 70% of the fleet with electric buses (more 100 electric buses)	-60% 15.139 MWh

Table 16: Up-scaling Scenario with 70% of electric buses in HF fleet

The expansion of electric mobility fleets in Madeira can contribute to environmental and public health of citizens and visitors, reducing to zero the local pollution emission and less noise target areas.

The demonstration of PV system allowed to draw conclusions about its technical economic viability in urban buses, and according with the results of this demonstration and the suggestions presented in the technical study, this can be a contribution to boost the installation of similar systems on other buses or fleets, in EU urban and interurban areas.

D Process Evaluation Findings

D1 Drivers

At a **political/strategic** level, there was a clear political commitment to study and develop a sustainable and credible fleet renovation plan to drive the transition from fossil fuel dependency to more sustainable energy sources. Such plan was also supported with the definition of a strategic goal at regional and local level to promote the soft modes and improve the accessibilities for both tourists and residents. **Financially**, implemented innovative action with relevant effects on the business model of the local public transport operators. To support a sustainable fleet renewal a precondition is the availability of relevant funding sources to define a long-term renovation plan. In the case of Madeira ERDF contribute with relevant resources to reduce the fleet ageing and to drive the change. Other funding sources at Natonal and Regional Level also supported partially this transition.

At a **cultural** level, citizens were more and more aware of climate change, so they were demanding the introduction of eco-friendly buses into the urban public transport fleet. Also, the promotion of electric mobility in public passenger transport, by conducting tests in the Region with a 100% electric bus arises as a chance at an **organizational** level.

D2 Barriers

The measure faced **planning** constraints, starting in the time plan, which was too optimistic at first. Some activities need to be rescheduled, also to fit the work plan of other Destinations measures and also to rely on the support of local partners such Municipalities and private operators. Due to delays, the equipment was purchased in a late stage and this diminished the return of the investment.

D3 Lessons Learned

Electric mobility represents a valid answer for the collective transport, of people and goods in the cities. Relevant advantage is related to the environmental and public health benefits that they confer to citizens and visitors, including also the absence of local polluting emissions. Another relevant aspect makes electric vehicles interesting are related to the internal and external economic benefits provoked, namely the running cost savings generated for companies and less negative externalities for tourist and citizens. Finally electric bus represents an important solution to reduce transport dependency on fossil fuels and to rebalance the energy mix general consumption scheme to more sustainable sources.

E Evaluation conclusions

The evaluation showed positive results for the demonstration program for electric vehicles in public transport, in which were tested three models of electric buses (mini, midi and standard buses) in the Madeira Region. The PT regional operators were able to test the buses in various services, verifying, through the feasibility studies, their technical, energetic and environmental feasibility, the added value in the fleet renewal taking into account the introduction of electric buses.

The evaluation measured positive results, in the specific case of the acquisition of five mini electric buses, by providing a service that runs in the city centre more cost-effective operationally. These buses also revealed to be adequate to these sensitive areas (city centre of Funchal) where the environmental and noise impacts must be reduced. The intermodal service tested with the electric bus is also relevant because it connects the city centre and the cruise port of Funchal, providing more quality of live for residents and tourists.

The installation of the onboard systems (ecomanager, tyre pressure, stratio and PV system), contributed to a more cost-effective operation, by reducing the maintenance costs. On the other hand, the systems did not contribute for an energy reduction (fuel consumption), as there was an increase, related to external factors such as changes in PT services, occupancy rates of public transport and commercial speed. The perceived quality of driving indicator had an increase between 2017 and 2019. It is understood that it is being provided a better service to the residents and tourists.

F Additional information

F1 Appraisal of evaluation approach

There was difficulty to perform an accurate evaluation of the contribution of the several systems installed onboard (Solar bus, stratio, ecomanager and tyres pressure sensors) as it was difficult to assess the impact of the other variables that influenced the results. Relevant events affected the measure impacts, such as the new bus drivers that joined the company and also several constraints related to the mobility conditions in Funchal, such as construction works and street closings in the city centre that caused congestion. Also, the fact of being installed in different type of buses, operating in different service conditions contributed to achieve different results.

