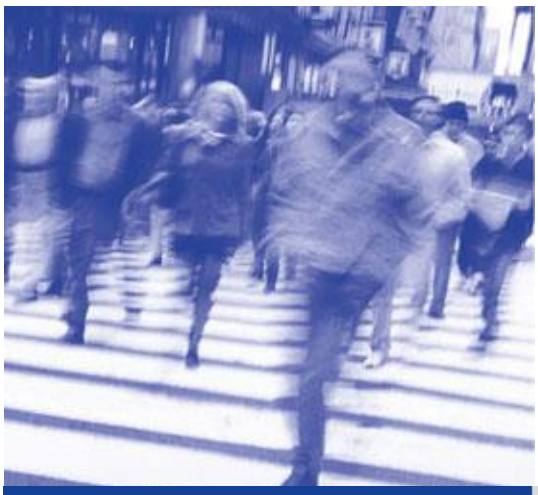

CiViTAS
Cleaner and better transport in cities

DYN@MO
AACHEN • GDYNIA • KOPRIVNICA • PALMA

P2.1 Implementation status report

CNG and biogas in municipal fleets in Palma

Deliverable No.:	D2.7
Project Acronym:	DYN@MO
Full Title:	
DYNamic citizens @ctive for sustainable MObility	
Grant Agreement No.:	MOVE/FP7/296057/DYN@MO
Workpackage/Measure No.:	WP2/ P2.1
Workpackage/ Measure Title:	
Innovative Clean and Energetic vehicle / CNG and biogas in municipal fleets	
Responsible Author(s):	
Carlos Martín, EMAYA	
Responsible Co-Author(s):	
Carles Petit, Eurolocal	
Date:	16 January 2017
Status:	Final
Dissemination level:	Public

CiViTAS
Cleaner and better transport in cities
DYN@MO

THE CIVITAS INITIATIVE IS CO-FINANCED BY THE EUROPEAN UNION

Abstract

This deliverable contains a description of the completed activities of the CIVITAS DYN@MO measure P2.1 “CNG and biogas in municipal fleets” that has been implemented in Palma de Mallorca. These activities have kicked off a long-term energy strategy within EMAYA, Palma’s municipal company responsible for water treatment and water distribution as well as for waste collection and street cleaning, which is also described in this document. During the DYN@MO project the use of CNG (compress natural gas) as a fuel for waste collection vehicles in Palma has become a reality. The first vehicles have been either acquired or converted from already existing diesel vehicles. Also, a CNG filling station has been built inside the EMAYA premises during the DYN@MO project, and it started operating using fossil CNG in the beginning of 2016. In the meantime, tests and accurate planning have been carried out in order to soon start producing high quality biogas from wastewater. This is actually the core of the clean energy strategy of EMAYA because it will make possible to reduce the external dependency on fuels thanks to the conversion of waste mud from Palma’s sewerage into a biofuel. In parallel, and under the umbrella of DYN@MO measure P2.2 “Electric vehicles in municipal fleets”, electric vehicles have also been introduced during DYN@MO for specific waste collection purposes (small vehicles that are very suitable for the old town type of streets).

Project Partners

Organization	Country	Abbreviation
Empresa Municipal d’Aigües i Clavegueram S.A.	ES	EMAYA

Document History

Date	Person	Action	Status	Diss. Level
23-07-2016	Carlos Martín	First draft version in Spanish	Draft	SC
23-11-2016	Carlos Martín	Complete draft version in Spanish	Draft	SC
30-11-2016	Carles Petit	Translation, final editing, language check and formatting	Final draft	TC
01-12-2016	Marcel Braun	Review and quality check	Final draft	SC
16-01-2017	Carlos Martín, Carles Petit	Preparation of final version	Final	PC

Status: Draft, Final, Approved, and Submitted (to European Commission).

Dissemination Level: PC = Project Coordinator, SC=Site Coordinator, TC=Technical Coordinator, EM=Evaluation Manager.

Table of Contents

List of Figures

1. INTRODUCTION

EMAYA is a municipal company owned by City of Palma and it is in charge of the water management (including catchment, purification, distribution, water supply and wastewater treatment) as well as the solid waste collection and street cleaning. The company joined the CIVITAS DYN@MO project in June 2013 in order to develop a new strategy towards a more efficient and clean transport system.

Within the DYN@MO project, EMAYA was the Measure Leader of measure P2.1 “Biogas and CNG in municipal fleets” which according to the Description of Work had the following objectives:

- Preparing the future introduction of CNG buses in the urban public transport fleet. The new buses will comply with the EEV standard.
- Evaluation of emissions and energy use of the 12 CNG buses that are already in operation
- Implement a biogas production plant at a municipal landfill site and make the biogas available for use in vehicles at a new biogas/ CNG filling station
- Purchase 8 new CNG trucks and convert 15 waste collection trucks running on diesel to CNG vehicles that will run on the locally produced biogas
- Trial of biogas in at least one of the CNG buses of the urban public transport fleet to determine the feasibility of large scale use of biogas in the bus fleet
- To reduce noise emissions and emissions of air pollutants (the data from the ex-ante evaluation will be verified with real measurements during the project):

  For the bus fleet:

  - Noise outside the CNG vehicle: 37% reduction compared to new diesel buses
  - Noise inside the CNG vehicle: 65% reduction compared to new diesel buses

  For the fleet of waste collection vehicles:

  - Noise outside the vehicles reduces from 80dB to 77dB
- To reduce annual emissions of pollutants compared to new diesel buses. Annual savings in tonnes when 50 new CNG buses are introduced (after CIVITAS):
  - 62,89 tonnes of CO
  - 6,04 tonnes of HC
  - 143,75 tonnes of NO_x
  - 1,94 tonnes of PM_{10}
- To reduce annual emissions of pollutants compared to current waste collection trucks. Annual savings in tons in project scenario (8 new trucks and 22 converted trucks):
  - 1,67 tonnes of CO
  - 0,52 tonnes of HC
  - 12,64 tonnes of NO_x

- 0,12 tonnes of PM_{10}

- To raise awareness about alternative fuels among citizens and other fleet operators

Before EMAYA joined the CIVITAS DYN@MO project, the company had developed a system in order to leverage the energy contained in the biogas generated during the purification of wastewater (anaerobic digestion), taking advantage of the existing synergies between the water cycle and energy. The availability of a considerably large amount of biogas (19,239 Nm^3/d) with a high energetic power and a relatively simple conversion process was the main driver of this system. The main objective was to optimize the energetic demand of the whole company, creating value from wastewater residues.

The need for energy in order to maintain at 37ºC the process of the anaerobic digestion of wastewater mud, initially drove the company to use the biogas in a cogeneration of thermal and electric energy. This energy has proved sufficient to cover both types of demands of the two wastewater treatment plants (EDAR number 1 and EDAR number 2). The unification of the mud treatment of both facilities took place in EDAR number 1, and it was possible due the construction of pipe of 10.3 km connecting both treatment plants.

Figure 1: Energy recovery installation at EMAYA EDAR 1

The processing of mud coming from both EDAR 1 and 2 allowed reaching the objective of compensating the energetic costs (thermal and electrical) of the purification activities while reducing the energetic surplus generated during peak hours.

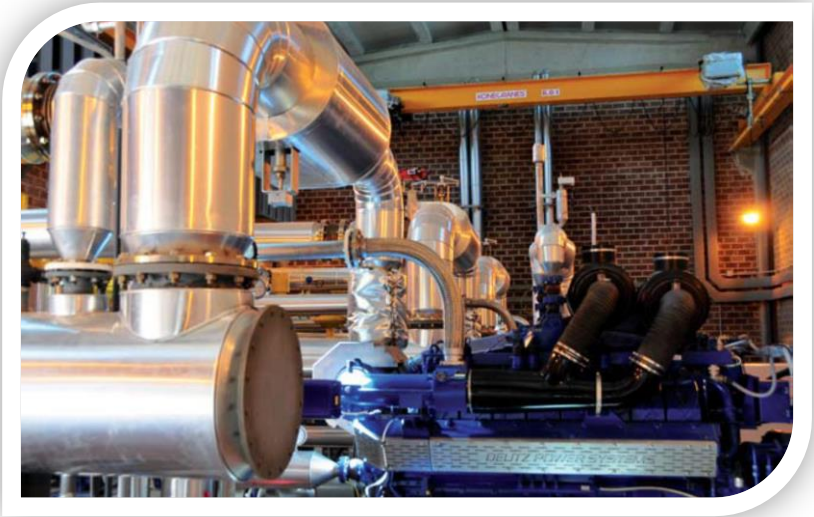

Figure 2: Energy recovery installation at EMAYA EDAR 1

Therefore, while electric production surplus was sold to the electricity network operated by REE (Red Eléctrica de España), thermal surplus was used to dehydrate wastewater mud and reduce the consumption of reactives and increase the dryness of the biosolids.

In 2010 the bus fleet of EMT, the municipal public transport operator, consisted of 201 buses, of which 150 were EURO 2, 11 were EURO4 and 40 were EURO5. During 2010, 12 new CNG buses were tested to prepare a future large-scale introduction of CNG vehicles. The evaluation of this testing phase was co-funded by the CIVITAS CATALIST project. The cost-benefit analysis performed during this evaluation predicted a favourable situation for the introduction of CNG vehicles in Palma's bus fleet. The future 50 new CNG buses would replace 50 existing EURO2 buses.

In 2010, a new pipeline for CNG from the Spanish mainland to Mallorca was finalised. The pipeline already comes close to EMT's premises. For the current fleet of 12 CNG vehicles, the buses use the filling station of the gas company.

