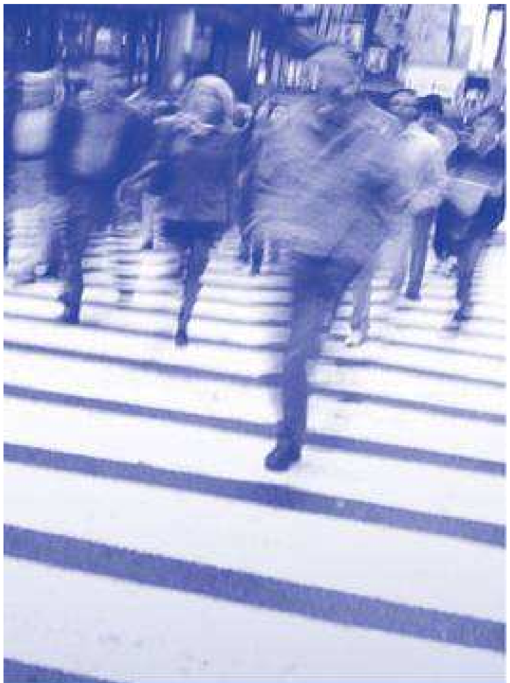

CIVITAS
Cleaner and better transport in cities

ARCHIMEDES
AALBORG • BRIGHTON & HOVE • DONOSTIA-SAN SEBASTIÁN • IAŞI • MONZA • ÚSTÍ NAD LABEM

# Monza

## R7.1 – Hybrid Bus Specification Study in Monza

City of Monza

June 2010

THE CIVITAS INITIATIVE
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# Contents

# 1. Introduction

## 1.1 Background CIVITAS

CIVITAS - cleaner and better transport in cities - stands for CIty-VITAlity-Sustainability. With the CIVITAS Initiative, the EC aims to generate a decisive breakthrough by supporting and evaluating the implementation of ambitious integrated sustainable urban transport strategies that should make a real difference for the welfare of European citizens.

**CIVITAS I** started in early 2002 (within the 5th Framework Research Programme);
**CIVITAS II** started in early 2005 (within the 6th Framework Research Programme) and
**CIVITAS PLUS** started in late 2008 (within the 7th Framework Research Programme).

The objective of CIVITAS-Plus is to test and increase the understanding of the frameworks, processes and packaging required to successfully introduce bold, integrated and innovative strategies for clean and sustainable urban transport that address concerns related to energy-efficiency, transport policy and road safety, alternative fuels and the environment.

Within CIVITAS I (2002-2006) there were 19 cities clustered in 4 demonstration projects, within CIVITAS II (2005-2009) 17 cities in 4 demonstration projects, whilst within CIVITAS PLUS (2008-2012) 25 cities in 5 demonstration projects are taking part. These demonstration cities all over Europe are funded by the European Commission.

**Objectives:**

- to promote and implement sustainable, clean and (energy) efficient urban transport measures
- to implement integrated packages of technology and policy measures in the field of energy and transport in 8 categories of measures
- to build up critical mass and markets for innovation

**Horizontal projects support the CIVITAS demonstration projects & cities by :**

- Cross-site evaluation and Europe wide dissemination in co-operation with the demonstration projects
- The organisation of the annual meeting of CIVITAS Forum members
- Providing the Secretariat for the Political Advisory Committee (PAC)
- Development of policy recommendations for a long-term multiplier effect of CIVITAS

**Key elements of CIVITAS**

- CIVITAS is co-ordinated by cities: it is a programme “of cities for cities”
- Cities are in the heart of local public private partnerships
- Political commitment is a basic requirement
- Cities are living ‘Laboratories' for learning and evaluating

## 1.2 Background ARCHIMEDES

ARCHIMEDES is an integrating project, bringing together 6 European cities to address problems and opportunities for creating environmentally sustainable, safe and energy efficient transport systems in medium sized urban areas.

The objective of ARCHIMEDES is to introduce innovative, integrated and ambitious strategies for clean, energy-efficient, sustainable urban transport to achieve significant impacts in the policy fields of energy, transport, and environmental sustainability. An ambitious blend of policy tools and measures will increase energy-efficiency in transport, provide safer and more convenient travel for all, using a higher share of clean engine technology and fuels, resulting in an enhanced urban environment (including reduced noise and air pollution). Visible and measurable impacts will result from significantly sized measures in specific innovation areas. Demonstrations of innovative transport technologies, policy measures and partnership working, combined with targeted research, will verify the best frameworks, processes and packaging required to successfully transfer the strategies to other cities.

## 1.3 Participant Cities

The ARCHIMEDES project focuses on activities in specific innovation areas of each city, known as the ARCHIMEDES corridor or zone (depending on shape and geography). These innovation areas extend to the peri-urban fringe and the administrative boundaries of regional authorities and neighbouring administrations.

The two Learning cities, to which experience and best-practice will be transferred, are Monza (Italy) and Ústí nad Labem (Czech Republic). The strategy for the project is to ensure that the tools and measures developed have the widest application throughout Europe, tested via the Learning Cities' activities and interaction with the Lead City partners.