According to the evaluation of the five mini electric buses, it was found that the verified impacts were much lower than expected, because the mini electric buses started the most intensive operation from October 2019, with an initial test period in September, and they worked in full until February 2020. Due to the COVID-19 situation, in March 2020 the service was reduced by 50%, being suspended in April. The operation was resumed in May and between May and September 2020 the service registered a small increase, although much lower than that observed in January and February in 2020.

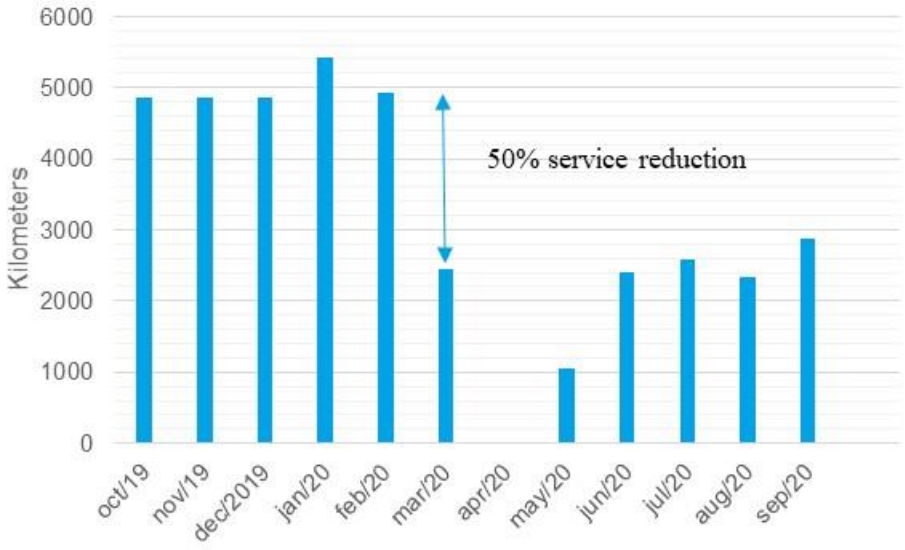

Figure 11: Monthly service of the five mini electric buses between October 2019 and September 2020

In addition, the PV system installed on two buses did not allow a full assessment due to the data between September and December 2019 not being monitored, because the Wi-Fi system of the two photovoltaic systems was not communicating correctly with the platform due to difficulties between network configurations and problems with the installed charge controllers. In January, a Solarbus technician was at Madeira, installed two new charge controllers and managed to configure the networks correctly, making it possible to download the data in real time once we have production data communication via GSM. It was decided to extend the evaluation period until September, since between March and May the buses circulated little, for bus 419 in particular, and there was thus a low PV production to which they would potentially have, if the service was not limited as it did during the COVID-19 confinement period. Based on

data between June and September, PV production was very similar to the production verified during the COVID-19 confinement period, perhaps relating to the reduction of bus services.

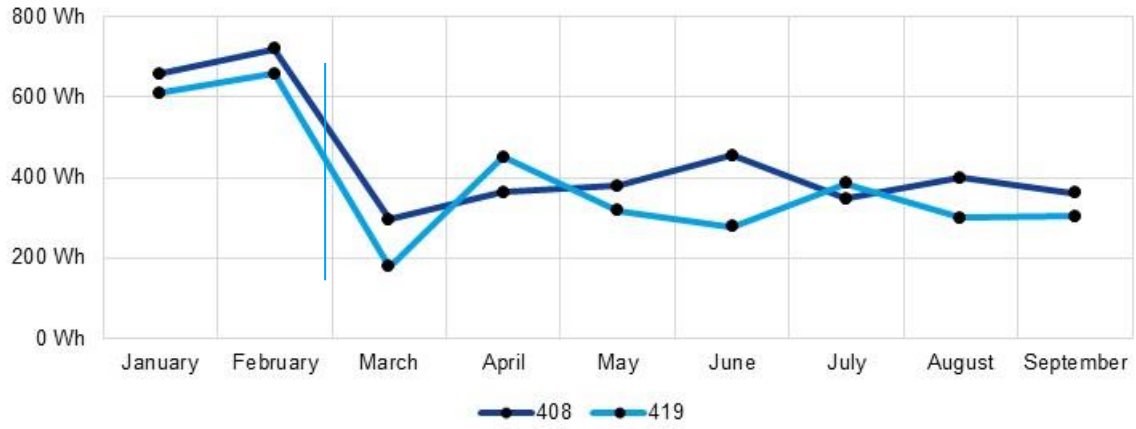

Figure 12: Daily average PV production for the buses 408 and 419 between January and September 2020

It was found that after May, from which the buses started to gradually increase its operation, the daily average PV production had only a minor increase. Comparing the monthly PV production with the distance travelled a slight decrease was verified for both buses.