During CIVITAS DYN@MO a CNG filling station has been built at the municipal premises of EMAYA and eight new CNG vehicles have been acquired for waste collection. The implementation of CNG buses didn't occur at EMT as originally planned due to lack of funding. However, the 12 CNG buses still operate and now fuel at EMAYA's station.

The following document describes the steps undertaken by EMAYA in order to move towards a locally produced biogas powered vehicle fleet in Palma. The potential of EMAYA's gas strategy can contribute to the future upscaling of CNG buses in the local public bus fleet, which will be modernised extensively in the next years.

2. BIOGAS STRATEGY

2.1. BIOGAS DEVELOPMENTS IN DYN@MO

As mentioned in the introduction, the energy strategies implemented before CIVITAS DYN@MO led to the construction of a biogas production unit at EDAR 1, which also processes mud from EDAR 2 thanks to a newly built pipeline. The system incorporates tanks for biogas storage, in order to separate biogas production (digestors) from combustion at the generators.

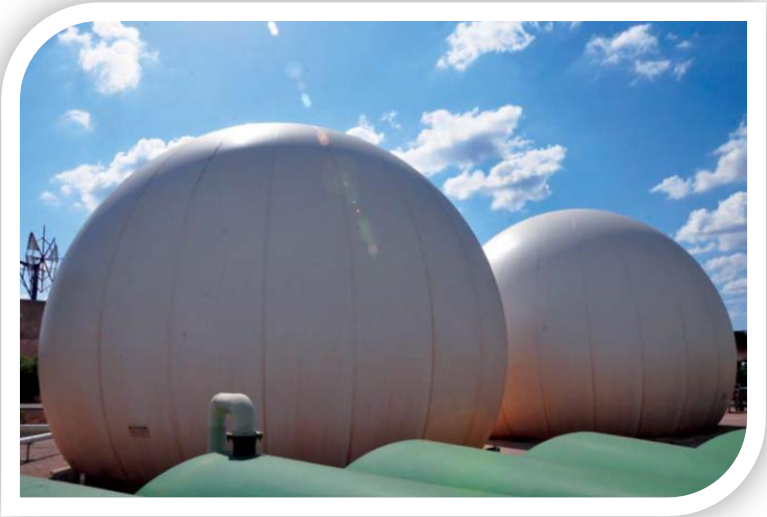

Figure 3: Biogas installations at EMAYA

During the first years of the project the company has performed the recovery system and fine-tuned its mechanisms. Many trials have been made in order to collect data and be able to improve biogas quality and production efficiency. The influence of seasonal changes/patterns, in terms of climate (temperature, humidity, etc.) and waste water characteristics (volume, content, etc.), has been taken into account in ordinary management as well as in planning of system improvements.

With the relatively short experience, EMAYA obtained 5,171,860 Nm^3/h of biogas in 2015. The average concentration of CH4 was approximately 62% of the volume. The low calorific value (PCI in Spanish) was around 5,362 $Kcal/Nm^3$, which according to national standard UNE EN 6976/05 is equivalent to 6,24 kWh/Nm^3 of biogas. This represents an estimate of 31,000 MWh/year of recovered energy.

This energy has been used to produce electricity and heat in order to retrofit the whole water treatment process at EDAR 1 (100% retrofitted nowadays). With the energy recovered from wastewater mud the company has reached annual savings over 1.2M€ in electricity and fossil fuels. Moreover, the excess in electricity production at EDAR 1 transformed the plant from electricity consumer to producer. This little “power plant” has generated over 82,000€ in revenues per year by exporting electricity to the general grid.

At the same time, the ecological footprint has been dramatically reduced by using existing methane instead of fossil fuels (most of the electricity in Palma comes from fossil fuelled power plants, coal and natural gas) in order to feed the plants' demands and feed renewable electricity into the grid.

Figure 4: Electricity generation installations at EMAYA

2.2. EMAYA'S GLOBAL ENERGY STRATEGY 2013-2020

Besides the actual production of biogas at EDAR 1, which amounts to 31,000 MWh/year, there are other potential sources for biogas production in Palma. However, improvements on the water treatment and biogas transformation processes are estimated to bring an additional 9,000 MWh/year. The company is implementing them at a gradual pace, by separating and optimizing the phases of the mud digestion process.

The main existing biogas source is a shut down dumping site at Son Reus that nowadays has no use and releases gases into the atmosphere. The recovery of methane and other gases at this site has an estimate of 16,000 MWh/year of energy potential.

The largest local source for biogas production is unfortunately not available yet in Palma as the organic fraction of the solid waste is not collected separately from households or business. For this reason the recovery of biogas is more complicated and less efficient. However, it is estimated that the digestion of sub-products from waste (separating the organic matter) would bring around 75,000 MWh/year. Many municipalities in Mallorca already have a separate collection scheme at the source, both for the organic fraction (using door to door and/or specific containers) and other types of waste materials. This means that for most of the population in Palma the separation of the organic fraction in their kitchen waste is already common (even usual for those who have a second residence or relatives outside the city). The option of implementing a source separation of organic waste at city level is feasible but at the

moment it is postponed and it is not included in any planning documents (though it would involve a higher production potential).

Having considered and analysed other existing sources of biogas (all of them from solid waste or wastewater), EMAYA has estimated that the potential for the municipality of Palma is to be able to produce 131,000 MWh/year from recovered biogas.

EMAYA foresees a global energy strategy based on a number of actions that would lead first to achieve almost 100% self-sufficiency and, second, to export (sell) larger amounts of energy to other consumers.

Locally produced biogas could have three different main uses at EMAYA:

- Electricity production in order to cover the demands of the company, with a clear goal to achieve 100% of self-sufficiency, or 44,000 MWh/year.
- Production of compressed biogas to supply the vehicle fleet, which leads to a strategy of fleet renovation and/or adaptation. A realistic estimate considering the speed of such a process is a consumption of 25,000 MWh/year only by EMAYA gas powered vehicles in 2020.
- Cogeneration and heat production, which is mainly used at the biogas digestion process and accounts for 17,000 MWh/year.

Therefore the company's energy demand that can be covered by using locally produced biogas can reach 86,000 MWh/year. This represents an energy excess of 45,000 MWh/year which could be sold as electricity and compressed gas (transportation). Depending on the energy market prices (heavily affected by taxation and variability at the global scale), EMAYA would also have the capacity to acquire electricity or natural gas from the conventional sources and sell more bio-energy externally in case this would be more profitable. This strategy is clearly leading EMAYA towards self-sufficiency (potential energy surplus of 52%) and renewability of energy sources.

In this respect, the potential excess of 45,000 MWh/year becomes a unique opportunity for the city's public bus fleet. The great economic and environmental benefits of substituting diesel by first using fossil CNG and later using locally produced CGB in Palma's public transport are being considered at the planning of the next bus fleet renovation (around 2019). The satisfactory experience in performance, consumption, emissions and noise of the 12 CNG buses in EMT Palma since 2010 provides a better acceptance of this technology at the company. The use of EMAYA's gas filling station since 2016 is somehow consolidating the idea of city level collaboration to reduce the footprint of city transport services.

Even though the additional investments for acquisition technology and vehicles can be balanced out via savings in consumption costs during the lifespan of the vehicles (not to mention the savings in external costs), the impossibility to finance the purchases with own funds (both at EMAYA and EMT) will require a city level decision and therefore sufficient political support towards the biogas strategy.

Moving towards biogas is a significant milestone for the city of Palma considering the island condition and the need to develop resilience mechanisms. Moreover, it is also a

success in urban sustainability which could/should be emphasized at the tourist marketing strategies. And ultimately, it will help achieving “climate action” targets in terms of emission reductions.

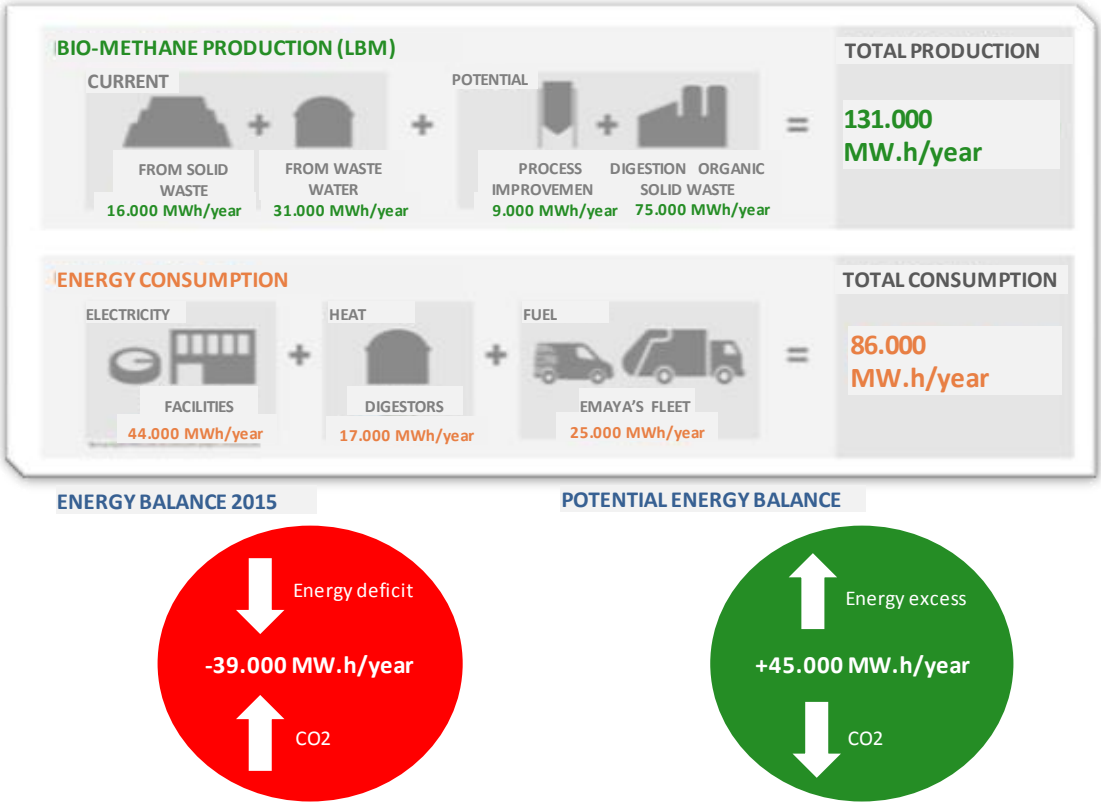

Figure 5: Diagram analysing energy production potential and energy consumption at EMAYA