### 1.3.1 Leading City Innovation Areas

The four Leading cities in the ARCHIMEDES project are:

- Aalborg (Denmark);
- Brighton & Hove (UK);
- Donostia-San Sebastián (Spain); and
- Iasi (Romania).

Together the Lead Cities in ARCHIMEDES cover different geographic parts of Europe. They have the full support of the relevant political representatives for the project, and are well able to implement the innovative range of demonstration activities.

The Lead Cities are joined in their local projects by a small number of key partners that show a high level of commitment to the project objectives of energy-efficient urban transportation. In all cases the public transport company features as a partner in the proposed project.

# 2. Monza

Monza is a city on the river Lambro, a tributary of the Po, in the Lombardy region of Italy, some 15km north-northeast of Milan. It is the third-largest city of Lombardy and the most important economic, industrial and administrative centre of the Brianza area, supporting textile industry and publishing trade. It is best known for its Grand Prix.

The City of Monza, with approximately 121,000 inhabitants, is located 15 km north of Milan, which is the centre of the Lombardia area. This area is one of the engines of the Italian economy; the number of companies is 58,500, i.e. a company for every 13 inhabitants.

Monza is affected by a huge amount of traffic that crosses the city to reach Milan and the highways nodes located between Monza and Milan. It is also an important node in the Railways network, crossed by routes connecting Milan with Como and Switzerland, Lecco and Sondrio, Bergamo and Brianza. "Regione Lombardia", which in the new devolution framework started in 1998, has full responsibility for establishing the Local Public Transportation System (trains, coaches and buses) and has created a new approach for urban rail routes using an approach similar to the German S-Line or Paris RER.

Monza has recently become the head of the new "Monza and Brianza" province, with approximately 750,000 inhabitants, so will gain the full range of administration functions by 2009. Plan-making responsibilities and an influence over peri-urban areas will require the city to develop new competencies.

In this context, the objective of the City of Monza in participating in CIVITAS as a Learning City is to set up an Urban Mobility System where the impact of private traffic can be reduced, creating a new mobility offer, where alternative modes become increasingly significant, leading to improvements to the urban environment and a reduction in energy consumption (and concurrent pollution).

# 3. Background to the Deliverable

Measure no. 7 of the ARCHIMEDES project concerns the implementation of a hybrid bus in Monza.

The measure covers 2 tasks.

**RTD Task: Hybrid Bus Specification Study:**
Undertake a study to gain best practice examples from other cities who have implemented a hybrid bus and to develop a technical specification for the delivery of a hybrid bus and assess the feasibility of hybrid buses in order to carry on the demonstration phase of a hybrid bus.

and

**DEMO Task: Hybrid Bus**
Procure a hybrid bus to make operational in the urban Public Transport according to the result of this study.

It is worth noting that Public Transport (PT) in Monza was managed by the Company "Trasporti Pubblici Monzesi – TPM" (100% owned by Comune of Monza) until September 2009. However, after the City Council decided to merge the branch of TPM concerning Public Transport with the Company "Nord-Est Trasporti – NET", another company already operating public transport in Monza, which is almost totally owned by "Azienda Trasporti Milanesi – ATM" Milan, the largest PT Operator in the area of Milan. Because the feasibility stage was due to be conducted by TPM the merger process introduced some delays.

Before the involvement of Monza in ARCHIMEDES, some choices in favour of clean fuels had already been taken:

- at the beginning of 2007, particulate filters were installed on all diesel buses of TPM fleet, in order to reduce PM10 emissions (by up to 90-95% reduction);
- in January 2008 9 EEV buses were procured (first ones to be delivered at a higher cost if compared with Euro 4 buses);
- an approach to a demonstration of hydrogen/diesel technology already tested in the USA on trucks had been made, but it had not been developed because of the merger with NET.

No vehicles with potentials of zero emission driving within the inner city are currently available in Monza.

## 3.1 Summary Description of the Task

The objective of this study is to gain best practical examples from other cities or other public transport companies which have implemented a hybrid bus and to develop a technical specification for the delivery of a hybrid bus that will be demonstrated in ARCHIMEDES WP1.

The use of hybrid buses in Monza, besides allowing to test new technologies in order to gather sound and precise data to take appropriate decisions on future procurement choices for Urban Public Transport buses, will contribute to reduce the environmental impact of Public Transport fleet in Monza, especially for $PM_{10}$ pollutant.

The objective of the introduction of the hybrid bus is to reduce emissions value of up to 25% with respect to classic diesel powered buses.

# 4. Hybrid Bus in Monza

## 4.1 Description of the Work Done

The present study does not aim at being a scientific treatise on all possible hybrid technologies applying to the traction of public transport: anyway it is useful to give a short description of what is generally meant by Hybrid Vehicle and to give a description of the main hybrid technology that has been taken into consideration for the experimentation of hybrid buses in Monza.