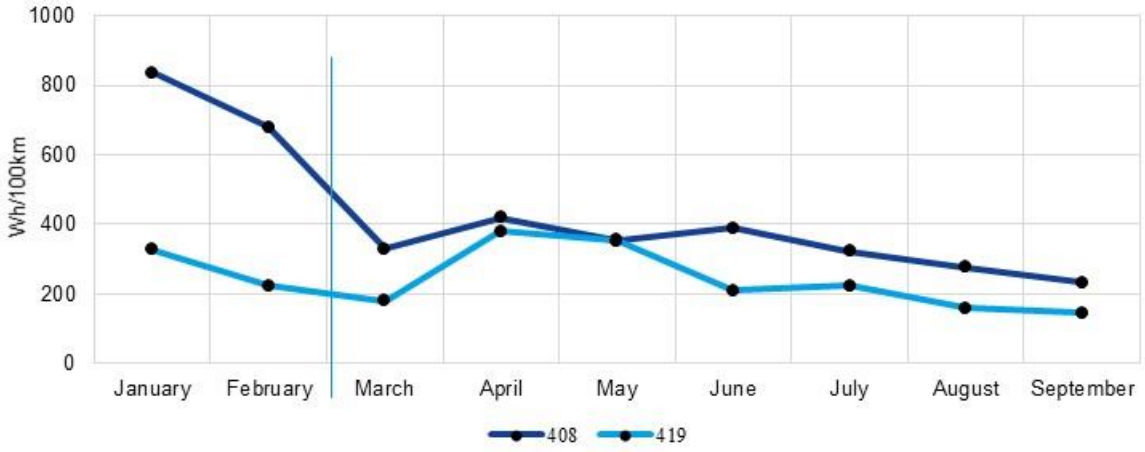

Figure 13: Monthly PV production by distance travelled [Wh/100km] for the buses 408 and 419 between January and September 2020

Overall, the best performing months, both in terms of total PV production and daily average production, were the months before the confinement period (January and February). On the other hand, after May, there was a decrease in production in relation to the distance travelled. Since there are many factors at play that influence this performance indicator, it is possible that changes in the frequency, travel routes or daily schedule in that period that may have affected the buses' roofs exposure to the sun and thus decreased the energy produced. Other possible reason for this decrease may have been a reduction in the buses' electricity consumption which also affects the measured PV production.

F2 Future activities relating to the measure

As a result, from the demonstration programs for electric or hybrid vehicles in public transport fleets performed by HF and AREAM, HF defined a fleet renovation strategy to achieve higher quality of service to the population. This resulted on the MUSA project, which is a project funded by the ERDF framework, in accordance with priority 4 of the Operational Program Madeira 14-20, supporting the transition to a low carbon economy.

The project consisted of the replacement of 35 standard PRE-EURO buses with five mini electric buses (already in operation in “Linha Eco Cidade” line since September 2019) and 30 EURO VI standard buses that arrived during 2020 and 2021, with greater energy efficiency.

This initiative is relevant for the environmental effect on energy saving and CO_2 emission, but also especially important because it increases the percentage of vehicles with access by wheelchair from 26,7% to 43,2%.

The renovation of the 35 buses is the first step towards a complete fleet renewal. On the coming years, HF plans to achieve a total of 129 renovated buses.

As a result of the positive impacts of the demonstration of the photovoltaic system, which is being evaluated in the demonstration report that is being developed, the conclusion of installing on more buses in the HF fleet, as well as defining the most adequate power (PV area), may be concluded best suited to the needs of the existing fleet, since the first analysis shows that part of the PV potential is not being used due to the power of the electrical equipment on board being about 30% of the installed PV power.