The previous long-term gas strategy relies on three key investments:

- biogas treatment technologies to be able to supply the CNG vehicle fleets
- progressive renovation of heavy vehicle fleets shifting from diesel to CNG
- new waste management technologies and processes that would enable to increase energy recovery from waste (from current 47,000 MWh/year to 131,000 MWh/year)

If the two first types of investment occur and these actions are implemented, EMAYA could run its entire fleet on renewable locally produced energy (demand of 25,000 MWh/year) while still providing 22,000 MWh/year to power its own facilities. The existing gap of 39,000 MWh/year in electricity and heat for the company’s facilities can already be covered with external non 100% renewable supply (e-grid), but the development of solar technologies at EMAYA (another energy strategy) will gradually increase the company’s self-sufficiency and use of renewable energy. The company already produces 100 kWh with photovoltaic panels at the gas/electric filling station in Son Pacs. This capacity will be extended to 700kWh over the next few years and solar heating is already studied to cover the water treatment and biogas production facility at EDAR 1. The external subsidy schemes and co-funding opportunities in the solar sector are a clear driver for the implementation of both photovoltaic and solar heat

panels, allowing to achieve full self-sufficiency with renewable energies at company level without the need to increase the energy recovery from solid waste.

The following chapters describe the activities related to CNG vehicles and the CNG filling station that have been done by EMAYA within the CIVITAS DYN@MO project. The findings of the undertaken analysis of the biogas treatment technologies that are required for supplying biomethane to the CNG vehicle fleet are also included.

3. DESCRIPTION OF CIVITAS DYN@MO ACTIVITIES

3.1. CONVERSION OF DIESEL VEHICLES TO BIOGAS, CNG & DIESEL VEHICLES

The process of converting a vehicle from using diesel to using gas consists of installing a kit of elements inside the fuel mixing device that allows the entry of gas into the intake system so that, when the engine sucks, it enters with the air. The ignition of the mixture is produced by the diesel, while the filling of the cylinder is produced by the diesel plus the aspirated gas. Therefore, it allows a vehicle powered by a diesel cycle engine to operate in dual mode, using CNG/ CBG (compressed biogas), without modifying the basic structure of its main components, accessories, regulations or set-up. In addition, as it continues to run on gas oil, the pump and injectors continue to operate in a way that keeps them lubricated and the engine does not deteriorate due to the use of the system.

The adaptation is external, without modification of the engine, achieving a quick and efficient start-up. When generating energy with the dual system, there is a reduction in operational costs of around 35%, using CNG acquired at the market in low quantities. This provides operational independence as it allows to take advantage of the existing engine or diesel equipment when used in conjunction with CNG/ CBG. In case there is a shortage in gas, the engine can run exclusively on diesel, as originally acquired from the manufacturer.

Other advantages of the conversion to the dual system are that the temperatures are lower inside the engine and in the exhaust gas, due to the higher proportion of gas instead of diesel at full speed. In addition, because the combustion is cleaner, the duration of the engine is increases from 10% to 15%, as well as the life of other preventive maintenance components.

The conversion increases the nominal power of the engine by the difference of calories and octanes between the diesel only and the diesel with CNG/ CBG contribution. The increase of the power of the motors is approximately 10%.

During CIVITAS DYN@MO EMAYA has converted its first two vehicles dual diesel & CNG/ CBG (clean, enriched and compressed biogas). These are heavy duty vehicles with three axes used in waste collection (Renault Premium 26t and Scania). A third vehicle (van) running on gasoline has been converted to using CNG only. The three vehicles have been homologated and have been performing satisfactorily at EMAYA's waste collection routines around the city of Palma since 2015.

Figure 6: First dual vehicles at EMAYA (diesel & CNG).

Figure 7: First converted van at EMAYA (from gasoline to CNG).

One of the objectives of measure P2.1 was to convert 15 waste collection trucks running on diesel to CNG vehicles that will run on the locally produced biogas. More precisely, EMAYA planned the conversion for its heavy vehicles with a load capacity of 26T and three axes. The local elections process of June 2015 and the change in the City Council's office delayed the conversion process. A tender for fifteen conversions was launched in November 2015 and works began in spring 2016. However, the contracted company had delays due to internal restructuring and the need to incorporate new vehicle components due to piece manufacturers' closing.

The first two conversions have been finalized in September 2016 and two more trucks a month later. These are all Renault Premium 26t trucks, similar to one of the first transformations of 2015. The result has been satisfactory in terms of performance during the vehicle tests at the depot. However, administrative barriers have delayed the homologation of these vehicles by the competent authorities (IDIADA). The closing of the gas tank manufacturer led to find and install a different tank. The new support structure for this tank, as it is a safety related component, had to be tested extensively by the authorities prior to grant the homologation permits that allow the operation of the vehicles in public roads. In November 2016 three vehicles were homologized while the remaining one is likely to be ready in December 2016.

These three vehicles have started operating in CNG mode and the result has been favourable, like of the other three previously transformed vehicles. Now EMAYA has six transformed vehicles operating in Palma's streets, running almost 100% CNG filled at the company's premises.

The pending eleven transformations include another Renault Premium truck and ten IVECO trucks with similar characteristics. The work has restarted in late November 2016 after the final approval by the industry authorities has been received and the recently transformed vehicles have started operating on 100% CNG. The remaining transformations are expected to be finalized before the end of April 2017, reaching a total of 18 transformed vehicles at EMAYA as planned in CIVITAS DYN@MO.

The following figures explain the type of vehicles that have been/ are being converted from diesel to CNG at EMAYA.

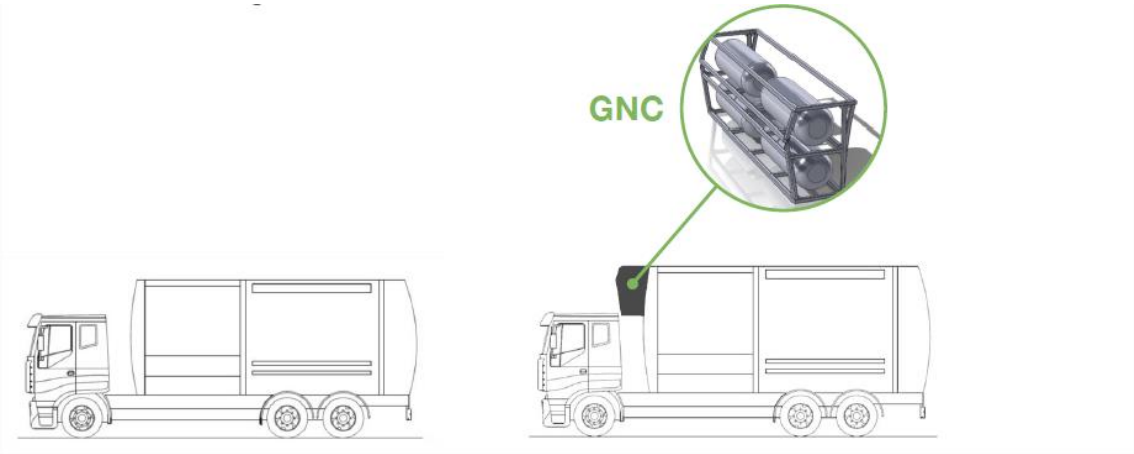

Figure 8: Gas tank location at the converted vehicles.

Figure 9: Selected vehicles to be converted from diesel to CNG at EMAYA.