## 4.2 Summary of the Activities Undertaken

### 4.2.1 The technology of hybrid engines.

A **hybrid vehicle**, more properly "hybrid propulsion vehicle", is a vehicle which combines two different power sources to move the vehicle, e.g. an **electric motor and a heat engine.** Nowadays this kind of solution is the most common on the market**.**

"Multi-fuel" (petrol/LPG, petrol/methane, diesel/kerosene, petrol/hydrogen) vehicles are sometimes defined hybrid, too.

This list might continue with many other types of fuel couples: these are all experiments which are taking place both in laboratories and on the market, but until now no one of these has prevailed on the others and has become a generally accepted standard.

- **Electric - heat engine**

The two engines are apt to coexist because they have complementary characteristics. The internal combustion engine transforms the chemical energy of the fuel (with high energy density and easily available in the filling stations network) with acceptable efficiency, particularly in some stages of operation. On the contrary the electric motor converts a smaller amount of energy available on board with higher efficiency and versatility. Each electric vehicle is theoretically capable to work in traction and generation (and in forward and reverse gear) in order to exploit the braking capability of the electric motor to produce energy which would otherwise be dispersed by the brakes themselves. The electric energy can be stored up in different ways, even at the same time:

- **Batteries:** they have lower energy density when compared with that of the combustible fuel, they can be shaped in order to store up the highest quantity of energy, to exchange the highest power or with a compromise between the two extremes. Batteries work through electrochemical processes taking place in their interior and all parameters (such as temperature) have to be controlled, in order to limit as much as possible the decay of electrodes and electrolytes.

- **Supercapacitors:** if compared with batteries, they present lower energy density but they can transfer and get higher powers. They are based on a more checkable physical process.

- **Electrically operated flywheel**: the energy is stored up through the kinetic energy of an electric operated flywheel which makes it turn; this process is totally mechanic and it shows control problems different from the previous ones.

According to the capacity of saving electric energy, different levels of hybridization are so defined:

- full hybrid
- mild hybrid
- minimal hybrid,

all characterized by a decreasing run with the electric motor and by a decreasing contribution of the electric motor compared with the total power of the heat engine.

All the vehicles with the *stop & start* function are not properly called “micro hybrid”, but this function, typical of many hybrid vehicles too, is obtained thanks to traditional components and not through a different propulsion mechanism.

There are three main structural schemes which combine a heat motor and an electric engine:

- ***series hybrid***
- ***parallel hybrid***
- ***mixed hybrid***

- **Series hybrid.**

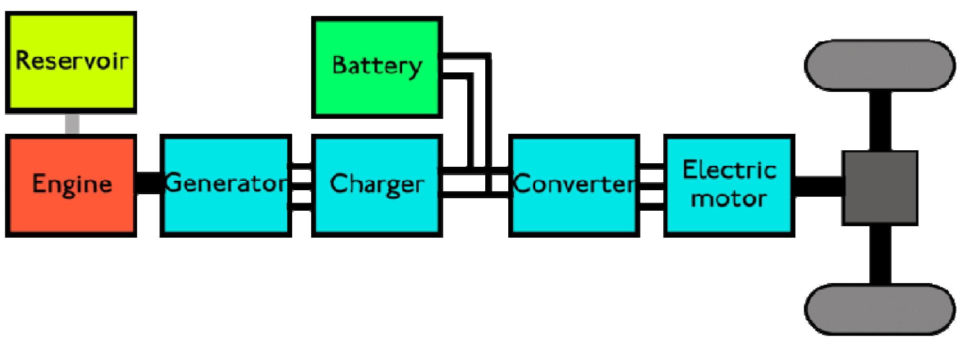



**Figure 1. Scheme of a series hybrid**

This technology is very similar to the one used by diesel-electric locomotives. In this case there is no mechanical link between the combustion engine and the wheels. In connection with a generator, the combustion engine solely has the purpose of generating power. The propulsive power flows from the generator to the drive shafts or directly to the wheels via one or more electric motors. This means that the combustion engine can always run at the ideal operating point, even if high speeds are required for starting and accelerating. The superfluous energy is used to recharge the batteries. In this context there is no distinction between batteries and supercapacitors (in alternative to batteries) even though the latter are imposing themselves in hybrid buses thanks to their higher deliverable power and less required maintenance.

When a great quantity of energy is required, it is drawn both from the heat engine and the batteries. Since engines are apt to work on a various range of rotation speed, this structure allows either to dismiss or reduce the necessity of a complex traction. The efficiency of internal combustion engines varies according to the number of revolution: in such systems the revolutions of heat engines are fixed in order to have the highest efficiency with no accelerations or decelerations. This condition given and to compensate further energy transformation, it can be used a heat engine (generator) which shows a very strict range of utilization/operation terms as compared to the whole running, which can, for this reason, have a higher efficiency than that of traditional heat engines, at least in that range of running.

In some prototypes small electric motors on each wheel are installed. The obvious advantage of this technique is the possibility to control the energy delivered to each single wheel. A possible goal could be the simplification of traction control or the activation/deactivation of the four-wheel drive.