The following table summarizes the later conversion of vehicles at EMAYA:

Nº vehicle	Manufacturer	Model	Engine	Year registration	Team
V571	RENAULT	PREMIUM 320.26	D-DXI 7 320-ECO6B	29/12/2008	ROS ROCA-FARID // FMO 25
V572	RENAULT	PREMIUM 320.26	D-DXI 7 320-ECO6B	29/12/2008	ROS ROCA-FARID // FMO 25
V573	RENAULT	PREMIUM 320.26	D-DXI 7 320-ECO6B	29/12/2008	ROS ROCA-FARID // FMO 25
V594	RENAULT	PREMIUM 320.26	D-DXI 7 320-ECO6B	04/12/2009	ROS ROCA-FARID // FMO 25
V595	RENAULT	PREMIUM 320.26	D-DXI 7 320-ECO6B	04/12/2009	ROS ROCA-FARID // FMO 25
V639	IVECO	ADS260S36Y/PS	D-F2BE3681A*U	19/09/2011	AMS // CL1
V640	IVECO	ADS260S36Y/PS	D-F2BE3681A*U	19/09/2011	AMS // CL1
V676	IVECO	ADS260SY/PS	F2CFE611B*C	09/07/2014	ROS ROCA-FARID // FMO-26
V677	IVECO	ADS260SY/PS	F2CFE611B*C	09/07/2014	ROS ROCA-FARID // FMO-26
V678	IVECO	ADS260SY/PS	F2CFE611B*C	09/01/2015	ROS ROCA-FARID // FMO-26
V679	IVECO	ADS260SY/PS	F2CFE611B*C	09/01/2015	ROS ROCA-FARID // FMO-26
V685	IVECO	ADS260SY/PS	F2CFE611B*C	06/05/2015	SITA-MAZZOCCHIA // ECOLATB726
V686	IVECO	ADS260SY/PS	F2CFE611B*C	06/05/2015	SITA-MAZZOCCHIA // ECOLATB726
V687	IVECO	ADS260SY/PS	F2CFE611B*C	06/05/2015	SITA-MAZZOCCHIA // ECOLATB726
V688	IVECO	ADS260SY/PS	F2CFE611B*C	06/05/2015	SITA-MAZZOCCHIA // ECOLATB726

Figure 10: Converted vehicles at EMAYA in 2016 (from diesel to CNG).

3.2. CHANGES IN THE COMPANY'S FLEET

Before CIVITAS DYN@MO started, EMAYA's fleet consisted of 550 vehicles with an average fleet age of ten years. The entire fleet was powered with conventional fossil fuels (diesel and gasoline).

With the participation in CIVITAS DIN@MO, EMAYA developed a new vehicle strategy. The main objectives were:

- A fleet renewal in favour of more efficient and less polluting technologies that aim at reducing particulate matter and other pollutants on behalf of human health at the urban environment.
- The reduction of the average age of the fleet which leads to lower operating costs, with savings in the areas of preventive and corrective maintenance.
- The trial of several propulsion technologies in order to achieve the initial target as well as further savings in energy and monetary costs.

The intense studies and acquisition of information carried out at EMAYA over the past years have led to establish a new strategy of vehicle diversification, taking into account all propulsion options suitable for each type of vehicle (depending on the final use). The goals for 2020 are summarized:

- To provide the necessary equipment for filling CNG/CBG vehicles and charging electric vehicles.
- To shift all light vehicles from conventional fuels to CNG/CBG or electric.
- To gradually shift heavy vehicles from diesel to gas.

The strategy contemplates both the acquisition of new CNG, hybrid and full electric vehicles of several types (depending on their function), as well as the conversion and dualization of the heavy duty vehicles (more expensive, also more consumption) with still a useful lifespan. In the future, biogas produced at EDAR1 will be delivered to the Son Pacs depot through virtual pipelines (trucks). A transfer station of biomethane will be installed at the existing gas station at the Son Pacs depot in order to finally fuel the fleet with recovered energy from waste.

There are eight new CNG trucks at EMAYA since the project started (all purchased during 2014 and 2015, though five arrived in the first half of 2016). Documents for a new tender of three more CNG trucks are being prepared and expected to be ready by February 2017.

The eight CNG vehicles acquired by EMAYA for waste collection during CIVITAS DYN@MO are:

- Two bilateral waste collection CNG trucks of 18T/13m^3 capacity and two axes which arrived in 2014. Manufacturer MEBASA (IVECO+Nord). Their power is 200kW/ 272 HP, and each truck cost over 270,000€.

Figure 11: First two CNG trucks at EMAYA.

- One lateral waste collection CNG truck of 26T/25m^3 capacity and three axes which also arrived in 2014. Manufacturer MEBASA (IVECO+Nord). The power is 243kW/ 330 HP, and the truck cost 241,000€. A purchase option for a second truck was established within the contract, and since the first one performed well, a second one was ordered and arrived at the company at the beginning of 2016.

Figure 12: First CNG three axes truck with side collector at EMAYA.

- Three medium sized CNG trucks of 7T/20m^3 and 9T/23m^3 capacity and two axes were bought in 2015 but arrived during the first half of 2016. They have a dumping tank on top. Manufacturer MEBASA (IVECO+Nord). These trucks cost 60,000€ each.

Figure 13: New medium sized CNG trucks with dumping tank at EMAYA.

- A CNG truck with high pressure water impulsion and void suction, of 26T and three axes arrived also in 2016. Manufacturer SVAT. This CNG truck is unique in Spain for its functionalities, designed to clean sewers and ditches.

Figure 14: New CNG truck with high pressure water impulsion and void suction at EMAYA.

By 2015 the number of vehicles had been reduced (retirement of vehicles) and together with the new acquisitions the average age of the fleet dropped to nine years.

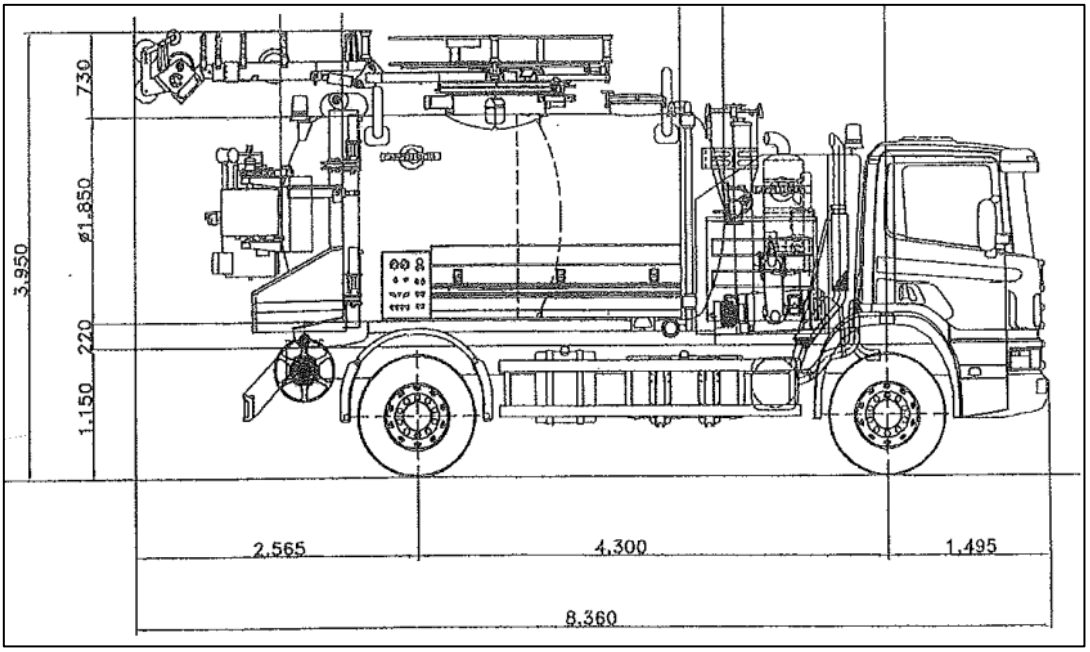

Figure 15: Dimensions of the CNG truck with high pressure water impulsion and void suction.

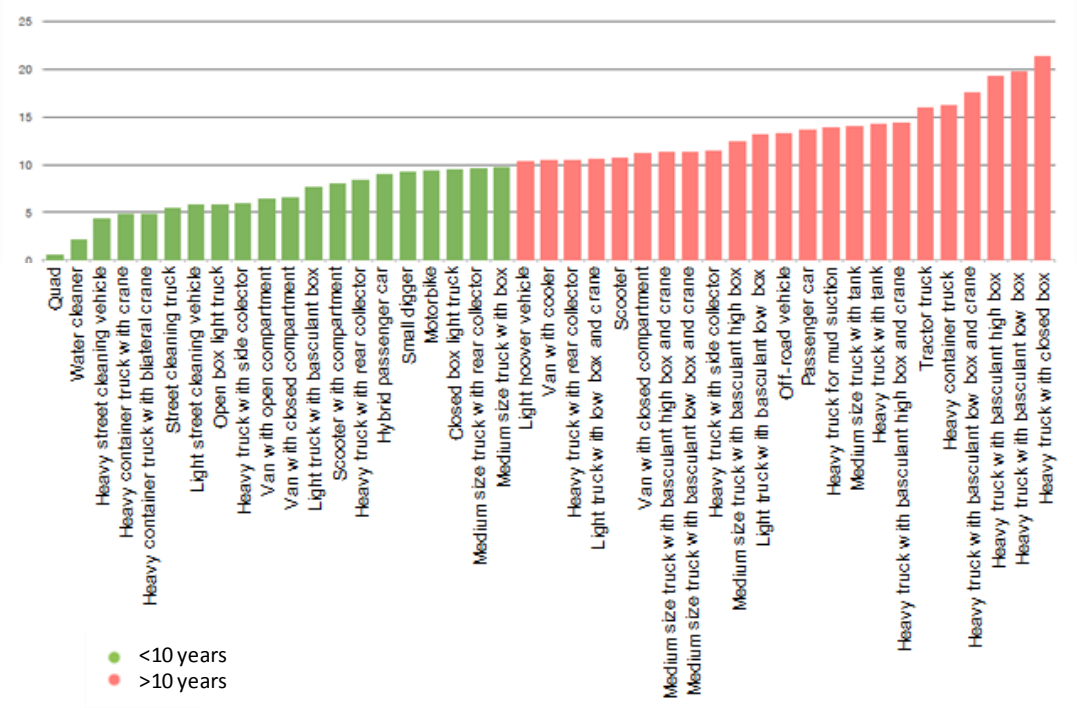

Figure 16: Age of EMAYA's vehicles per types, 2015.

Type of vehicle	Units	Operation 2015 in km (or hours)
Light street cleaning vehicles	51	50512 (hours)
Heavy street cleaning vehicles	18	20875 (hours)
Light trucks	57	645.697
Medium sized trucks	29	564.575
Heavy trucks	92	1.874.726
Large vans	29	262.396
Light vans	121	1.260.381
Motorbikes and scooters	36	89.580
Light trailers	22	0
Off-road vehicles	5	237.754
Passenger cars	57	413.803
TOTAL	**517**	**5.443.807**

Figure 17: Number of vehicles and use per type, 2015.

The introduction of CNG vehicles in the company led to a series of capacity building courses among employees, mainly drivers and maintenance staff. The following figure summarizes the training programme at EMAYA during 2014 and 2015.

Course	Students	Date
Training course (CNG)	6	October, 2014
CNG engine course	16	March, 2015
Course of use, maintenance, and repair assurances collection box	6	April, 2015

Figure 18: GNC courses and students (2014 – 2015).

The EMAYA advances in the electric propulsion are better described within the reports from CIVITAS DYN@MO measures P2.2 and P2.3 available (soon) from www.civitas.eu/P2.2 and www.civitas.eu/P2.3. In these measures, a total of five full electric light vehicles and one hybrid heavy vehicle have been implemented during the project within EMAYA's fleet.

Figure 19: First full electric vehicles at EMAYA, 2015.

Figure 20: First hybrid truck at EMAYA, 2015.

Figure 21: First three full electric mini-trucks for waste collection at EMAYA, 2016.

The hybrid vehicle is performing with 30% fuel savings, and investigations on CNG hybrid vehicles began in 2016. However, at this point, no vehicles on the market have been found yet.

In parallel, EMAYA has successfully installed 20 charging points at its premises, 14 for municipal vehicles (including the five full electric at EMAYA's fleet and vehicles from other City departments) and six open to the general public.

Moreover, the company has installed photovoltaic panels at the roof of the depot and feeds the EV chargers with renewable energy. Currently, 100 kWh are produced with these panels, and it is foreseen to increment the number of panels to reach a 700 kWh production capacity. Studies in using the electricity for other purposes than EV charging or own buildings power supply are being carried out, in particular in the field of wastewater treatment.

Figure 22: Photovoltaic installation connected to EV charging station at EMAYA depot, January 2016

Electric vehicles are expected to grow in numbers concerning the light vehicle part of the fleet, though the main priority of EMAYA in terms of fleet renovation is to move towards CNG or CBG at a larger scale in heavy vehicles.

3.3. PURIFICATION OF BIOGAS FROM WASTEWATER PLANT FOR VEHICLE FUELLING

The biogas purification project will be executed at EDAR 1 by means of “upgrading” techniques (biogas cleaning) and a subsequent stage of compression at 200 bar pressure. The collection trucks and sewers of the city are transporting the future fuel for EMAYA’s fleet but first the quality of the already obtained biogas must be improved in order to guarantee a proper combustion and avoid unnecessary damage to the vehicle engines. The loop will then be closed.

The objectives of this measure are:

- Production of fuel from locally available and renewable resources.
- Reduction of external energy dependence of the company.
- Minimization of operative costs.
- Improvement of the environment due to the reduction of the consumption of more polluting fossil fuels.

The technology for the conversions of the “dirty” biogas in BGC (clean and enriched) is formed by different modules that interact with each other to guarantee that the gas has the desired conditions. These modules are, in turn, the different stages exiting in the current technology, and are described below:

- Pre-treatment or cleaning/ conditioning of the biogas: its purpose is to condition the biogas for its entry into the enrichment process. In this stage undesirable compounds such as siloxanes, moisture and particles are eliminated or removed.
- Enrichment/ concentration: it consists of washing biogas to eliminate from this stream up to 98% of the CO_2 contained in it, as well as the hydrogen sulfide (H_2S) that can be in biogas. As a result of the process, a CH_4 enriched gas is obtained, with characteristics similar to those of natural gas, and even higher in CH_4 concentration. O_2 obtained from the process can be compressed for other uses (filling fire extinguishers, dry ice production, petrochemical, etc.)
- Gas drying: its purpose is to guarantee a dry gas for its compression and storage. For this, both moisture filters and adsorption beds (with substances with high moisture adsorption capacity) are used.
- Compression and storage: once the biogas is concentrated and dry it is sent to the compression station where it is compressed to values close to 250 bars. This pressure is kept at the storage tank were the gas remains until it is inserted in the vehicles. This tank allows direct distribution (via pipelines) and can feed mobile deposits (in trucks) for distribution to different independent stations.

This measure has been elaborated in 2016 and at the moment EMAYA is trying to find enough funding to implement it at EDAR 1. In the meantime, several technology providers are being analysed.

Having considered the particularities of the measure and given the dimensions of the plant in question, it has been decided that the enrichment of biogas to biomethane must comply with the following premises:

- It has to allow the increase of treatment capacity in a simple manner, that is to say a modular and expandable system.
- The purge gas containing residues of methane must be conducted for combustion, thus avoiding the emissions of residual CH_4 and recovering at a 100% rate the treated methane.
- The process has to be clean and without impact on the environment, without water or chemicals consumption.
- The system must have minimal maintenance needs, with a reduced amount of moving parts.
- Minimization of consumables (active carbon) in the pre-treatment stage.
- Minimization of energy consumption per kWh/ m^3 of treated biogas.
- Methane recovery rates >97.5%.

- The cleaning and enrichment system must have flexibility to adapt to changes in the flow and composition of the biogas to be treated.
- The start and stop of the installation must be able to be carried out in short periods of time.
- The system must be able to regulate the desired purity of biogas.

The following table shows energy efficiency parameters of the different purification techniques as well as a qualitative comparison of the costs of investment, maintenance and operation of the purification installations according to the EMAYA findings on the technique used for the removal of the CO_2.

Technique	Purity limit (%)	Availability (%)	Methane (CH4) losses (%)	Energy Consumption (kWh/m3 biogas)
Water absorption	97-99	95-96	0,5-3	0,20 – 0,40
Organic physic absorption	>96	96-98	01/04/16	0,23 – 0,51
Chemical absorption	>99	96-98	<0,5	0,26 – 0,60
PSA	>96	94	1 – 5	0,20 – 0,35
Membrane	>95	95-96	>5	0,20 – 0,40
Cryogenia	>99	-	<1	0,18 – 0,33

Figure 23: Efficiency results of different biogas purification techniques.
Source: University of Zaragoza.

Technique	Investment cost	Operational and maintenance costs	Chemical products cost
Water absorption	2	1,5	0
Organic physic absorption	2	2	2
Chemical absorption	2	2,5	1
PSA	2,5	2,5	2
Membrane	1,5	1,5	0
Cryogenia	3	2	0

Grading scale:
0- Zero cost 1-Low cost 2-Medium cost 3-High cost

Figure 24: Qualitative cost comparison between biogas purification techniques.
Source: University of Zaragoza.

The size of the first plant is designed for a flow rate of 200 Nm^3/ h. This plant will be able to produce approximately 1,200,000 Nm^3/ year of biomethane [11,000 MWh/ year], equivalent to approximately 1,000,000 litres of diesel.

The estimated availability of the plant is 96% and the estimated supply capacity is about 30 trucks per hour. The investment costs are estimated to be about:

- 0.9M€ for the pre-conditioning equipment.
- 1M€ for the enrichment system.

- 0.25M€ for the compression system of biomethane.
- 0.15M€ for the virtual pipeline storage system (truck) with a storage capacity of 18,240 litres (5,600 m^3 at 15ºC), including chassis and transfer frame built into the chassis, for injection in a natural gas transfer station.

The 2.3M€ envisaged for the production of CBG at EMAYA will require the allocation of funding from the city budget. In order to demonstrate the viability of the project to the decision makers, EMAYA wants to participate in the Smart Green Gas project (http://www.seat.com/corporate/news/corporate/smart-green-gas-project.html) currently developed by two large companies: the vehicle manufacturer SEAT and the water services provider Aqualia (FCC Group). These multinationals are demonstrating the same process that EMAYA aims at implementing, covering transformation of wastewater mud into biomethane, purification and enrichment of the gas to finally supply it to CNG vehicles. The pilot site is a large wastewater treatment facility in Jerez de la Frontera (Cádiz), and the test vehicles are two SEAT Leon TGI. EMAYA aims at exchanging information on biogas processes with Aqualia and, more importantly, at acquiring biogas in order to supply it to its own CNG fleet. A virtual biomethane pipeline would bring the gas to the island and EMAYA could test and disseminate the results in order to gain attention and raise interest.

3.4. GAS FILLING STATION WITH NATURAL GAS SUPPLY

Prior to the start of the CIVITAS DYN@MO project, the whole EMAYA fleet was powered by conventional fossil fuels (diesel + ADBLUE). The intensive study of operating and investment costs carried out for six months in 2013 showed relevant results for the company. According to the study, an annual reduction of around 925,000€ of operating costs for EMAYA was estimated, considering a scenario in which 100% of the fleet was converted to CNG/CBG or electric. The study highlighted as well the reduction of polluting emissions (NO_x, PM, CO_2, HC, C0).

Figure 25: Poster with the results of the gas study at EMAYA.