The main disadvantage of *series hybrids* lies in the considerable efficiency reduction when compared to traditional heat engines when speed is high and constant (e.g. 130km/h on highways). This happens because in the conversion heat-electrical energy-movement part of the energy is lost; this would not happen with a direct transmission. This disadvantage is not shown in *parallel hybrids. Series hybrids* are much more efficient for those vehicles that need continuous braking and leaving such as urban cars, buses, and taxis. This situation is typical of public transport in Monza, because of high congestion.

Many models of *series hybrid* vehicles are equipped with a button which switches off the heat engine. This function is specially used by vehicles circulating in traffic restricted areas. The range depends on the charge of batteries; anyway the heat engine can be switched on with the same button. Furthermore the heat engine is automatically turned off when the vehicle stops.

- **Parallel hybrid.**

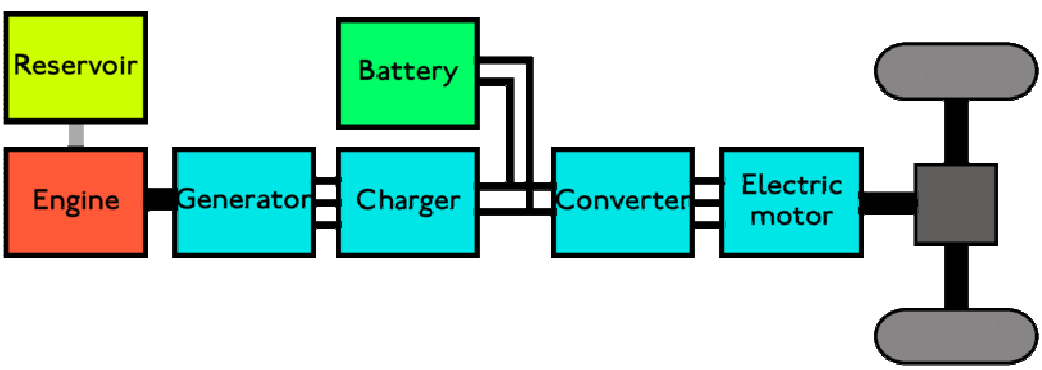



**Figure 2. Scheme of an in parallel hybrid**

It is the most common of hybrid vehicles. The combustion – engine drive and the electric drive are connected in parallel and both give torque to the wheels. They can be used separately or together. The parallel hybrid can get by with only one electric motor, which saves costs. Moreover, the electric motor can be installed in the transmission housing in a space-saving manner. This has the advantage that the available transmissions can be used with their benefits regarding driving dynamics. Besides the heat engine can be used to charge the batteries in case of need. The *parallel hybrid vehicles* could be further divided into different classes according to the balancing of the two engines in supplying energy. In most cases, for instance, the internal combustion engine plays the dominant role while the electric motor has the simple function of supplying more energy if necessary (especially leaving, accelerating and at the maximum speed).

Most of the projects combine a big electric generator with an engine in a single unit, generally located between the combustion engine and the traction, where generally the flywheel lies, so replacing both the starting device and the alternator. Generally these vehicles have automatic transmission.

The advantage of this technical scheme lies both in the elimination of lower gears (the ones which burn too much fuel) and in low consumption when the vehicle stops or when it runs at a walking pace. Besides it allows the production of low-powered vehicles since the heat engine at the maximum speed can be supported by electric motors (even if only for few kilometres). For this reason these vehicles are ideal for cities rather than for highways.

- **Mixed hybrid**

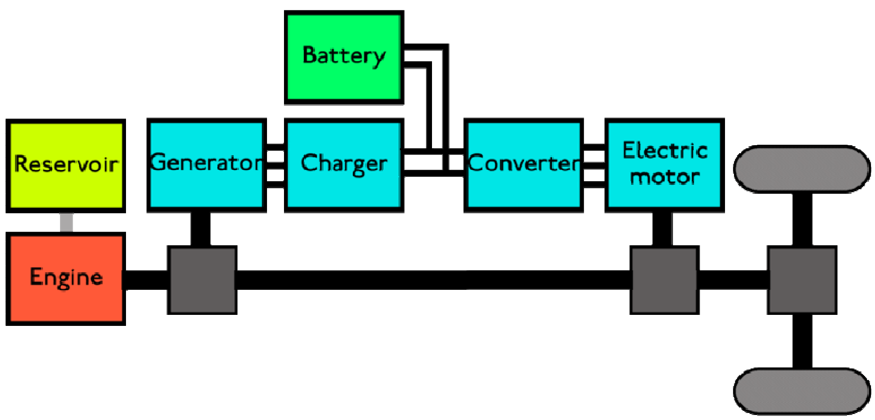



**Figure 3. Scheme of a mixed hybrid**

In *mixed hybrid vehicles* the engine is particularly versatile and it allows the switching from the in series system to the in parallel one and vice versa.

### 4.2.2. Environmental issues

- **Fuel consumption and emissions reductions**

Hybrid vehicles typically achieve greater fuel economy and lower emissions than conventional internal combustion engine vehicles (ICEVs), resulting in fewer emissions. These savings are primarily achieved by three elements of a typical hybrid design:

1. relying on both the engine and the electric motors for peak power needs, resulting in a smaller engine sized more for average usage rather than peak power usage. A smaller engine can have less internal losses and lower weight.;
2. having significant battery storage capacity to store and reuse recaptured energy, especially in stop-and-go traffic;
3. recapturing significant amounts of energy during braking that are normally wasted as heat. This regenerative braking reduces vehicle speed by converting

some of its kinetic energy into electricity, depending upon the power rating of the motor/generator.

Other techniques that are not necessarily 'hybrid' features, but that are frequently found on hybrid vehicles include:

1. shutting down the engine during traffic stops or while coasting or during other idle periods;
2. improving aerodynamics and shape as a good way to help better the fuel economy and also improve handling at the same time;
3. using low rolling resistance tyres (tyres were often made to give a quiet, smooth ride, high grip, etc., but efficiency was a lower priority). Tyres cause mechanical drag, once again making the engine work harder, consuming more fuel. Hybrid cars may use special tyres that are stiffer and more inflated than regular tyres or that, by choice of carcass structure and rubber compound, have lower rolling resistance while retaining acceptable grip, and so improving fuel economy whatever the power source;
4. powering the a/c, power steering, and other auxiliary pumps electrically as and when needed ; this reduces mechanical losses when compared with driving them continuously with traditional engine belts.

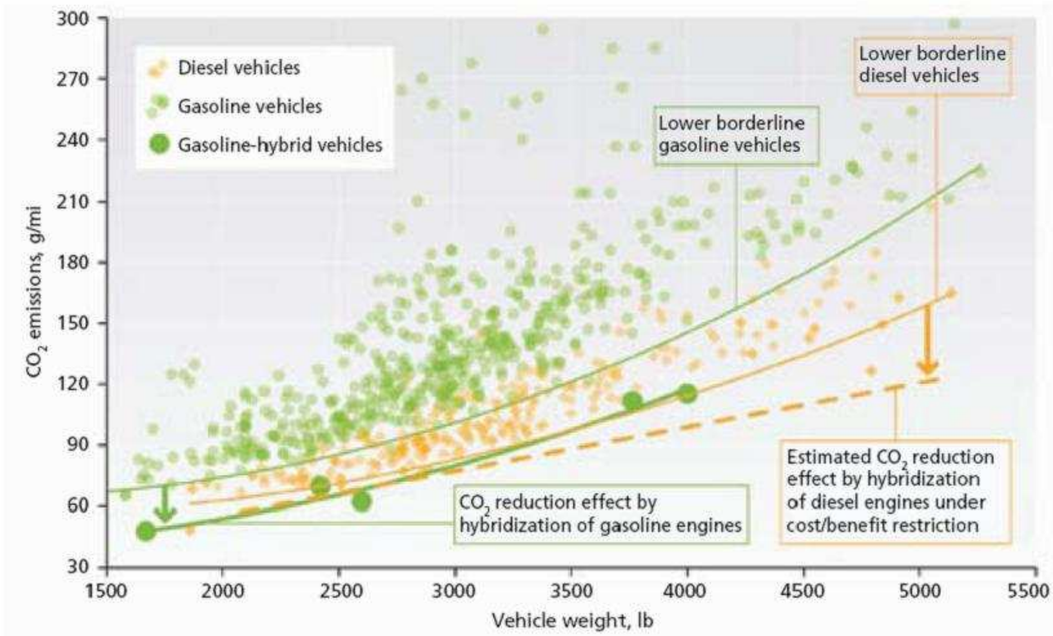
These features make a hybrid vehicle particularly efficient for city traffic where there are frequent stops, coasting and idling periods. In addition noise emissions are reduced, particularly at idling and low operating speeds, in comparison to conventional engine vehicles. For continuous high speed highway use these features are much less useful in reducing emissions.

- **Hybrid Vehicle Emissions**

Hybrid vehicles have an excellent improvement towards the environment when dealing with air quality emissions, for those vehicles powered by fuel. This is a big step in the environmental impact of these vehicles.

Anyway, hybrid vehicles with an electric engine and a gasoline one, still do contribute to a very small percentage of greenhouse emissions due to the fact that they are still powered by petroleum based fuel which is used in other gasoline powered vehicles. Due to their small and lightweight size these current hybrid vehicles use less energy and fuel which produces fewer emissions. With the assistance of the electric motor the gasoline engine can be smaller (and therefore less polluting).

Hybrid vehicles can reduce air emissions of smog-forming pollutants by up to 90% and cut carbon dioxide emissions in half. Most of these vehicles are designed for commuting through cities, where there is an excessive amount of traffic with the expectation of reducing the gaseous emissions and having a positive effect on the environment. Based on the average driving habits of an individual, pollution from these vehicles can be reduced by anywhere between 25% to 60%, compared to an everyday conventionally-powered vehicle. The following graph shows the amount of $CO_2$ emissions of hybrid vehicles compared to gasoline vehicles.




$CO_2$ emissions levels for gasoline and diesel vehicles showing the effect of hybridization.