Thanks to this study a high-efficiency gas filling station was projected. The installation should have a connection to the 59 bar natural gas grid in order to minimize long term fuel price and maximize capacity, as well as an intake to discharge 3 bar natural gas from tank trucks in order to guarantee supply. The connection to the primary grid should allow a capacity of up to 25GWh/ year.

The planned filling station was to incorporate a storage buffer of 18,750 litres that enables fast loads within four minutes. Its supply capacity can feed 30 vehicles with 80 kg of gas at 200 bar in one hour.

The construction of the gas filling station took place mainly during 2015, and in February 2016 most of the installation was finalized and first trials began. In spring 2016 staff was trained and maintenance and emergency plans were set up. EMAYA also took the launch of the new gas filling station as an opportunity to introduce a new corporate image in all vehicles, website and existing channels.

Figure 26: Building the new gas filling station at EMAYA's premises in Son Pacs.

EMAYA's gas filling station has a double intake of 3 bar and 59 bar of natural gas from the distribution network operated by the company REDEXIS. This double connection increases the reliability of supply, two compressors have been installed that raise the pressure up to 300 bar. Thanks to these compressors the natural gas is stored in the storage buffer to enable the feed 80 kg of 200 bar pressured gas to 30 trucks, in just one hour. The storage capacity of the buffer is 4,972 Nm^3, and it has the possibility of feeding six trucks at the same time, since it has three CNG dispensers with double

NGV2 cargo nozzles, with a capacity to deliver 80 kg in four minutes per truck. The 59 bar compressor improves the compression efficiency by around 65%. Since the pressure gap to be compressed is lower (from 59 bar to 300 bar), this represents a competitive advantage over the rest of the market because compression costs are reduced by around 1.20 €/ MWh approximately, with respect to the current raw material cost referenced on the Iberian gas market (www.mibgas.es). All and all, it represents a reduction of 9% of the cost for the raw material.

	22/06/16	21/06/16
National Gas Price Index MIBGAS-ES (€/MWh)	15,05	14,92
National Gas Volume (MW h)	26,515	14,987

PVB-ES: Negotiated prices	23/06/16	24/06/16	25/06/16	26/06/16
Daily reference price	15,04 €			
Daily bid price	15,04 €	15,04 €	15,00 €	15,00 €
Last daily price	15,04 €			
Maximum daily price	15,04 €			
Minimum daily price	15,04 €			
Price variation	5,33 €			
Total daily volume (sales)	6.740			

Figure 27: Market results of gas prices for vehicles in Spain, June 2016.

The gas filling station performs well but at the moment it has only been able to compress gas brought by trucks. The connection to the 59 bar grid has been delayed for a number of reasons, including property related issues in the pipeline pathway to EMAYA's depot at Son Pacs. The construction works have been completely finalized in November 2016. The gas counters are being installed and the definitive connection with the grid will be fully operative by March 2017.

The compressed CNG at EMAYA's filling station is supplied to the eight CNG vehicles of the company's fleet, as well as to other CNG vehicles in the city. Among them there are a few taxis and 12 public CNG buses from the municipal public transport company (EMT). The approximate filling time for a CNG bus is five minutes for a full load. This means that the station has sufficient capacity to allow a broader extension of CNG vehicles both at waste collection (EMAYA) and public transport (EMT) municipal fleets. The following figure shows the quantities of gas and energy served at EMAYA's filling station since the start of operations in late May 2016.

Time frame	Biled kWh	Cosumed CNG kg
29/05/2016 – 30/06/2016	64,124.30	4,052.32
01/07/2016 – 31/06/2016	110,055.52	7,495.52

Figure 28: Consumption of filling station EMAYA.

The following drawings and pictures show EMAYA's filling station, including the new corporate image of the company.

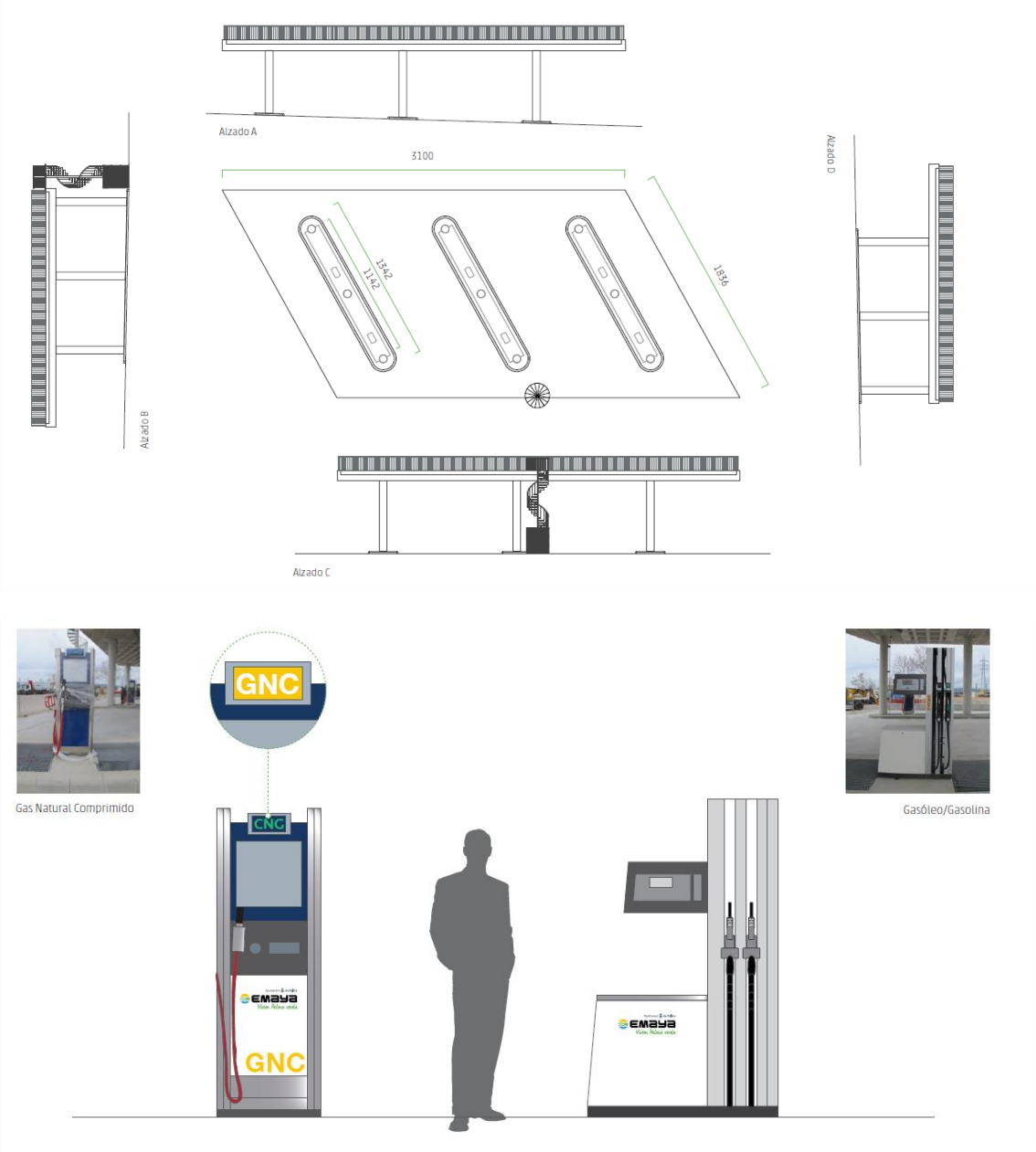

Figure 29: Plans for the gas filling facility at EMAYA.

Figure 30: The finalized gas filling station at EMAYA, 2016.

Figure 31: CNG 18m long public bus filling at EMAYA's premises.

The currently installed 3 bar compressor will be used in the future to complete the emptying of the biomethane virtual pipeline (truck) bringing biogas from the wastewater

treatment plant (EDAR 1). The compressed biomethane in the truck will be fully discharged into the filling station storage tanks, achieving a high transport efficiency from source to final vehicle tank.

Figure 32: Virtual pipelines envisaged for EMAYA.

Thanks to this system, locally produced biogas could be delivered to the three defined potential uses:

- Electricity production in order to cover EMAYA's needs.
- Fuel for the vehicle fleet.
- Cogeneration and heat production.

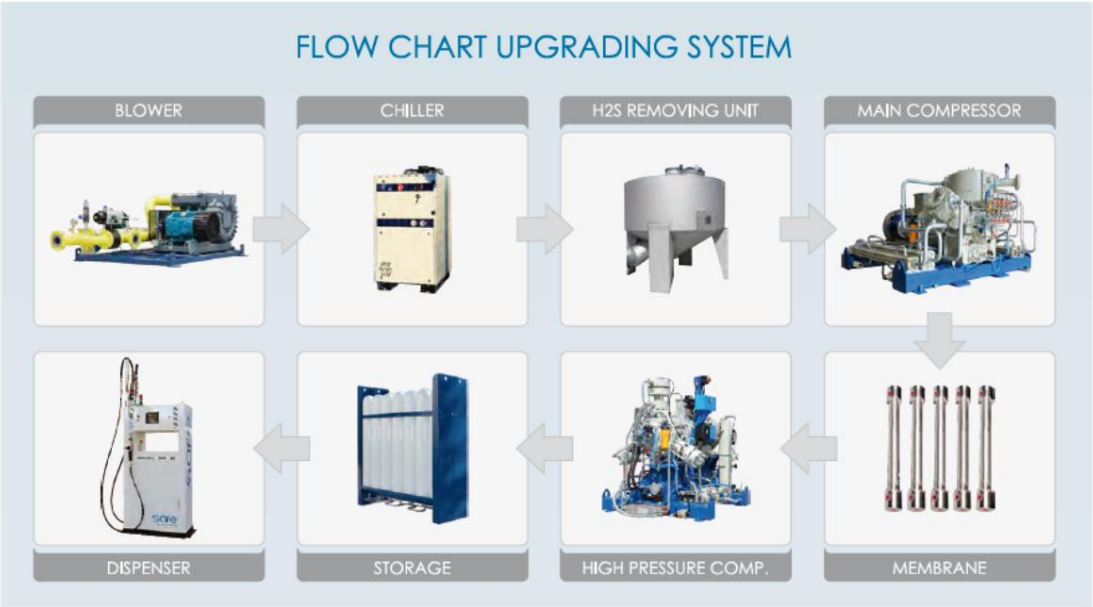

Figure 33: Biogas cycle from production plant to dispenser.