**Figure 4. $CO_2$ emissions levels**

Emissions vary when comparing different brands of hybrid vehicles. Some manufacturers of hybrid vehicles add this technology to their existing models, whilst other manufacturers redesign their vehicles with this new technology

- **Environmental impact of hybrid vehicles batteries**

Though hybrid vehicles consume less petroleum than conventional cars, there is still an issue regarding the environmental damage caused by batteries. Today most Hybrid batteries are one of two types: (1) nickel metal hydride, or (2) lithium-ion; both are regarded as more environmentally friendly than lead–based batteries which constitute the bulk of vehicle batteries today.

There are many types of batteries. Some are far more toxic than others. While batteries like lead acid or nickel cadmium are incredibly bad for the environment, the toxicity levels and environmental impact of nickel metal hydride batteries - the type currently used in hybrids - are much lower. Nickel-based batteries are known carcinogens, and have been shown to cause a variety of teratogen effects.

The Lithium-ion battery has attracted attention due to its potential for use in hybrid electric vehicles, since its market is rapidly expanding as an alternative to the nickel-metal hydride batteries, which have been utilized in the hybrid market thus far. In addition to its smaller size and lighter weight, lithium-ion batteries deliver performances which help to protect the environment with features such as improved charge efficiency.

The lithium-ion batteries are also appealing because they have the highest energy density of any rechargeable batteries and can produce a voltage three times superior to that of nickel-metal hydride battery cell while simultaneously storing large quantities of electricity as well. The batteries also produce higher output (boosting vehicle power), higher efficiency (avoiding wasteful use of electricity), and provide excellent durability, compared with the life of the battery being roughly equivalent to the life of the vehicle. Additionally, use of lithium-ion batteries reduces the overall weight of the vehicle and also achieves improved fuel economy of 30% better than gasoline-powered vehicles with a consequent reduction in $CO_2$ emissions helping to prevent global warming.

### 4.2.3. Evaluation of the Italian marketplace

Till now no accurate interviews have been made to the major public transport companies concerning what they think about hybrid buses and what they are going to do to test them in their fleet, but we can gather which tendencies are developing in Italy by reading PT companies websites or press reviews or meeting the main retailers/manufacturers in Italy.

The picture of the situation reflects the actual state of hybrid technology: many companies state they want to follow different paths of the available technologies in the medium and short period while waiting for a particular technology to impose on the market in the long term.

So there are companies which have already converted all their fleet to the methane technology (natural gas) or to LPG; others are experimenting diesel/electric buses; others again use hydrogen/electric buses: they generally test buses which are built by the main manufacturers and which are available for tests during the run.

### 4.2.4 The trend of Italian transport companies

ATM in Milan (together with few other Italian and European cities such as Bolzano, Turin, London, Oslo and Aargau in Swiss) concentrates on both diesel/electric and hydrogen/electric hybrid buses and it will be experimenting three hydrogen buses since 2011, and for the duration of five years. This is confirmed by Elio Catania, President of ATM in Milan, who has declared that ATM is the first company in Europe for percentage of public electric buses in operation: furthermore ATM has allocated funds to renew its fleet of transport with the main aim to use hydrogen buses in the long term.

On the AIM Vicenza transport website it can be read that the company owns two innovative buses characterized by electric traction, LPG/electric turbine engine, which are to be added to 24 already operational LPG buses. These buses have a LPG turbine controlling an alternator that produces the energy needed to charge the batteries. These accumulators supply energy to the electric traction motor that moves the vehicle.

Since 2003 Brescia Trasporti has procured 8 metres electric motor buses whose electric energy is produced by a micro-engine with a methane-supplied turbine.

Since years LPT in Reggio Emilia has been developing a methane-supplied fleet; despite this ideal situation the company is still evaluating other types of hybrid traction depending on the availability of new technologies, on their costs and reliability.

Considering that the 60% of the used LPG derives from oil refining, during which oil is generally burned and wasted with no utility in the torches of the oil refineries, the ecological price is very high. The use of LPG in that context would contribute to the reduction of carbon dioxide production, one of the major factors producing the greenhouse effect. Besides, this kind of propulsion is characterized by silence and strongly reduced emissions.

Many other PT companies might be mentioned for having undertaken similar activities in the medium and short period or for evaluating the possible experimentations on hybrid buses of various technologies.

It is quite frequent in the north of Italy to find PT companies experimenting LPG or methane since these are simply affordable; these combustibles are instead difficult to find in the centre and south of Italy, where companies prefer to experiment other types of technologies (diesel/electric).

## 4.3 Main Outcomes

### 4.3.1 Retailers available in Italy

Public Transport in Italy is not in perfect health: for this reason most companies show negative budget sheets. The ticket sale proceeds reach the 18-20 of budget % in the worst cases and the 31-35% in the best ones.

The latest rise in price of fuel has not been supported by the State or local authority (regions, provinces, cities) in order to give more contractual compensation (in case of call for tenders) or more grants (in case of in house providing) to managing companies; these could do anything but counting higher operating deficits.

The splitting of the marketplace is high: there are too many small companies which manage some hundreds of thousands or millions of kilometres, whilst very few large-sized companies manage millions of kilometres.

Small companies had to face with deregulation, on the one hand, and with the rise in prices, on the other, and certainly have no available funds to renew their fleets or to experiment hybrid vehicles whose cost is 50% higher when compared with traditional diesel buses. The marketplace is thus characterized only by large-sized PT companies (ATM Milan, AMT Genoa, GTT Turin, COTRAL Rome, etc) which have at their own disposal funds to renew their fleets with innovative vehicles and the experimentation of other types of traction produced by the main manufacturers.

Anyway, since pollution in towns is everyday higher, hybrid technology in PT is becoming more and more interesting and the main Italian transport companies (ATM Milan, GTT Turin, ATC Bologna and ATAF Florence) show particular sensibility towards the problem of pollution and a great interest in hybrid technology; in the medium and short period (2010 and 2011) some Italian companies will call for tenders in order to purchase hybrid public transport vehicles to be tested in their fleets and so draw useful data to set in the medium and long term a strategic planning to be adopted on their fleets and vehicles.

In other European countries, Belgium De Lijn, a company which manages public transport in the Flemish part of the country, has purchased about 90 hybrid buses of different length, from 9 metres until 18; in Holland De Lijn has purchased 27 12 metres hybrid buses.

Worldwide producers of innovative technologies are therefore barely present on the Italian market place, since they cannot count on a great interest in the medium and short period or great numbers in terms of possible purchased buses to be experimented "on field".

A series of discussions were held either face to face or by telephone with the major manufacturers available on the Italian market: in particular **Mercedes Benz, Man, VanHool and Iveco**. Other European public transport vehicle manufacturers (even large-sized) have not been taken into consideration since they are not present on the Italian marketplace.

Hereafter there is a synthesis of the answers received by different manufacturers: among the verified information, great importance has been placed on the availability of the vehicles within the deadlines scheduled in ARCHIMEDES for the demonstration stage of the hybrid bus, in order to allow a sound evaluation of the measure.

- **Mercedes Benz**: the company has at its own disposal only Citaro G BlueTech hybrid 18 metres vehicles. Nowadays there are no diesel/electric hybrid vehicles. There is no information about the availability of 10/12 metres buses, the length that Monza would like to test in ARCHIMEDES.

- **Man**: The length of its buses is 10/12 metres, the one that Monza would like to test. Unfortunately, because of the worldwide economic crisis, Man has cut down investments on hybrid buses; so the production of hybrid buses (of any kind) is destined mainly to those principal European capitals that have shown a deep interest in testing hybrid vehicles for a long time. Man has committed itself to deliver to Monza a hybrid bus with fixed characteristics (dimension and technology) within a year by the confirmation of the order.

- **VanHool**: the company has two different available technologies: the diesel/electric and the hydrogen ones. The length of the vehicle corresponds with the one wished for the demonstration stage in the area of Monza; as regards the availability in terms of time, VanHool conforms to the needs of ARCHIMEDES for both technologies. As a matter of fact VanHool has begun the production of hybrid buses some time ago; it did not expect such type of orders and for this reason vehicles are available on the marketplace in short time (3/6 months).

- **Iveco**: the company has decided to produce hybrid vehicles only on order. If Monza wants to order the bus in this period, the delivery of the vehicle for the experimentation will be within a year: apart from the available technology, scheduled deadlines risk not to be respected.

- **Other companies**: other hybrid technologies offered by other manufacturers (e.g. Scania and its ethanol) have been addressed, but for the explained reasons (compliance to deadlines in order to allow sound demonstration and evaluation) it has been decided not to focus on them.

### 4.3.2 Comments and conclusions of the feasibility study

From the survey carried out, the availability of consultation documents, the different technologies offered by manufacturers, the picture that emerges shows signs of strong development in which the different technical solutions are still being tested by the manufacturers/retailers; a single solution has not prevailed on the others yet and for this reason many other criteria of evaluation have been taken into consideration before reaching a conclusion about the type of vehicle that Monza could choose to experiment. Hereafter there is a list of some of the key factors taken into consideration:

- The configuration of the streets on which Public Transport runs;
- The type of service (mainly urban with a lot of stops and low commercial speed);
- The range of swerve of some town streets;
- The average passengers' number;
- The proposed technology;
- The compatibility between the scheduled deadlines in ARCHIMEDES and the availability of vehicles.