The biogas unit of the gas filling station is not yet built but it has already been designed and space has been reserved at EMAYA's premises. The construction will go hand in hand with the purification of biogas implementations.

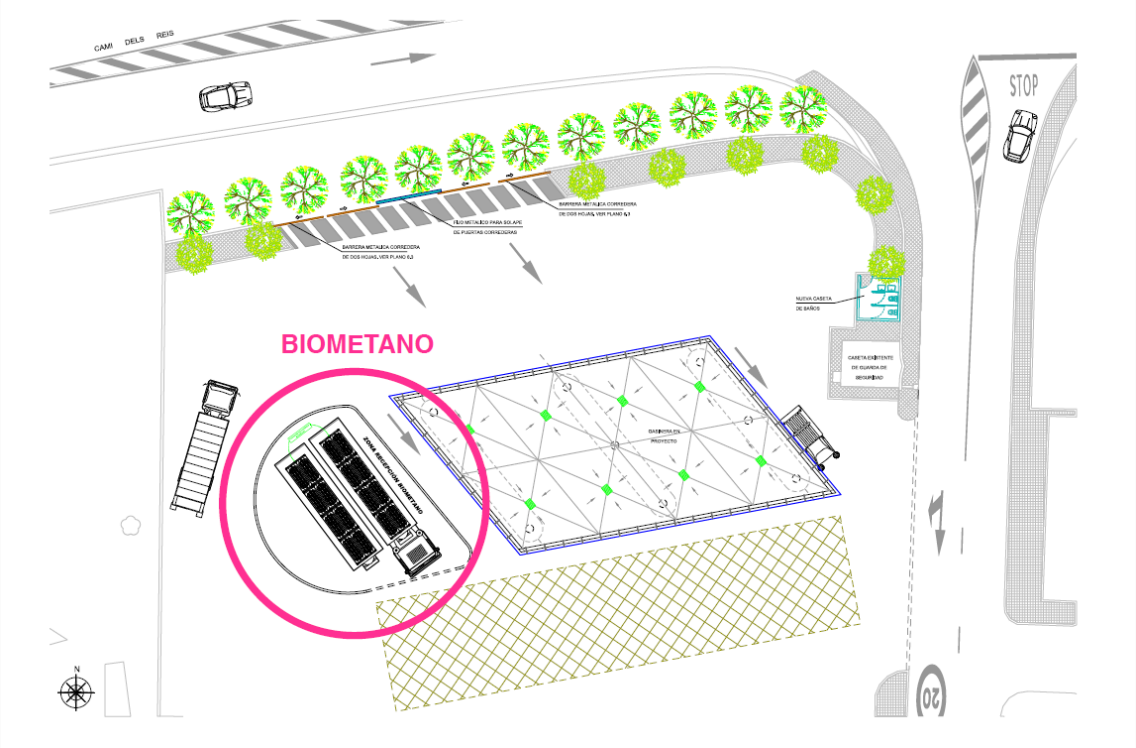

Figure 34: Location of the future biomethane filling station at EMAYA's depot.

The gas filling station will then be complemented with the contribution of self-generated local fuels. These will compete in price and will be environmentally friendly especially when compared to conventional fossil fuels. They will also contribute to achieve external energy dependency. In addition, the process will be a job generator as new operations will start taking place. Thanks to this diversification, both economically and environmentally advantageous for the municipality of Palma, the fleet of vehicles in the municipal park, including cleaning and waste collection vehicles as well as public transport vehicles, will be efficiently powered.

4. CONCLUSIONS AND RECOMMENDATIONS

Thanks to the CIVITAS DYN@MO measure *P2.1: CNG and biogas in municipal fleets*, Palma has successfully implemented eight new CNG powered trucks and transformed six diesel trucks and one gasoline van into CNG vehicles. There are also eleven ongoing transformations, meaning that in April 2017 the waste collection company will have 26 CNG vehicles in operation (eight new vehicles plus 18 transformed vehicles). Moreover, during the project a new gas filling station has been installed and is already in operation using the 3 bar gas intake, filling the seven CNG vehicles of EMAYA and the twelve CNG buses previously implemented at EMT. The connection with the 59 bar grid has been also built and it will be fully operational in March 2017, leading to reduced costs and increased supply capacity.

In order to extract conclusions and recommendations about the experience gained within this measure, a series of comparisons have been conducted.

The operation costs and the average consumption of the vehicle fleet of EMAYA are shown below, including light and heavy vehicles.

Average consumption	Gasoline/100km	Diesel/100km	GNC/100km	kWh/100km	€/100km
Passenger car	8			80	8,00 €
Light van		9		90	8,10 €
Light electric truck				10	1,10 €
26t diesel truck with lateral collector		80		800	72,00 €
26t CNG truck with lateral collector			70	1050	40,60 €

Figure 35: Average consumption and cost per vehicle category and type of fuel, EMAYA 2015.

Type of vehicle	Units	km (or hours)	Diesel (L)	Gasoline (L)	GLP (kg)	NGC (kg)
Light street cleaning vehicles	51	50512 (hours)	245.669	122	0	0
Heavy street cleaning vehicles	18	20875 (hours)	198.410	47	0	0
Light trucks	57	645.697	98.521	194	0	0
Medium sized trucks	29	564.575	143.244	0	0	0
Heavy trucks	92	1.874.726	1.261.724	0	0	8.580
Large vans	29	262.396	30.967	186	0	0
Light vans	121	1.260.381	9.520	64.030	82.480	183
Motorbikes and scooters	36	89.580	190	8.663	0	0
Light trailers	22	0	8.961	208	0	0
Off-road vehicles	5	237.754	5.916	0	0	0
Passenger cars	57	413.803	88	30.904	0	0

Figure 36: Annual consumption per vehicle category and type of fuel, EMAYA 2015.

The figures show how much higher the efficiency of electric vehicles is compared to vehicles with combustion engines. It is worth mentioning that the energy for these vehicles comes 100% from solar photovoltaic panels installed by EMAYA. The operative cost for EVs is almost ten times lower than the cost of conventional fuels.

For CNG vehicles, comparing the same 26T truck but with different fuels (100% diesel against 100% CNG), over a 40% decrease in average operating costs has been experienced due to the reduced taxation at national level for gas fuels: from 72€ per 100 km with diesel trucks to 40.60€ per 100km with CNG trucks. Since the average annual mileage of a heavy collection vehicle is 30,000 – 35,000 km, the annual

reduction per truck amounts to 10,205€, i.e. 102,500€ when considering a ten year lifespan and amortization. This reduction in operation costs can balance out the increase in acquisition costs of CNG trucks compared to diesel trucks.

These results have been used to estimate the future savings in operation costs when EMAYA is able to fuel vehicles with its own recovered biogas. In this case, the savings for the same type of vehicle could be 28,000€/ year considering a fixed price for diesel (1€/ litre). Savings of 280,000€ per vehicle with a ten year lifespan hypothesis can be achieved. The conservative perspective of the calculations doesn't leave space for doubts: it is well worth for EMAYA (and the City of Palma) to strive towards a 100% biogas propelled fleet, not only from an economic point of view but also regarding the environmental impact. However, the 2.3M€ estimated for the installation of equipment to purify biogas will require not only a specific allocation of company's budget but also the contribution of external funds in order to achieve acceptable return periods for the investments.

The following figure shows a comparison between current prices of different fuels:

Concept	Explanation	Units	Rate 1.1 P>60 bar	**Rate 2.4 16 bar < P < 60 bar**	Current rate Endesa 2.3 16 bar < P < 60 bar	LNG plant	Diesel
Energy term	Commercial index	€/Mwh	29-31,5	**29-31,5**	32,05	30-35	
Volume term	Public regulated	€/Mwh	2,31	**2,79**	3,72	9,5	
Compression term	Depends on price and periods	€/Mwh	1,24	**1,77**	3,57	0,5	
Special tax	Public regulated	€/Mwh	4,14	**4,14**	4,14	4,14	
		Subtotal €/Mwh	36,69-39,19	**37,7-40,2**	43,48	44,14-19,14	
Use term	Station amortization	Tes	7,00-11,66	**7,00-11,66**	12	5	
		Subtotal €/Mwh	43,69-50,85	**44,7-51,86**	55,48	49,14-54,14	107
Prices reduction Vs Diesel			59%-52%	**58%-51%**	0,48	54%-49%	
€/kg CNG	(conversion kWh to kg 13,72)		0,64-0,74	**0,66-0,76**	0,81	0,72	1,57

Figure 37: Fossil fuel price comparison, 2013.