Thus:

- The streets of the town of Monza and of neighbouring ones are in some parts difficult to drive through because they are "historical" and show a narrow roadway, so that the crossing between two buses comes out to be difficult: for these reasons 18 metre buses cannot be tested, and this implies that Mercedes buses are not suitable to be tested.
- In some areas of the town the bus has to make just one manoeuvring because it cannot reverse. For this reason the turning radius declared in technical sheets of the different models proposed by retailers has been taken into consideration. Not all the buses could satisfy this need.
- It is important that the vehicle could transport the highest number of passengers in comparison with diesel buses. Thus excluding 18 metre buses, which would be barely adaptable to the peculiar streets of Monza, the capacity declared by retailers became a key decision criterion.
- NET, the PT company which is actually managing the PT service in Monza, can rely on a garage located in TPM premises in Monza where the fleet running in the city is serviced; even during the demonstration phase the garage should be able to give emergency assistance and also ordinary maintenance suggested by the retailer itself. This is why it has been chosen to test an electric/diesel hybrid bus since mechanics have already experienced with such type of mechanisms.
- LPG, methane, and hydrogen buses have been rejected: it was not possible to build in TPM premises tanks suitable to contain any kind of gas (LPG or methane) in this location: the supply in service stations would not be easy because vehicles would be forced to travel for many kilometres to find one; travelling with an empty tank would be very expensive due to higher costs of time and staff.
- According to ARCHIMEDES timing, in order to experiment at least for one year a hybrid bus in order to ensure a sound evaluation stage, the comparison was between Man and VanHool, both having reduced delivery time.

Besides these main reasons there are many other minor remarks taken into account in order to choose the best bus to experiment. For instance: in many parts of the town commercial speed is strongly reduced (4-5 km/h) while the threshold of noise is very high. So the opportunity has been considered to use these long stretches of road where commercial speed is very low for a wholly electric vehicle: like this it is possible either to reduce environmental pollution in these areas or to cut down the background noise with great benefit for both pedestrians and passengers.

For all the reasons mentioned above, it has been decided to go on with experimenting a VanHool in series hybrid bus, model A330Hyb in particular, which seems to satisfy the largest part of the identified requirements for the city of Monza.

## 4.4 Problems Identified

The main obstacle met during the development of this study was the difficulty to obtain detailed and reliable information about the state of hybrid technology by vehicle providers. In many cases hybrid technology is just being experimented and the worldwide financial crisis has forced manufacturers to revise investments and to diminish the number of available / demonstrator buses. This was manifested by 3 specific effects:

- It was difficult to get up-to-date information on the pros and the cons of the different specific technical approaches adopted by manufacturers – even obtaining written brochures was difficult
- It was even harder to obtain information about future research strategies, which is important when making initial purchase decisions, in case you initially commit to a vehicle or technology that might very soon become obsolete
- Availability to obtain a hybrid bus in the short term to test in operation was extremely limited.

The buses produced by the main manufacturers have to satisfy the whole European marketplace: so principal European capitals and the main companies that since years have manifested the intention to invest in hybrid technology have been favoured.

## 4.5 Mitigating Activities

Now that the Public Transport in Monza is managed by NET, a PT company almost fully owned by ATM (and the largest PT company operating in and around Milan), it will be easier to procure a hybrid bus from retailers to be tested in Monza.  This opportunity exploits the experience and the interest that ATM has already shown in alternative fuels for public transport.

## 4.6 Future Plans

The test will be a delicate phase during which many aspects of the bus will have to be checked.

As far as the environmental impact is concerned, the main chemical elements dispersed in the air will be controlled (PM10 particulate, NOx, $CO_2$, and so on) and emissions will be compared with those coming from “ecologic” buses such as the ones already operational in Monza, e.g. traditional EEV diesel buses.

The noise produced by the bus, both internal and external, will be compared with the one produced by a traditional bus in order to understand if the environmental impact can be improved.

The respect of technical data provided by manufacturers will also be verified.

In order to verify the reliability, it will be useful to obtain the number of operational hours that the bus carries out during the testing phase and to compare the data with the average reliability of a traditional diesel bus.

Since a hybrid bus is mainly involves fresh planning of all electrical, mechanical and electronic components, there is also the need to verify the reliability of all the equipment installed on board; for instance, the effectiveness of heating during winter and of air-conditioning during summer. Furthermore braking system, opening of the doors, suspensions and duration of batteries/supercapacitors should be tested.

On the hybrid bus further equipment than the standard one will be assembled which will be useful for the positioning of the bus (GPRS), communication via radio and video surveillance: the equipment will be electrically supplied and will use electric energy. Thus it is really fundamental to understand the duration of batteries either as whole cycle of life or as duration after the recharging.

Furthermore during the demonstration phase it will be possible to verify if expected benefits of the hybrid bus are actually fulfilled.

- Increasing of energy efficiency
- Lower costs for engine maintenance
- Costs of the life-cycle
- Less risks due to smaller quantity of fuel
- Lower operating costs compared to standard diesel buses.
- Costs of facilities:
    - Same diesel pumps
    - Same garages

The diesel engine of a hybrid bus is used only for charging and not for traction; developed by the downsizing point of view, it normally consists of an in line 6-cylinders unit which substitutes the traditional 12 litres one commonly used. Consumption will benefit of the average weight reduction (in some cases around a tonne): fuel consumption and emissions of carbon dioxide and greenhouse effect gases is expected to be reduced to 40-50% in comparison with a traditional diesel bus.

By using a hybrid bus the consumption of energy per passenger would be cut down to 50-75% in comparison with private car use. This will have relevant advantages for environment and for the reduction of fuel costs.