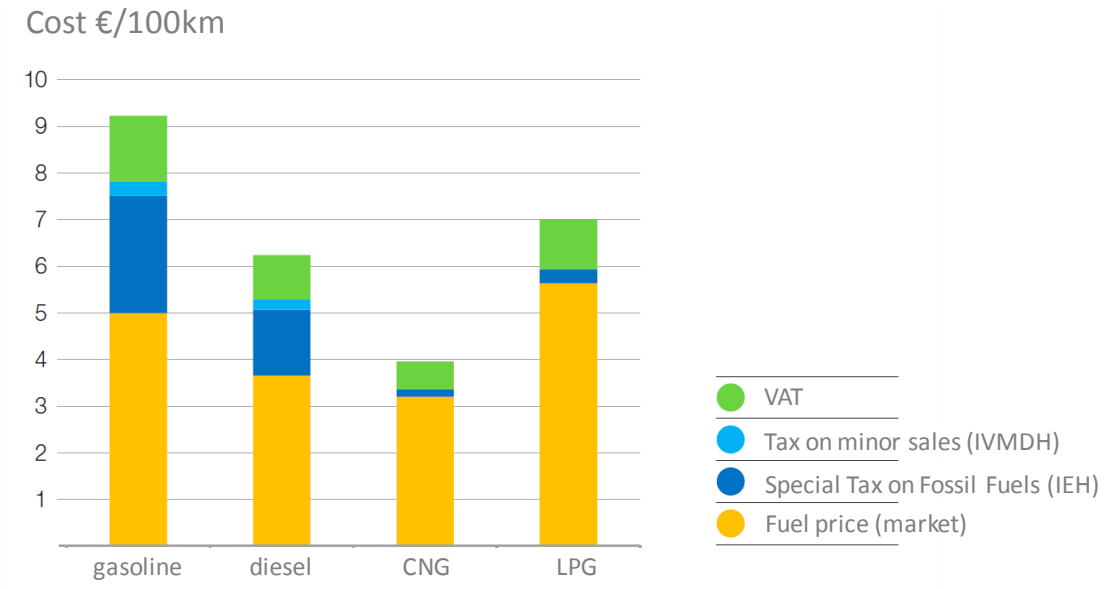

Figure 38: Prices of different fossil fuels disaggregated (taxes on top of net price), 2013.

The following figure shows the savings in fuel derived from moving EMAYA's fleet to 100% CNG, acquiring the gas from the current market providers.

	UNITS	2010	2011	2012	2013	POTENTIAL SAVINGS (100% CNG FLEET)
ANNUAL AMOUNT	LITRES	2.071.039	2.033.373	2.200.243	2.117.358	
COST	EUROS	1.779.132	2.001.869	2.352.216	2.350.557	1.223.938
AVERAGE PRICE	EUROS	0,86	0,98	1,07	1,11	
PCS (DIESEL LITRE)	kWh	10,51 kWh	10,51 kWh	10,51 kWh	10,51 kWh	
CONSUMPTION	ANNUAL	21.766.620	21.370.750	23.124.554	22.253.433	
GAS PRICE (EMT)	Euros/MWh	55,33	55,33	55,33	55,33	55,33 (0,83 Euros/kg)
GAS PRICE (EMAYA)	Euros/MWh	37--44	37--43	37--42	37--41	37--40

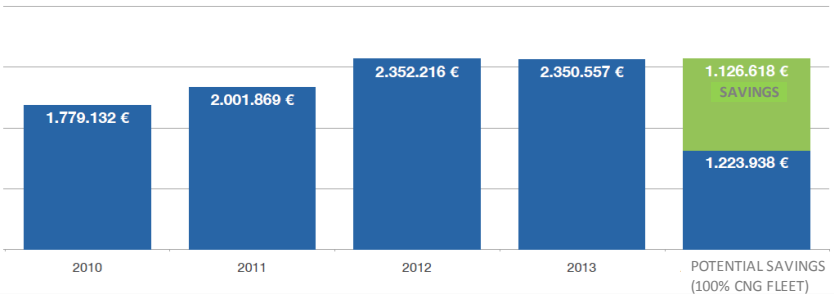

Figure 39: Savings forecast at EMAYA and EMT with the introduction of CNG.

The shift towards CNG has been also studied at city level. The following figure shows the overall annual savings that could be achieved by abandoning diesel powered vehicles.

FUEL COST COMPARISON AT CITY LEVEL	Taxi fleet	EMAYA fleet	EMT bus fleet	Local police fleet	TOTAL
Vehicles/type	1200 cars	517 (trucks and light vehicles)	178 buses	-	-
Annual consumption (Gwh/year)	48.000	25.000	83.000	5.000	161.000
Cost diesel (€/Mwh)	107,00 €	107,00 €	107,00 €	107,00 €	-
Annual cost diesel (€)	5.136.000,00 €	2.675.000,00 €	8.881.000,00 €	535.000,00 €	17.227.000,00 €
Cost CNG (€/Mwh)	70,00 €	70,00 €	70,00 €	70,00 €	-
Annual cost CNG (€)	3.360.000,00 €	1.750.000,00 €	5.810.000,00 €	350.000,00 €	11.270.000,00 €
Annual savings if CNG is used instead of diesel	1.776.000,00 €	925.000,00 €	3.071.000,00 €	185.000,00 €	5.957.000,00 €
% savings					34,58%

Figure 40: Fuel cost savings in Palma by shifting from diesel to CNG.

As can be seen in the previous figure, annual savings of almost 35% could be achieved by shifting from diesel to CNG. In city level terms, including taxis as well, this amounts to almost 6M€ per year of cost reduction. The emissions (pollutants, CO_2 and noise) derived from CNG technology have been evaluated during the development of the measure. The Measure Evaluation Results Sheet (MERS) included in the DYN@MO Final Evaluation Report includes details on the methodologies and results obtained with the study of these parameters. As mentioned in the MERS, several complications have been encountered, including the excessive costs to carry out specific measurements. For this reason, manufacturers data have also been used (when there was no experimental data) and most of the results can be considered as estimates.

The key results in terms of emissions are:

- According to the emissions study carried out by the EMT, the emission of NO_x in CNG buses is reduced by 379%, below 3 g/ km. For the remaining pollutant gases CNG buses have higher emission values.

- According to the manufacturers' certificates, the emission of NO_x in the new CNG trucks purchased by EMAYA is reduced by 64%, with NO_x emission values of 214.1 mg/ KWh. In addition, these new CNG trucks have also managed to reduce CO_2 emissions, but a much lower reduction: 9.3%, with values of 626.99 g/ kWh.
- Noise emissions on CNG buses show a reduction compared to diesel buses. Thus on the outside of the CNG buses the noise emission has been reduced by 13.5% and in the interior by 9.8%.
- In the CNG trucks of EMAYA, noise reduction has been lower, 1.3%.

If data is extrapolated, shifting the municipal fleet from diesel propulsion to CNG propulsion would bring the following savings of pollutants:

ENVIRONMENTAL IMPACT REDUCTION	Taxi fleet	EMAYA fleet	EMT bus fleet	Local police fleet	TOTAL
Annual consumption (Gwh/year)	48.000	25.000	83.000	5.000	161.000
Reduction of Nox emisions (kg)	48.359	25.187	83.620	5.037	162.203
Reduction of CO+HC+PM emissions (kg)	274.571	143.011	474.796	28.602	920.980
Reduction of CO2 emissions (kg)	807.329	420.484	1.396.006	84.096	2.707.915

Figure 41: Emissions reduction in Palma by shifting from diesel to CNG.

The strategy of renewing municipal fleets at the EMAYA waste collection municipal company and the EMT bus municipal company have been different, with different results as well:

- EMT's strategy for vehicle renewal was conditioned upon receipt of financial assistance that would allow the investment necessary for the purchase of buses. Finally, this financial contribution by the national administrations was not possible and EMT decided to postpone the fleet renewal. The availability of funding will determine the percentage of new CNG vehicles. In addition, this strategy only included the purchase of CNG vehicles and no investments in building the necessary filling infrastructure.
- In the case of EMAYA, before starting the shift towards CNG, a preliminary study of the situation and future viability of this technology was performed. In order to achieve the transformation of its municipal fleet towards CNG vehicles a strategy (Strategic Energy Plan 2013-2020) was defined. This strategy was based on the use of their own (waste) resources, the creation and construction of filling infrastructure and the acquisition of CNG vehicles as well transformation to CNG of existing diesel vehicles.

This second approach has proved more effective. In this way, those cities who aim at shifting their municipal fleets to CNG vehicles, should be able to design a medium and long term plan, including all necessary phases, as well as an economic budget for transformation, which should at least include a scenario in which external funding is not received. This plan should include the purchase of vehicles, but also building the necessary infrastructure to fill the new CNG vehicles.

The shift towards gas propulsion is therefore highly recommended to other cities/ regions with either one of these fuel market conditions:

- Lower prices of fossil CNG compared to other fossil fuels (due to producers prices and/or favourable taxation schemes).

- Availability of enough biogas resources (not still in use or used in heating or electricity).

The degree in which these conditions are established at the local level is crucial to determine the speed of the process and the extent of the required investments. In this respect, attention must be paid to the availability of commercial CNG filling stations, connection to main gas supply networks, existing biogas production facilities, wastewater mud disposal, organic waste fraction separated, etc.

By using CNG in municipal vehicle fleets significant economic and environmental benefits can be achieved at the local level. If a city/region meets the two prior requirements it is possible then to diversify the strategy (fossil and renewable gas) and implement CNG vehicles running on fossil gas while preparing the path for biogas production. This is the current status at Palma de Mallorca, who aims at becoming a reference in energy management in the Mediterranean.